THE PICTURE OF THE TAOIST GENII PRINTED ON THE COVER of this book is part of a painted temple scroll, recent but traditional, given to Mr Brian Harland in Szechuan province (1946). Concerning these four divinities, of respectable rank in the Taoist bureaucracy, the following particulars have been handed down. The title of the first of the four signifies 'Heavenly Prince', that of the other three 'Mysterious Commander'.

At the top, on the left, is Liu Thien Chîn, Comptroller-General of Crops and Weather. Before his deification (so it was said) he was a rain-making magician and weather forecaster named Liu Chiin, born in the Chin dynasty about +340. Among his attributes may be seen the sun and moon, and a measuring-rod or carpenter's square. The two great luminaries imply the making of the calendar, so important for a primarily agricultural society, the efforts, ever renewed, to reconcile celestial periodicities. The carpenter's square is no ordinary tool, but the gnomon for measuring the lengths of the sun's solstitial shadows. The Comptroller-General also carries a bell because in ancient and medieval times there was thought to be a close connection between calendrical calculations and the arithmetical acoustics of bells and pitch-pipes.

At the top, on the right, is Wen Yuan Shuai, Intendant of the Spiritual Officials of the Sacred Mountain, Thai Shan. He was taken to be an incarnation of one of the Hour-Presidents (Chia Shen), i.e. tutelary deities of the twelve cyclical characters (see Vol. 4, pt. 2, p. 440). During his earthly pilgrimage his name was Huan Tzu-Yü and he was a scholar and astronomer in the Later Han (b. +142). He is seen holding an armillary ring.

Below, on the left, is Kou Yuan Shuai, Assistant Secretary of State in the Ministry of Thunder. He is therefore a late emanation of a very ancient god, Le Kung. Before he became deified he was Hsin Hsing, a poor woodcutter, but no doubt an incarnation of the spirit of the constellation Kou-Chhen (the Angular Arranger), part of the group of stars which we know as Ursa Minor. He is equipped with hammer and chisel.

Below, on the right, is Pi Yuan Shuai, Commander of the Lightning, with his flashing sword, a deity with distinct alchemical and cosmological interests. According to tradition, in his early life he was a countryman whose name was Thien Hua. Together with the colleague on his right, he controlled the Spirits of the Five Directions.

Such is the legendary folklore of common men canonised by popular acclamation. An interesting scroll, of no great artistic merit, destined to decorate a temple wall, to be looked upon by humble people, it symbolises something which this book has to say. Chinese art and literature have been so profuse, Chinese mythological imagery so fertile, that the West has often missed other aspects, perhaps more important, of Chinese civilisation. Here the graduated scale of Liu Chiin, at first sight unexpected in this setting, reminds us of the ever-present theme of quantitative measurement in Chinese culture; there were rain-gauges already in the Sung (+12th century) and sliding calipers in the Han (+1st). The armillary ring of Huan Tzu-Yü bears witness that Naburiannu and Hipparchus, al-Naqsh and Tycho, had worthy counterparts in China. The tools of Hsin Hsing symbolise that great empirical tradition which informed the work of Chinese artisans and technicians all through the ages.
In all the world there be no better workmen for buildings than the inhabitants of China.

Galeote Pereira

C. 1577

The Chinese have their Contrivances for everything.

Domíngo de Navarrete

1676

C'est le pays le plus peuplé et le mieux cultivé qu'il y ait au monde; il est arrosé de plusieurs grandes rivières, et coupé d'une infinité de canaux que l'on y fait pour faciliter le commerce. Le plus remarquable est celui que l'on nomme le canal royal, qui traverse toute la Chine.

Denis Diderot

1752

As regards the people who protect and manage the dykes and channels of the nine rivers and the four lakes, they are the same in all ages; they did not learn their business from Yu the Great, they learnt it from the waters.

Shen Tzu

C. 4th century

Those who know how to manage ships learnt from boats and not from Wo the Shipman. Those who can think learnt from themselves, and not from the Sages.

Kuan Yin Tzu

8th century
SCIENCE AND CIVILISATION IN CHINA

BY

JOSEPH NEEDHAM, F.R.S.
MASTER OF GONVILLE AND CAIUS COLLEGE, CAMBRIDGE
FOREIGN MEMBER OF ACADEMIA SINICA

With the collaboration of

WANG LING, PH.D.
PROFESSORIAL FELLOW IN THE INSTITUTE OF ADVANCED STUDIES
AUSTRALIAN NATIONAL UNIVERSITY, CANBERRA

and

LU GWEI-DJEN, PH.D.
FELLOW OF LUCY CAVENDISH COLLEGE, CAMBRIDGE

VOLUME 4

PHYSICS AND PHYSICAL TECHNOLOGY
PART III: CIVIL ENGINEERING AND NAUTICS

CAMBRIDGE
AT THE UNIVERSITY PRESS
1971
To the memory of

CHI CHHAO-TING

Historian of China's water ways and works

a friend beside the Chiailing River

economic and financial leader in a resurgent land

and of

HERBERT CHATLEY

Once Professor of Engineering at Thang-shan College

and

Chief Engineer of the Huang-po Conservancy

an 'Old China Hand' who loved the Chinese people

historian of the engineers of Cathay and Manzi

this volume is
dedicated
The Syndics of the Cambridge University Press desire to acknowledge with gratitude certain financial aid towards the production of this book, afforded by the Bollingen Foundation.

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On the system of romanisation of Chinese characters adopted in this work, see Vol. 1, pp. 23 ff.

LIST OF ABBREVIATIONS

The following abbreviations are used in the text and footnotes. For abbreviations used for journals and similar publications in the bibliographies, see pp. 701 ff.

B  Bretschneider, E., Botanicon Sinicum.
BCFA  Britain-China Friendship Association.
CCL  Chê Chiang Lu (Biographies of [Chinese] Engineers, Architects, Technologists and Master-Craftsmen). 1 to 6 See Chu Chhi-Chhien & Liang Chhi-Hsiung (1 to 6); 7 See Chu Chhi-Chhien, Liang Chhi-Hsiung & Liu Ju-Lin (1); 8, 9 See Chu Chhi-Chhien & Liu T'ai-Chen (1, 2).
CFC  Chao Ju-Kua, Chu Fan Chih (Records of Foreign Peoples), +1225.
CLPT  Thang Shen-Wei et al. (ed.), Chêng Lei Pên Tshao (Reorganised Pharmacopoeia), ed. of +1249.
CPCRA  Chinese People's Association for Cultural Relations with Foreign Countries.
CSHK  Yen Kho-Chun (ed.), Chhüan Shang-lu San-Tai Chhin Han San-Kuo Liu Chhao Wen (Complete Collection of Prose Literature (including fragments) from Remote Antiquity through the Chhin and Han Dynasties, the Three Kingdoms, and the Six Dynasties), 1836.
CTS  Liu Hsiu, Chu T'ang Shu (Old History of the Thang Dynasty), +945.
EB  Encyclopaedia Britannica.
ERE  Encyclopaedia of Religion and Ethics (ed. Hastings).
HCCC  Yen Chieh (ed.), Huang Chhing Ching Chieh (monographs by Ching scholars on classical subjects), 1829, contd. 1860.
HTCKM  Shang Lu (ed.), Hsiü Thung Chien Kang Mu = Thung Chien Kang Mu Hsiü Pien (Continuation of the Short View of the Comprehensive Mirror (of History, for Aid in Government)), +1476, pr. after +1500.
K  Karlgren, Grammata Serica (dictionary giving the ancient forms and phonetic values of Chinese characters).
KCCY  Chhen Yuan-Lung, Ko Chih Ching Yuan (Mirror of Scientific and Technological Origins), an encyclopaedia of +1735.
LIST OF ABBREVIATIONS


LCCCL Li Chao-Hsiang, Lung-Chiang Chhuian Chiang Chhii (Record of the Shipyards on the Dragon River, at Nanking), +1553.

MCPT Shen Kua, Meng Chi Pi Thian (Dream Pool Essays), +1089.

N Nanjio, B., A Catalogue of the Chinese Translations of the Buddhist Tripitaka, with index by Ross (3).

NCCS Hui Kuang-Chhi, Nung Ch'eng Chhiiian Shu (Complete Treatise on Agriculture), +1639.


PWYF Chang Yu-Shu (ed.), P'ei Wen Yin Fu (encyclopaedia), +1711.

R Read, Bernard E. et al., Indexes, translations and précis of certain chapters of the P'en Ts'ao Kang Mu of Li Shih-Chen. If the reference is to a plant, see Read (1); if to a mammal, see Read (2); if to a bird, see Read (3); if to a reptile, see Read (4 or 5); if to a mollusc, see Read (6); if to a fish, see Read (6); if to an insect, see Read (7).

SCTS Chhin-Ting Shu Ching Thu Shuo (imperial illustrated edition of the Historical Classic), 1905.

SKCS Tsu Khu Chhiiian Shu (Complete Library of the Four Categories), +1782; here the reference is to the thung-shu collection printed as a selection from one of the seven imperially commissioned MSS.

SKCS/TMY Tsu Khu Chhiiian Shu Tsung Mu Thii Yao (Analytical Catalogue of the Complete Library of the Four Categories), +1782; the great bibliographical catalogue of the imperial MS. collection ordered by the Chhiun-Lung emperor in +1772.

STTH Wang Chhi, San Tehai Thu Hai (Universal Encyclopaedia), +1609.

T Tunhuang Archaeological Research Institute numbers of the Chhiun-fo-tung cave-temples. If an identification is given according to the system of Hsiieh Chih-Liu in his Tunhuang I Shu Hsi Lu (Shanghai, 1955) the Institute number and the Pelliot number are also given, but if a single number is given it is the Institute number. A valuable concordance table of the three systems is given in Hsiieh's book, and a still more complete one in Chhen Tsu-Lung (1).

TCKM Chu Hsi et al. (ed.), Tsung Chhien Kang Mu (Short View of the Comprehensive Mirror of History, for Aid in Government), classified into Headings and Subheadings; the Tsung Chhien Thung Chhien condensed, a general history of China, +1189; with later continuations.

TCCT Ssuma Kuang, Tsu Chhi Thung Chhien (Comprehensive Mirror of History) for Aid in Government, +1084.

TH Wieger, L. (1), Textes Historiques.

TKKW Sung Ying-Hsiang, Thien Kung Khai Wu (The Exploitation of the Works of Nature), +1637.

TPYC Li Chhiuan, Thai Pai Yin Chhing (Manual of the White and Gloomy Planet (of War, Venus)), treatise on military and naval affairs, +759.

TPYL Li Fang (ed.), Thai-Phing Yü Lan (the Thai-Phing reign-period (Sung) Imperial Encyclopaedia), +983.

TSCC Chhen Meng-Lei et al. (ed.), Thu Shu Chi Chheng (the Imperial Encyclopaedia of +1726). Index by Giles, L. (2).

TSFY Ku Tsu-Yu, Thu Shih Fang Yu Chi Yao (The Historian's Geographical Companion) begun before +1666, finished before +1692; but not printed till the end of the eighteenth century (1796 to 1821).

TTN Tu Yu, Thung Tien (Comprehensive Institutes), a reservoir of source material on political and social history, c. +812.

TW Takakusu, J. & Watanabe, K. Tables du Taishó Isuhyó (nouvelle édition (Japonaise) du Canon bouddhique chinoise). Index-catalogue of the Tripitaka.

WCTY/CC Tseng Kung-Liang (ed.), Wu Ching Tsung Yao (Chi Chien Chi), military encyclopaedia, first section, +1044.

WHTK Ma Tuan-Lin, Wén Hsien Thung Kiao (Comprehensive Study of the History of Civilisation), +1319.

WPC Mao Yuan-I, Wu Pei Chhiih (Treatise on Armament Technology), +1628.

YHSF Ma Kuo-Han (ed.), Yü Han Shan Fang Chi I Shu (Jade-Box Mountain Studio Collection of (reconstituted and sometimes fragmentary) Lost Books), 1853.

YTFS Li Chhih, Ying Tsho Fa Shih (Treatise on Architectural Methods), +1097, pr. +1103, repr. +1145.
ACKNOWLEDGEMENTS

LIST OF THOSE WHO HAVE KINDLY READ THROUGH SECTIONS IN DRAFT


Mr R. C. Anderson (Greenwich)  Nautics (Shipping).
Prof. Guy Beaujouan (Montrouge)  Nautics (Navigation and Voyages).
Dr Asit K. Biswas (Ottawa)  Hydraulics.
The late Mr Andrew Boyd (London)  Building Technology, Bridges.
The late Dr Herbert Chatley (Bath)  Hydraulics.
Mr Wells Coates (London)  Nautics (Sails).
Mr F. R. Cowell (Kemsing)  Perspective.
Mr Basil Davidson (London)  Nautics (Voyages).
Dr R. D. Davies (Cambridge)  Bridges.
Prof. Edwin Doran (College, Texas)  Both sections.
Prof. V. Elisséeff (Paris)  Nautics.
Prof. James M. Fitch (New York)  Building Technology.
Mr Klaus Flessel (Tübingen)  Hydraulics.
Mrs Else Glahn (Copenhagen)  Building Technology.
Mr Philip Grierson (Cambridge)  Nautics (Voyages).
Dr Trevor Hodge (Cambridge)  Building Technology.
Prof. Huang Jen-Yü (New York)  Hydraulics.
Mr Bryan J. Hudson (Hongkong)  Hydraulics.
Mr John Hunter (Thaxted)  Building Technology.
Mr David H. Kelley (Lubbock, Texas)  Nautics (pre-Columbian contact).
Mr James Kirkman (Mombasa)  Nautics (Voyages).
Mr N. E. Lee (Victoria, N.S.W.)  Nautics.
Mr Alfred Lieber (Jerusalem)  Nautics (Voyages).
Prof. Lo Jung-Pang (Davis, California)  Roads, Walls, Bridges, Nautics.
Dr Ian McPherson (Cambridge)  Nautics (Voyages).
Sir Leslie Martin (Cambridge)  Building Technology.
Mr J. V. Mills (La Tour de Peilz, Vaud)  Nautics (Navigation and Voyages).
Mr J. S. Morrison (Cambridge)  Nautics (Shipping).
Lt.-Cdr George Naish (Greenwich)  Nautics (Shipping).
Dr Anthony Pearson (Cambridge)  Hydraulics.
Prof. Luciano Petech (Rome)  Both sections.
The late Dr Victor Purcell (Cambridge)  Nautics (Voyages).
Mr Francisco Quintanilha (Cambridge)  Nautics (Voyages).
Mr Nathan Silver (Cambridge)  Building Technology.
AUTHOR’S NOTE

Pursuing our exploration of the almost limitless caverns of Chinese scientific history, so much of which has never yet come to the knowledge and recognition of the rest of the world, we now approach the glittering veins of physics and physical technology; a subject which forms a single whole, constituting Volume Four, though delivered to the reader in three separate volumes. First come the physical sciences themselves (Vol. 4, pt. 1), and then their diverse applications in all the many branches of mechanical engineering (Vol. 4, pt. 2), civil and hydraulic engineering, and nautical technology (Vol. 4, pt. 3).

With the opening chapter we find ourselves at a focal point in the present study, for mechanics and dynamics were the first of all the conquests of modern science. Mechanics was the starting-point because the direct physical experience of man in his immediate environment is predominantly mechanical, and the application of mathematics to mechanical magnitudes was relatively simple. But ancient and medieval China belonged to a world in which the mathematisation of hypotheses had not yet brought modern science to birth, and what the scientific minds of pre-Renaissance China neglected might prove almost as revealing as that which aroused their interest and investigation. Three branches of physics were well developed among them, optics (Section 26g), acoustics (26h), and magnetism (26i); mechanics was weakly studied and formulated, dynamics almost absent. We have attempted to offer some explanation for this pattern but without any great conviction, and better understanding of the imbalance must await further research. The contrast with Europe, at least, where there was a different sort of one-sidedness, is striking enough, for in Byzantine and late medieval times mechanics and dynamics were relatively advanced while magnetic phenomena were almost unknown.

In optics the Chinese of the Middle Ages kept empirically more or less abreast of the Arabs, though greatly hampered in theory by the lack of that Greek deductive geometry of which the latter were the inheritors. On the other hand they never entertained that peculiar Hellenistic aberration according to which vision involved rays radiating from, not into, the eye. In acoustics the Chinese proceeded along their own lines because of the particular and characteristic features of their ancient music, and here they produced a body of doctrine deeply interesting but not readily comparable with those of other civilisations. Inventors of the bell, and of a great variety of percussion instruments not known in the West, they were especially concerned with timbre both in theory and practice; developing their unique theories of melodic composition within the framework of a twelve-note gamut rather than an eight-note scale. At the end of the +16th century Chinese mathematical acoustics succeeded in solving the problem of equal temperament just a few decades before its solution was reached in the West (Section 26h, 10). Lastly, Chinese investigation of magnetic phenomena and their practical application constituted a veritable epic. Men were arguing in China
about the cause of the declination of the magnetic needle, and using it at sea, before Westerners even knew of its directive property.

Readers pressed for time will doubtless welcome once more a few suggestions. In the chapters which we now present it is possible to perceive certain outstanding traditions of Chinese physical thought and practice. Just as Chinese mathematics was indubitably algebraic rather than geometrical, so Chinese physics was wedded to a prototypic wave-theory and perennially averse to atoms, always envisaging an almost Stoic continuum; this may be seen in Section 26b and followed through in relation to tension and fracture (c, 3) and to sound vibrations (h, 9). Another constant Chinese tendency was to think in pneumatic terms, faithfully developing the implications of the ancient concept of chhi (= pneuma, prana). Naturally this shows itself most prominently in the field of acoustics (Section 26h, 3, 7, etc.), but it was also connected with some brilliant successes in the field of technology such as the inventions of the double-acting piston-bellows and the rotary winnowing-fan (Section 27b, 8), together with the water-powered metallurgical blowing-engine (27h, 3, 4, direct ancestor of the steam engine itself). It was also responsible for some extraordinary insights and predictions in aeronautical pre-history (27m, 4). Traditions equally strong and diametrically opposite to those of Europe also make their appearance in the purely technical field. Thus the Chinese had a deep predilection for mounting wheels and machinery of all kinds horizontally instead of vertically whenever possible; as may be followed in Section 27 (h, k, l, m).

Beyond this point, guidance to the reader is not very practicable since so many different preoccupations are involved. If he is interested in the history of land transport he will turn to the discussion of vehicles and harness (Section 27e, f), if he delights, like Leviathan, in the deep waters, a whole chapter (29) will speak to him of Chinese ships and their builders. The navigator will turn from the compass itself (26l, 5) to its fuller context in the haven-finding art (29g); the civil engineer, attracted by a survey of those grand water-works which outdid the 'pyramids of Aegypt', will find it in Section 28f.

The folklorist and the ethnographer will appreciate that 'dark side' of history where we surmise that the compass-needle, most ancient of all those pointer-readings that make up modern science, began as a 'chess-man' thrown on to a diviner's board in Sections 27h, 3, 4, 5, direct ancestor of the steam engine itself. The sociologist too will already find much of interest, for besides discussing the place of artisans and engineers in feudal-bureaucratic society (27a, 1, 2, 3), we have ventured to raise certain problems of labour-saving invention, man-power, slave status and the like, especially with regard to animal harness (27f, 2), massive stone buildings (28d, 1), oared propulsion (29g, 2), and water-powered milling and textile machinery (27h).

Many are the ways in which these volumes link up with those which have gone before. We shall leave the reader's perspicacity to trace how the philosophia perennis of China manifested itself in the discoveries and inventions here reported. We may point out, however, that mathematics, metrology and astronomy find numerous echoes; in the origins of the metric system (Section 26c, 6), the development of lenses (g, 5), and the estimation of pitch-pipe volumes (h, 8)—or the rise of astronomical clocks (Section 27f), the varying conceptions of perspective (28d, 5) and the planning of hydraulic works (f, 9). Similarly, much in the present volumes points forward to chapters still to come. All uses of metal in medieval Chinese engineering imply what we have yet to say on metallurgical achievements; in the meantime reference may be made to the separate monograph The Development of Iron and Steel Technology in China, published as a Newcomen Lecture in 1958. In all mentions of mining and the salt industry it is understood that these subjects will be fully dealt with at a later stage. All water-raising techniques remind us of their basic agricultural purpose, the raising of crops.

As for the discoveries and inventions which have left permanent mark on human affairs, it would be impossible even to summarise here the Chinese contributions. Perhaps the newest and most surprising revelation (so unexpected even to ourselves that we have to withdraw a relevant statement in Vol. 1) is that of the six hidden centuries of mechanical clockwork which preceded the clocks of the 14th-century Europe. Section 27j is a fresh though condensed treatment of this subject, incorporating still further new and strange material not available when the separate monograph Heavenly Clockwork was written in 1957 with our friend Prof. Derek J. de Solla Price, now of Yale University. It still seems startling that the key invention of the escapement should have been made in a pre-industrial agrarian civilisation among a people proverbially supposed by bustling 19th-century Westerners to take no account of time. But there are many other equally important Chinese gifts to the world: the development of the magnetic compass (Section 26i, 4, 6), the invention of the first cybernetic machine (27e, 5), both forms of efficient equine harness (27f, 1), the canal lock-gate (28f, 9, 5) and the iron-chain suspension bridge (28e, 4). The first true crane (Section 27b, 4), the stern-post rudder (Section 29h), the man-lifting kite (Section 27m)—we cannot enumerate them all.

In these circumstances it seems hardly believable that writers on technology have run up and down to prove reasons why China contributed nothing to the sciences, pure or applied. At the beginning of a recent popular florilegium of passages on the history of technology one comes across a citation from the 8th-century Taoist book Kuan Yin Tzu, given as an example of 'oriental rejection of this world' and of worldly activity'. It had been culled from an interesting essay on religion and the idea of progress, well known in the 'thirties and still stimulating, the author of which, led astray by the old rendering of Fr Wieger, had written: 'It is obvious that such beliefs can afford no basis for social activity and no incentive to material progress.' He was, of course, concerned to contrast the Christian acceptance of the material world with 'oriental' other-worldliness, in which the Taoists were supposed to participate. Yet in almost every one of the inventions and discoveries we here describe the Taoists and Mohists were intimately involved (cf. e.g. Sections 26c, g, h, i, 27a, c, h, j, 28e, 29f, h). As it happened, we had ourselves studied the same Kuan Yin Tzu passage and given parts of it in

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a Needham (23), cf. (31).
c Cf. Needham (55, 56).
d Cf. Needham (57).

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a Needham (23), cf. (31).
c Cf. Needham (55, 56).
d Cf. Needham (57).
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translation at an earlier stage; from this it can be seen that Wiegert's version was no more than a grievously distorted paraphrase. Far from being an obscurationist document, denying the existence of laws of Nature (a concept totally unheard of by the original writer) and confusing reality with dream, the text is a poem in praise of the immanent Tao, the Order of Nature from which space and time proceed, the eternal pattern according to which matter disperses and reassembles in forms ever new; full of Taoist relativism, mystical but in no way anti-scientific or anti-technical, on the contrary prophesying of the quasi-magical quasi-rational command over Nature which Taoist relativism, mystical but in no way anti-scientific or anti-technical, on the contrary prophesying of the quasi-magical quasi-rational command over Nature which he who truly knows and understands the Tao will achieve. Thus upon close examination, an argument purporting to demonstrate the philosophical impotence of 'oriental thought' turns out to be nothing but a figment of occidental imagination.

Another method is to admit that China did something but to find a satisfying reason for saying nothing about it. Thus a recent compendious history of science published in Paris maintains that the sciences of ancient and medieval China and India were so closely bound to their peculiar cultures that they cannot be understood without them. The sciences of the ancient Greek world, however, were truly sciences as such, free of all subordination to their cultural matrix and fit subjects with which to begin a story of human endeavour in all its abstract purity. It would be much more honest to say that while the social background of Hellenistic science and technology can be taken for granted because it is quite familiar to us from our schooldays onwards, we do not yet know much about the social background of Chinese and Indian science, and that we ought to make efforts to get acquainted with it. In fact, of course, no ancient or medieval science and technology can be separated from its ethnic stamp, and though that of the post-Renaissance period is truly universal, it is no better understandable historically without a knowledge of the milieu in which it came to birth.

Finally, many will be desirous of looking into questions of intercultural contacts, transmissions and influences. Here we may only mention examples still puzzling of inventions which occur almost simultaneously at both ends of the Old World, e.g. rotary milling (Section 27 d, 2) and the water-mill (h, 2). Parallels between China and ancient Alexandria often arise (for instance in Section 27 b) and the powerful influence of Chinese technology on pre-Renaissance Europe appears again and again (26c, h, i; 27b, d, e, f, g, j, m; 28e, f; 29j).

Important inventions in metal engineering travelled westwards; and despite the supposed conservatism of sailors, there was hardly any Western century in the past twenty which did not see the adoption of some nautical technique from the East.

In a brilliant ponencia at the Ninth International Congress of the History of Sciences at Barcelona in 1959 Professor Willy Hartner raised the difficult question of how far anyone can ever anticipate anyone else. What does it mean to be a predecessor or a precursor? For those who are interested in intercultural transmissions this is a vital point. In European history the problem has assumed acute form since the school of Duham acclaimed Nicholas d'Oresme and other medieval scientists as the precursors of

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Copernicus, Bruno, Francis Bacon, Galileo, Fermat and Hegel. Here the difficulty is that every mind is necessarily the denizen of the organic intellectual medium of its own time, and propositions which may look very much alike cannot have had quite the same meaning when considered by minds at very different periods. Discoveries and inventions are no doubt organically connected with the milieu in which they arose. Similairities may be purely fortuitous. Yet to affirm the true originality of Galileo and his contemporaries is not necessarily to deny the existence of precursors, so long as that term is not taken to mean absolute priority or anticipation; and in the same way there were many Chinese precursors or predecessors who adumbrated scientific principles later acknowledged—one thinks immediately of Hutonian geology (Vol. 3, p. 654), the comet tail law (p. 432) or the declination of the magnetic needle (Section 25f).

So much for science more or less pure; in applied science we need hesitate less. For example, the gaining of power of the flow and descent of water by a wheel can only have been first successfully executed once. Within a limited lapse of time thereafter the invention may have occurred once or twice independently elsewhere, but such a thing is not invented over and over again. All subsequent successes must therefore derive from one or other of these events. In all these cases, whether of science pure or science applied, it remains the task of the historian to elucidate if possible how much genetic connection there was between the precursor and the grand figures which followed him.

Did they know certain actual written texts? Did they work by hearsay? Did they first conceive their ideas alone and find them unexpectedly confirmed? As Hartner says, the variations range from the certain to the impossible. Often hearsay seems to have been followed by a new and different solution (cf. Section 27j, 1). In our work here presented to the reader he will find that we are very often quite unable to establish a genetic connection (for example between the suspension of Ting Huan and that of Jerome Cardan, in Section 27d, 41 or between the rotary ballista of Ma Chün and that of Leonardo, in Sections 27a, 2 and 305, 4), but in general we tend to assume that when the spread of intervening centuries is large and the solution closely similar, the burden of proof must lie on those who desire to maintain independence of thought or invention. On the other hand the genetic connection can sometimes be established with a high degree of probability (for example, in the matters of equal temperament, Section 26h, 10, sailing-carrages, Section 27e, 3, and the kite, the parachute and the helicopter, Section 27m). Elsewhere one is left with strong suspicions, as with regard to the water-wheel escapement clock (Section 27j, 6). Although every attempt has been made to take into account the most recent research in the fields here covered, we regret that it has generally not been possible to mention work appearing after May 1968.

We have not printed a contents-table of the entire project since the beginning of

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* Many a surprise is still in store for us. After the discovery by Al-Tawābi in 1932 that Ibn al-Naftsi (+1240 to +1288) had clearly described the pulmonary circulation (cf. Meyerhof, 1, 2; Haddad & Khairallah), it was long considered extremely unlikely that any hint of this could have reached the Renaissance discoverer of the same phenomenon, Miguel Servetus (cf. Temkin, 2). But now O'Malley (1) has found a Latin translation of some of the writings of Ibn al-Naftsi published in +1547.

b On the criterion of genetic connection in the history of science and technology in general, see Needham (45).
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Vol. 1, and it has now been felt desirable to revise it in prospectus form. So much work has now been done in preparation for the later volumes that it is possible to give their outline subheadings with much greater precision than could be done seven years ago. More important, perhaps, is the division into volumes. Here we have sought to retain unaltered the original numbering of the successive Sections, as for the needs of cross-referencing we must. Vol. 4, as originally planned, included physics, all branches of engineering, military and textile technology and the arts of paper and printing. As will be seen, we now entitle Vol. 4 Physics and Physical Technology, Vol. 5 Chemistry and Chemical Technology and Vol. 6 Biology and Biological Technology. This is a logical division, and Vol. 4 concludes very reasonably with Nautics (29) for in ancient and medieval times the techniques of shipping were almost entirely physical. Similarly Vol. 5 starts with Martial Technology (30), for in this field and in those times the opposite was the case; the chemical factor was essential. We found not only that we must embody iron and steel metallurgy therein (hence the slight but significant change of title), but also that without the epic of gunpowder, the fundamental discovery of the history of Chinese military technique could not be written. With Textiles (31) and the other arts (32) the same argument was found to apply, for so many of the processes (retting, fulling, dyeing, ink-making) allied them to chemistry rather than to physics. Of course we could not always consistently adhere to this principle; for instance, no discussion of lenses was possible without some knowledge of glass technology, and this had therefore to be introduced at an early stage in the present volume (26g, 5, i). For the rest, it is altogether natural that Mining (36), Salt-winning (37) and Ceramic Technology (38) should find their place in Vol. 5. The only asymmetry is that while in Vols. 4 and 6 the fundamental sciences are dealt with at the beginning of the first part, in Vol. 5 the basic science, chemistry, with its precursor, alchemy, is discussed in the second part. This probably matters the less because in ready response to the critics who found Vol. 3 too heavy and bulky for comfortable meditative evening reading, the University Press has decided to produce the present volume in three physically separate parts, each being as usual independent and complete in itself.

In Vol. 1, pp. 18 ff., we gave details of the plan of the work (conventions, bibliographies, indexes, etc.) to which we have since closely adhered, and we promised that in the last volume a list would be given of the editions of the Chinese books used. It now seems undesirable to wait so long, and thus for the convenience of readers with knowledge of the Chinese language, we append to the present volume an interim list of these editions down to the point now reached. We are grateful to Miss Léonie Callaghan of Canberra for carrying out the bulk of the work involved. Two further related points may be mentioned here. First, in this and recent volumes some page references to Chinese texts are placed in round brackets without recto and verso letters; this directs to the modern edition as against the old one. Secondly, the reader is reminded that where in these volumes two statements disagree, that in the latest of the series is to be preferred. 

The great humanists of the past were very well aware of their limitations in these matters, and sought always, so far as possible, to gain acquaintance with what my friend and teacher, Gustav Haloun, used half-wistfully, half-ironically to call the realia. In a passage we have already quoted (Vol. I, p. 7), another outstanding sinologist, Friedrich Hirth, urged that the Western translator of Chinese texts must not only translate, he must identify, he must not only know the language but he must also be a collector of the objects talked about in that language. The conviction was sound, but if porcelain or cloisonné could (at any rate in those days) be collected and contemplated with relative ease, how much more difficult is it to acquire an understanding of machinery, of tanning or of pyrotechnics, if one has never handled a lathe, fitted a gear-wheel or set up a distillation.

What is true of living humanists in the West is also true of some of the Chinese

AUTHOR'S NOTE

China to Europeans has been like the moon, always showing the same face—a myriad peasant-farmers, a scattering of artists and recluses, an urban minority of scholars, mandarins and shopkeepers. Thus as civilizations acquire 'stereotypes' of one another. Now, raised upon the wings of the space-ship of linguistic resource and riding the rocket of technical understanding (to use an Arabic trope), we intend to see what is on the other side of the disc, and to meet the artisans and engineers, the shipwrights and the metallurgists of China's three-thousand-year-old culture.

In our note at the beginning of Vol. 3 we took occasion to say something of the principles of translation of old scientific texts and of the technical terms contained in them. Since this is the first volume largely devoted to the applied sciences we are moved to insert a few reflections here on the present position of the history of technology, a discipline which has suffered even more perhaps than the history of science itself from that dreadful dichotomy between those who know and those who write, the doers and the recorders. If men of scientific training, with all their handicaps, have contributed far more than professional historians to the history of science and medicine (as is demonstrably true), technologists as a whole have been even less well equipped with the tools and skills of historical scholarship, the languages, the criticism of sources, and the use of documentary evidence. Yet nothing can be more futile than the work of a historian who does not really understand the crafts and techniques with which he is dealing, and for any literary scholar it is hard to acquire that familiarity with things and materials, that sense of possibilities and probabilities, that understanding of Nature's ways, in fact, which comes (in greater or lesser measure) to everyone who has worked with his hands whether at the laboratory bench or in the factory workshop. I always remember once studying some medieval Chinese texts on 'light-penetration mirrors' (thou huang chien), that is to say, bronze mirrors which have the property of reflecting from their polished surfaces the designs executed in relief on their backs. A non-scientific friend was really persuaded that the Sung artisans had found out some way of rendering metal transparent to light-rays, but I knew that there must be some other explanation and it was duly found (cf. Section 26g, 3). The great humanists of the past were very well aware of their limitations in these matters, and sought always, so far as possible, to gain acquaintance with what my friend and teacher, Gustav Haloun, used half-wistfully, half-ironically to call the realia. In a passage we have already quoted (Vol. I, p. 7), another outstanding sinologist, Friedrich Hirth, urged that the Western translator of Chinese texts must not only translate, he must identify, he must not only know the language but he must also be a collector of the objects talked about in that language. The conviction was sound, but if porcelain or cloisonné could (at any rate in those days) be collected and contemplated with relative ease, how much more difficult is it to acquire an understanding of machinery, of tanning or of pyrotechnics, if one has never handled a lathe, fitted a gear-wheel or set up a distillation.

What is true of living humanists in the West is also true of some of the Chinese

* Cf. Needham (34).
there is no substitute for personal intercourse with the practising technicians themselves. To be sure the scholarly standard of any particular work must necessarily depend upon the ground which is covered. Only the specialist using intensive methods—a Rosen elucidating the tangled roots of ophthalmic lenses or a Drachmann exploring Roman oil-presses—can afford the time to go into a matter "au fond" and bring truth wholly out of the well. We have tried to do this only in very few fields, such as that of medieval Chinese clockwork, because our aim is essentially extensive and pioneering. There is no escape, much must be taken on trust. If we are deficient in our knowledge of the objects of occidental archaeology, it is because we have laboured to study in situ those of the Chinese culture-area, our primary responsibility. If we had been able at that time to visit the museum in Copenhagen where the Dejbjerg wagons are kept we might have been more wary of accepting current statements about them, but—5 βλος βραχώς ἢ δέ τέχνη μακρή, the craft is long but life is short. On the other side of the scale a deep debt of gratitude is owing to the President and Council of Academia Sinica for generous facilities which enabled me in 1958, together with Dr Lu Gwei-Djen, to visit or revisit many of the great museums and archaeological sites in China.

But not with archaeologists only must one converse. One must follow the example of little Dr Harvey (of Caius College). In the seventeenth century John Aubrey tells us of a conversation he had with a sow-gelder, a countryman of little learning but much practical experience and wisdom. He told him that he had met Dr William Harvey, who had conversed with him above two or three hours, and 'if he had been', the man remarked, 'as stiffe as some of our starched and formal Doctors, he had known no more than they'. A Kansu carter threw light upon the harness not only of our own time but indirectly of the Han and Tang, Szechuanese iron-workers were well able to help our understanding of how Chhiwu Huai-Wen in 545 made co-fusion steel, and a Peking kite-maker could reveal with his simple materials those secrets of the cambered wing and the airscrew which lie at the heart of modern aeronautical science. Nor may the technicians of one's own civilisation be neglected, for a traditional Surrey wheelwright can explain how wheels were 'dished' by the artisans of the State of Chihi two thousand years and more ago. A friend in the zinc industry disclosed to us that the familiar hotel cutlery found today all over the world is made essentially of the medieval Chinese alloy pakting; a nautical scholar from Greenwich demonstrated the significance of the Chinese lead in fore-and-aft sailing, and it took a professional hydraulic engineer to appreciate at their true value the Han meas. elements of the silt-content of river-waters. As Confucius put it, "Where there are three men walking together, one or other of them will certainly be able to teach me something".

The demonstrable continuity and universality of science and technology prompts a final observation. Some time ago a not wholly unfriendly critic of our previous volumes wrote, in effect: this book is fundamentally unsound for the following reasons. The
A year later (early in 1958) we were joined by Dr Ho Ping-Yü, then Reader in Physics at the University of Malaya, Singapore. Primarily an astro-physicist by training, and the translator of the astronomical chapters of the Ch'in Shu, he was happily willing to broaden his experience in the history of science by devoting himself to the study of alchemy and early chemistry, helping thus to lay the foundations for the relevant volume (Vol. 5). Such work had been initiated some years earlier by yet another friend, Dr Tshao Thien-Chhin, when a Research Fellow of Caius College, before his return to the Biochemical Institute of Academia Sinica at Shanghai. Dr Tshao had been one of my wartime companions, and while in Cambridge made a most valuable study of the alchemical books in the Tao T'ang. Dr Ho Ping-Yü was able to extend this work with great success in many directions. Although Dr Ho is now Professor of Chinese at the University of Malaya, Kuala Lumpur, he has been able to rejoin us in Cambridge for a period for the further preparation of the volume on chemistry and chemical technology.

It is good to record that already a number of important sub-sections of both these volumes (5 and 6) have been written. The publication of some of them in draft form facilitates criticism and aid by specialists in the different fields.

Lastly, an occasional collaborator appears with us on the title-page of the first part of this volume, Mr Kenneth Robinson, one who combines most unusually sinological and musical knowledge. Professionally he is an educationalist, and with a Malayan background in teachers' training, frequented as Director of Education in Sarawak the villages and long-houses of the Dayaks and other peoples, whose remarkable orchestras seemed to him to evoke the music of the Chou and Han. We were fortunate indeed that he was willing to undertake the drafting of the Section on the recondite but fascinating subject of physical acoustics, indispensable because it was one of the major interests of the scientific minds of the Chinese Middle Ages. He is thus the only participant in this enterprise so far who has contributed direct authorship as well as research activity. Another European colleague, Mr John Combridge, of the Engineering Department of the General Post Office, has greatly added to our understanding of medieval Chinese clockwork, especially by experiments with working models.

Once again it is a pleasure to offer public gratitude to those who have helped us in many different ways. First, our advisers in linguistic and cultural fields unfamiliar to us, notably Prof. D. M. Dunlop for Arabic, Dr Shackleton Bailey for Sanskrit, Dr Charles Shelden for Japanese, and Prof. G. Ledyard for Korean. Secondly, those who have given us special assistance and counsel, Mr E. G. Sterland in mechanical engineering, Prof. Lo Jung-Pang in the history of transport, Prof. A. W. Skempton and the late Dr Herbert Chatley in hydraulic engineering, Mr J. V. Mills in navigation and Cdr. George Naish and Cdr. D. W. Waters in nautics. Thirdly, all those whose names will be found in the adjoining list of readers and kind critics of Sections in draft or proof form. But only Dr Dorothy Needham, F.R.S., has weighed every word in these volumes and our debt to her is incalculable.


AUTHOR'S NOTE
Once again we renew our warmest thanks to Mrs Margaret Anderson for her indispensable and meticulous help with press work, and to Mr Charles Curwen and Mr Ian McMaster for acting as our agents-general with regard to the ever-increasing flood of current Chinese literature on the history and archaeology of science and technics. A particularly generous service was given to the project recently by Mr Walter Sheringham, who carried out an expert valuation of our working library on an honorary basis. Miss Muriel Moyle has continued to provide her very detailed indexes, the excellence of which has been saluted by many reviewers. As the enterprise continues, the burden of typing and secretarial work seems to grow beyond expectation, and we have had many occasions to recognise that a good copyist is like the spouse in Holy Writ, precious beyond rubies. Thus we most gratefully acknowledge the help of the late Mrs Betty May, Miss Margaret Webb, Miss Jennie Plant, Mrs Evelyn Beebe, Miss June Lewis, Mr Frank Brand, Mrs W. M. Mitchell, Miss Frances Boughton, Mrs Gillian Rickaysen and Mrs Anne Scott McKenzie.

The part played by publisher and printer in a work such as this, considered in terms either of finance or technical skill, is no less vital than the research, the organisation and the writing itself. Few authors could have more appreciation of their colleagues executive and executant than we for the Syndics and the Staff of the Cambridge University Press. Among the latter formerly was our friend Frank Kendon, for many years Assistant Secretary, whose death occurred after the appearance of Volume 3. Known in many circles as a poet and literary scholar of high achievement, he was capable of divining the poetry implicit in some of the books which passed through the Press, and the form which his understanding took was the bestowal of infinite pains to achieve the external dress best adapted to the content. I shall always remember how when Science and Civilization in China was crystallising in this way, he 'lived with' trial volumes made up in different styles and colours for some weeks before arriving at a decision most agreeable to the author and his collaborators—and what was perhaps more important, equally so to thousands of readers all over the world. Infinite debt we owe also to our friend Mr Peter Burbidge, now Production Manager of the Cambridge University Press, who has watched over the complicated travail of the successive volumes as Editor, with warm appreciation and enthusiasm, from the first beginnings of the project. No trouble was too much on its behalf.

'To the Master and Fellows of the Hall of the Annunciation, commonly called Gonville and Caius College, a family of immediate colleagues, I can offer only inadequate words. I do not know where else conditions so perfect for carrying out an enterprise such as this could be found, a peaceful workshop in the topographical centre of the University and all its libraries, between the President's apple-tree and the Porta Honoris. Here our study of Chinese shipping, the results of which are reported in this volume, has had a special appropriateness, for these rooms knew as their previous occupant my own tutor, Sir William Bate Hardy, F.R.S. Hardy as a discoverer and organiser, one of the founders of modern cytology, biophysics and food preservation technology, has now long himself become part of the history of science—but he was also a master-mariner of fame in his day. He would have delighted to know that the

breath of the sea still penetrates to the court which Dr Caius expressly left open to receive it. So also would that much earlier 'mathematical practitioner', Edward Wright, Fellow from 1587 to 1596, vir morum simplicitate et candore omnis gratum, the author of 'Certaine Errors in Navigation' and one of the greatest of Elizabethan boffins. Meanwhile, the daily appreciation and encouragement of every one in the Society helps us to surmount all the difficulties of the task. Nor could I omit need of thanks to the Head of the Department of Biochemistry and its Staff for the indulgent understanding which they showed to a colleague seconded, as it were, to another universe.

The above paragraph was written before I was elevated to the responsibility of being Master myself, but the work continues nothing changed, and my gratitude to my colleagues ever increases.

The financing of the research work for our project has always been difficult and still presents serious problems. We are nevertheless deeply indebted to the Wellcome Trust, whose exceptionally generous support has relieved us of all anxiety concerning the biological and medical volume. We cannot forbear from offering our deepest gratitude for this to its Scientific Consultant, formerly long its Chairman, the late Sir Henry Dale, O.M., F.R.S. An ample benefaction by the Bollingen Foundation, elsewhere acknowledged, has assured the adequate illustration of the successive volumes. To Dato Lee Kong-Chian of Singapore we are beholden for a splendid contribution towards the expenses of research for the chemical volume, and Prof. Ho's work towards this has been made possible by sabbatical leave from the University of Malaya. Here we wish to pay a tribute to the memory of a great physician and servant of his country, Wu Lien-Té, of Emmanuel College, already Major in the Chinese Army Medical Corps before the fall of the Chhing dynasty, founder long ago of the Manchurian Plague Prevention Service and pioneer organiser of public health work in China. During the last year of his life Dr Wu exerted himself to help in securing funds for our work, and his benevolence in this will always be warmly remembered. Certain kind well-wishers of our enterprise grouped themselves together some time ago in a committee of 'Friends of the Project' with a view to securing further necessary financial support, and to our friend the late Victor Purcell, C.M.G., who kindly accepted the honorary secretariaship of this committee, our best thanks are recorded. We are grateful indeed to Prof. E. Pulleyblank, Sir Eric Ashby, F.R.S. and Dr E. H. Carr, F.B.A., who have continued the oversight of this operation. At various periods during the studies which see the light in these volumes we have also received financial help from the Universities' China Committee and from the Managers of the Ocean Steamship Company acting as Trustees of funds bequeathed by members of the Holt family, more recently from the American Philosophical Society; for all this we record most grateful thanks.
Fig. 711. Map of road communications in ancient China, and of the lines of the great defensive walls.
munications in ancient China, and of the lines of the great defensive walls. Scale 1:5,000,000.
28. CIVIL ENGINEERING

(a) INTRODUCTION

No ancient country in the world did more in civil engineering, both as to scale and skill, than China, yet very little has been done towards making known the history of it. Perhaps this is the less surprising when we reflect that competence in civil, preferably hydraulic, engineering is rarely combined with sinological knowledge and a good understanding of Chinese historical literature, nor much more often with the opportunity of travelling over the country to study the vestiges of the great engineering works of former times. However, a beginning has been made, and in the present Section we shall try to sketch some of their most important features, beginning with roads and walls, going on to bridges, and then devoting the major part of our space to the great public works of hydraulic engineering in which the Chinese excelled.

There seems to be no general history of Chinese civil engineering (thu mu hung chheng) in the vernacular, and even well-balanced accounts of the development of the science in the West, essential for comparative purposes, are not too easy to find. Chinese literature does of course embody a wealth of notable books on water conservancy and control, but few which treat of the history of the techniques concerned in a modern manner, the authors preferring to discuss the geographical and economic aspects of the great works. Again, there was almost no coherent treatment of bridge-building until the Society for the History of Chinese Architecture took up the matter during the past thirty years, and published a number of important studies in its journal. All helpful sources will be mentioned in detailed reference as we proceed.

(b) ROADS

'Good roads, canals and navigable rivers', wrote Adam Smith in +1776, 'by diminishing the expense of carriage, put the remote parts of a country more nearly upon a level with those in the neighbourhood of the town. They are upon that account the greatest of all improvements.' His opinion is none the less just if we recognise, as is unavoidable, that the greatest highway systems of the ancient and medieval worlds were planned and constructed with strategic intent. Of the engineering techniques, as well as the geographical pattern, of the famous Roman roads, much is known, since besides the numerous remains which it has been possible to excavate, there are detailed literary descriptions of theory and practice. We know how the largest stones were laid

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*a* For antiquity see Merckel (1) and, better, Leger (1); for the Renaissance there is Parsons (3). The only modern general survey is that of Straub (1), unfortunately too short. Pannell's illustrated history (1), confined to occidental material, appeared too late to be of assistance to us. So also the collected articles of Merdinger (1).

*b* (1), p. 62. For a history of road engineering in general see Schreiber (1).

*c* The classical description of the Roman road system, and still the most complete, is that of Bergier (1), but it has long been out-dated by the results of modern archeology, as in Leger (1), especially p. 157.
at the bottom to form the _statumen_, rubble and chips of different sizes laid above for the _ruderatio_, then the nucleus of sand or gravel, or of broken pottery and bricks cemented with lime, the whole being topped with flat stone slabs to form the _summa crusta_ or _sumnum dorsum_. Kerbs were often provided. The body of the Roman road thus occupied an excavated trough as deep as five or six feet, some three times the depth required for a modern road. Sometimes the lower layers extended widely beyond the breadth of the actual road itself, with a ditch on each side, sometimes the road was accompanied by a drainage canal of substantial size, sometimes it ran on embankments or through cuttings, and elsewhere it might have retaining-walls along the sides of steep slopes. Such were the _viae munitectae_, but besides these fully paved roads the Romans also used graded earth tracks ( _viae terrenae_ ) and gravelled-surface side-roads ( _viae glareatæ_).

It has often been observed that roads in the Roman style resembled to some extent a series of walls lying horizontally. The methods of their engineers were for long the object of great admiration on the part of archaeologists, but, as des Noëttes (1, 9) pointed out, they were in truth primitive and ill-suited to their purpose. Allowing nothing for expansion and contraction due to temperature, frost fissures and unequal drainage, they depended on thickness and rigidity, while the more successful modern methods, culminating in the compacted chips of McAdam, and all their asphalted and other developments, depend on thinness and elasticity. These appear to be medieval in origin, but Chinese roads of similar light and elastic type long preceded them, as we shall see.

Although we can trace the origin of highways back to prehistoric tracks, bronze-age ridgeways and the like, impressive and complex systems do not develop until the rise of strong and centralised government. Hence the Persian Royal Road of the early 5th century from Susa (the capital in the mountains north of Baarî) to Sardis (the most westerly city in the Iranian empire, near the port of Ephesus in Asia Minor), a distance of some 1,400 miles; and another road which led eastwards, about as far, to Sogdiana. Hence also the remarkable road-system, at least as large, and covering much more difficult terrain in the Andes, built by the Incas State and its predecessors.

Comparable road-building work, perhaps not so extensive, was also carried on in Mauya India, judging from indications in the _Arthålalista_.

(1) _Nature and Expansion of the Network_.

Gazing down upon the Old World during the few centuries before and after the turn of the era, some demigure might have seen, as in a slow-motion film, the appearance and radiation of two dendritic systems of highway communication springing from two different centres, one near the western coast about the middle of the Italian peninsula, the other near the great bend of the Yellow River where it swings round the Shansi mountains to flow eastwards to the Yellow Sea. The vision would have resembled somewhat the radiation of blood-vessels from the body of the foetal bird to make their ramifying way all over its yolk-store of food—and the bio-sociological analogy is not invalid altogether, for the tax-goods coming in would pass the legions on their outward ways. Could the Romans have ever succeeded in conquering the Parthians and Persians the two road systems might have met, perhaps, anastomosing somewhere west of Sinkiang, but this was not to be. The octopus-like arms expanded independently, each in a world of its own, their builders troubled only occasionally by the vaguest rumours of another system too far away to matter.

There is a curious parallel between the Roman and the Chinese systems in that both, after the +3rd century, fell into a long period of decay, but while Europe became parcelled out into feudal kingdoms and domains with poor communications except by sea, the role of the Chinese highways passed over to an immense system of navigable rivers and artificial canals, leaving only the mountain roads to continue their age-old function. As the chief sources of knowledge about the ancient Chinese network and its growth the dynastic histories take first place, together with the abundant remains of the historical geographers, a numerous tribe among the Chinese literati. And always, as would be expected in a feudal-bureaucratic society, the central government concerned itself with the construction and maintenance of the principal routes of communication.

In China [wrote Adam Smith], and in several other governments of Asia, the executive power charges itself both with the reparation of the high-roads and with the maintenance of the navigable canals. In the Instructions which are given to the governor of each province, these objects, it is said, are constantly recommended to him, and the judgment which the court forms of his conduct is very much regulated by the attention which he appears to have paid to this part of his instructions. This branch of public policy, accordingly, is said to be very much attended to in all those countries, but particularly in China, where the high-roads,
and still more the navigable canals, it is pretended, exceed very much everything of the same kind which is known in Europe. a

These features may be illustrated by some of the oldest records of road-building in the Chinese culture-area which have come down to us. A verse in the Shi Ssu Ching (Book of Odes) expresses admiration of the roads in the neighbourhood of the Chou capital. b

The roads of Chou are (smooth) as a whetstone,
Straight as an arrow’s flight; 
Ways where the lords and officials pass,
Ways where the common people look on.

As this folk-song is considered rather ancient, perhaps of the 9th century, in the Western Chou period, it may refer either to the Wei Valley, Kuan-chung (‘within the passen’) as it was later called, or to the eastern capital and domains of the Hih King near the later site of Lo-yang. c The route between Chiang-an (I) and Lo-yang (6) must certainly be one of the most ancient tracks in all China. d When we come to the Chou Li (Record of Institutions, lit. Rites) of the Chou Dynasty, that —2nd-century compilation of the ideal structure of the feudal-bureaucratic State, we have much more detailed information on the technical terms for roads, though it seems to incorporate two distinct traditions, probably from different earlier feudal States. In the entry for the Ssu Hsien (Director of Communications) we read: e

He studies the maps of the nine provinces in order to obtain a perfect knowledge of the mountains, forests, lakes, rivers and marshes, and to understand the (natural) routes of communication.

Comm. When mountains and forests present obstacles, he cuts through them. When rivers and lakes offer impediment, he bridges them.

He lays out the five kinds of canal and the five kinds of road, planting trees and hedges along them for defence. All special points, passes and junctions have guard-posts, and he knows the ways and roads that lead to them.

Comm. The five kinds of canal (kou) are sui 3 (ditches), kou 4 (conduits), hsiieh 5 (or hsi 6 , small canals), hui 6 (or hui 7 , medium canals), and chhuau 8 (great canals). The five kinds of road (thu) are ching 9 (paths or ways), chen 10 (larger, paved, ways), thu 8 (one-width roads), tao 11 (two-width roads), and lü 11 (three-width roads).

If there is alarm in the empire he fortifies the roads and difficult points, halts wanderers, and guards the positions with his men, letting past the barriers only those with the imperial seal.

The systematisation of the capacities of roads and canals, doubtless largely schematic, appears in the passages devoted to the Sui Jen (Grand Extensioner, or Minister of Agriculture). f

This is how he organises the countryside. Between each farm there is a ditch (mai 12 ) with a path (ching 9 ) along it. Past every ten farms there runs a conduit (kou 4 ) with a way (chen 10 ) alongside. Past every hundred farms there runs a small canal (an 10 ) with a one-width road (thu 8 ) accompanying it. Past every thousand farms there runs a medium-sized canal (kuei 12 ) with a two-width road (tao 11 ) along its bank. Past every ten thousand farms there runs a large canal (chhuau 8 ) with a three-width road (lü 11 ) at its side. Such are the communications in the imperial domains.

Comm. The five grades of roads are all to connect the country and the capital for carriages and pedestrians. (Apart from men) paths will take only horses and oxen, the wider (paved) ways will take large hand-carts, a one-width road will take a single chariot, a two-width road will take two abreast, and a three-width road will take three abreast. One may make the country roads the same width as the ring-roads of cities.

Now we know what was meant by a ‘two-width road’. b But another text in the same book has more spacious ideas. Under the heading of Chiang Jen (Master-Builders) we find: g that in the capital the main streets (ching thu 11 ) are to carry nine chariots abreast, the ring-roads (huau thu 11 ) are to carry seven, and the country roads (presumably imperial highways, yeh thu 11 ) are to carry five (Fig. 712). Furthermore, capitals of feudal princes are to have their main streets of the seven-width grade, their ring-roads five-width, and their approach roads three-width. Other cities must not exceed the five-width grade for their broadest streets, with all their other roads at the three-width level. Perhaps there is no discrepancy if the grandeur of the Chou (or Han) capital is at issue only in this second text.

During the Warring States period there was much road-building activity both for military and commercial purposes but the details are still unclear. The State of Chihin, however, as we shall see, had been particularly busy, and the works achieved may well have been a great factor in its success. As soon as the whole empire was for the first time united under Chihin Shih Huang Ti in —221, he embarked upon his celebrated policy of metrological standardisation and fixed, among other things, the gauge of chariot-wheels. d In —220 he made a tour of inspection in Kansu and Shensi, after which...

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a Ch. 2, pp. 108 ff.

b Ch. 2, pp. 108 ff.

c Ch. 2, pp. 108 ff.

d Ch. 2, pp. 108 ff.

e Ch. 2, pp. 108 ff.

f Ch. 4, pp. 24b, 25a (ch. 15), tr. auct. adjuv. Biot (1), vol. 1, p. 341. Note the decimal progression, with regard to Vol. 3, pp. 88 ff., 89.

g An interesting Indian parallel of a few centuries later occurs in the Arthasatra (Shamsayati 12, p. 53). Roads to military stations are to be 48 ft. wide, royal chariot roads in the countryside 24 ft., elephant forest roads 12 ft., ordinary chariot roads 7½ ft., cattle ways 6 ft. and paths for men 1 ft. Inca data from Peru range from 75 ft. (processional) through 45 ft. and 24 ft. (‘regulation’) to 15 ft. (quite frequent). Widths of 12 ft. and 6 ft. only occur in the communications of the subsidiary cultures (von Hagen, 3).

h Ch. 12, pp. 175, 180, 20a (ch. 43), tr. Biot (1), vol. 2, p. 264 ff.

i Shih Chi, ch. 6, pp. 126–132, 13b, tr. Chavannes (7), vol. 2, pp. 130, 133. The text says that the Chihin double-pace (pu) was fixed at 6 ft., and that the chariot gauge was uniformised throughout the empire. The gauge has always been taken as one double-pace, and indeed the Chen Li (Khoa Rung Chi) says that the ‘distance between the wheels is 6 ft.’ (ch. 13, p. 344, tr. Biot (1), vol. 2, p. 358). But what this means

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Though contemporary descriptions are not available, it is worth giving one from only a few years afterwards. About -178 Chia Shan, one of the emperor Wen Ti's counsellors, presented him with a horatian essay, entitled Chih Yen (Words to the Point), in which he analysed the causes of good government and civil confusion, particularly criticising Chhin Shih Huang Ti. After decrying the luxury of the palaces built at Hsien-yang, he continued:  

He also ordered the building of the post-roads all over the Empire, east to the uttermost bounds of Chhi and Yen, south to the extremities of Wu and Chhu, around the lakes and rivers, and along the coasts of the sea; so that all was made accessible. These highways were 50 paces wide, and a tree was planted every 30 ft. along them. The road was made very thick and firm at the edge, and ramped with metal rammers (chhin chiu). The planting of the green pine-trees was what gave beauty to the roads. Yet all this was done (only) so that (Chhin Shih Huang Ti's) successors (on the throne) should not have to take circuitous routes.

Later commentators were a little puzzled by the statement about the structure of the roads (hou chu chhi tai), some thinking that they were lined by walls on each side, like raised causeways (yung tao), others that the ramping referred simply to the consolidation of the edges, especially where there was an embankment. That little trace of these roads remained in later ages presumably implies that they were less massively built than the Roman roads. Yet if they consisted chiefly of rubble and gravel tamped down in the manner of pisé walls (see on, p. .35), they were more elastic and therefore much more modern in conception. Such 'water-bound macadam' was in fact the traditional material of Chinese highways in all periods.

As for the width, it is generally agreed that the '50 paces' of the Chhien Han Shu was a scribal error for 50 ft. So that the imperial highways would have been approximately nine-width roads equivalent to the broadest described in the Chou Li. They were thus rather larger than most of the Roman roads. The inner lanes of these nine-lane thoroughfares were apparently reserved for the equipages of the emperor himself and authorised members of the ruling house; messengers, officials and merchants using the outer ones.

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Let us look at the course of the imperial highways shown on the map (Fig. 7II). A more easterly centre, San-chhuan (6) in the neighbourhood of modern Loyang, was chosen as the hub of the system, the road from Chhang-an (1) negotiating the Han-ku Pass (12) much as the Lung-hai railway does today, and traversing the smaller centres of Hua-yin (57) and Hung-nung (58) in the Yellow River valley. Thence the Eastern road went straight to Lin-tzu (8) in Shantung, capital of the former State of Chhi, following the Chi River and passing places not now exactly identifiable. Branching from San-chhuan, the North-eastern road went up diagonally through Hopei to Chi (7), near modern Peking, capital of the former State of Yen, probably passing through Han-tan (62) and Chung-shan (63), well-known cities of the Warring States period. Following the Chi River near Hsiang-yang (71) and reaching Nan-chiin Pass (45x486) a more easterly centre, San-chhuan (6) in the neighbourhood of modern Loyang, was following the Chi from San-chhuan, the North-eastern road went up diagonally through Hopei to Chi (7), near modern Peking, capital of the former State of Yen, probably passing through Han-tan (62) and Chung-shan (63), well-known cities of the Warring States period. Nearly as long as the South-eastern road was the Han-tan (62) and Chung-shan (63), well-known cities of the Warring States period. From Nan-chiin Pass the road went straight to Lin-tzu (8) in Shantung, capital of the former State of Chhi, which it turned south, crossed the Yangtze in the vicinity of modern Nanking (54) after crossing it not far from Loyang, and water transport probably proved useful for the conveyance of the road metal. The longest road was that which struck off south-east towards the mouth of the Yangtze. Skirting first the northern edge of the capital of the former State of Wu. Nearly as long as the South-eastern road was the Han-tan (62) and Chung-shan (63), well-known cities of the Warring States period. Such was the way in which the order was carried out to link the ancient countries of Chhi and Yen, Wu and Chhu, with the capital of the Chhin empire. It remains to speak of the Great North Road, the only one for which we have any details concerning its construction. In 212 Mêng Tien, one of the First Emperor's attendants, built a great military road from the Yellow Sea to Chfang-sha (16). It then proceeded up the Hsiang River valley past Hêng-yang (17) to its terminus at Ling-lîng (18). Although it was now going eastwards again this was no mistake, for as we shall see later on (pp. 290 ff.) the upper waters of the Hsiang were made to connect in Chhin times by a remarkable canal with the upper waters of the West River (Hai Chiang) of Kuangtung, thus permitting the transport of arms and supplies for the conquest of the Cantonese State of Nan Yüeh. Such was the way in which the order was carried out to link the ancient countries of Chhi and Yen, Wu and Chhu, with the capital of the Chhin empire.

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Table 60 (continued)

51. Yung-chang (in Kansu)
   = Feng-hsiang (Eastern Gate of the Great Wall)

52. Hsiao Kuan (Hsiao Pass)
   = Ku-yuan (Kan-chow)

53. Hui-chung Kung (Western Gate of the Great Wall)
   = Kalgan

54. Li-ying Pass
   = Issedon Serica (the kuan-thai gate)

55. Hua-yin (or Huang-nung, Huang-nung Pass)
   = Kuo-lieh (or Kuo-liieh)

56. Shang-chin
   = Kuang-chou (Canton)

57. Tai-ta (Tai-chiin)
   = Cheng-chiang (Chengchow) west

Table 60 (continued)

76. Liu-pa (or Lia-pa)
77. Mei-hsien 蕭縣
78. Chou-chih Pass
79. Ning-chhiang 雲陽 (or 雲陽 Pass)
80. Chao-hua 鬆化
81. Chien-men Kuan 關門關 (Sword-gate Pass)
82. Mien-yang 靜陽
83. Shu [5] 蜀
84. Pa [58] 巴 (former capital of Pai State)
85. Pa-yu Kuan 保安關 (Pass)
86. Phing-chieng 平縣
87. Fei-hu Khou 樂狐口 (Flying-fox Gate)
88. Tung-kuan 通關
89. Tsang-kho (or Thung-tzu, Thung-tzu Pass)
90. Yeh-lang 雲陽 (or Pao-cheng State)
91. Yeh-lang Pass
92. Tsang-ku (or Thung-tzu Pass)
93. Yeh-chang 興昌
94. Yeh-chang Pass
95. Chiao-chou 潮州
96. Han-kuang 漢口
97. Ying-te (Yingtak)
98. Old Nan-hai 紅海
99. Chü-yan 周延
100. Yung-chang 永昌 (in Yunnan)
101. Shen-chang 宣昌
102. Shen-chang (Su-chou, Suchow) State
103. I-chou 益州
104. I-chou 大州
105. Chü-chiang 漢江
106. Tai-chiin 移支
107. Jung-yang 員陽
108. Ku-pe-khou 古北口
109. Nan-khou 南口
110. Chang-chi-khou 張家口
111. Phing-hi Khou 菁滄教 (Pass)
112. Phing-hi 普渡 (Pass)
113. Yen-mén 雁門
114. Ning-hsiang 永昌
115. Hai-kuang 海康
116. Yang Kuan 楊關 (Gat)
117. Kao-chihie 高陽
118. Shen-yang 沈陽
119. Yen-chiang (or Thung-tzu) Gate
120. Shou-chou (Suchow) State
121. She-haien 宣化
122. Shou-chou 勝州
123. Tsing-ming 大名
124. Lin-chhing 隆清
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Table 61. Highway names on the map of road communications in ancient China (Fig. 711)

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</tbody>
</table>
most important generals, whose name will always be connected with the Great Wall (see on, p. 52), was ordered to build a road from Hsien-yang (2), the imperial capital (3, 4) and out through the Wall, striding across the Ordos Desert to the northernmost line of the Yellow River. Here, somewhere not far west of the modern steel city of Pao-thou, there was a fortified outpost called Chiu-yuan (5), probably a vantage-point for observing the affairs of the Huns and other nomadic peoples, and doubtless also a trading centre for their products. The texts expressly say that this road was carried in a straight line through the mountains by cuttings and across the valleys by embankments (chhien shan yin hu chhing chhing chih).

It is interesting to assess the total length of these imperial highways which fanned out from the metropolitan region of Kuan-chung in the - 3rd century. The figures are approximately as shown in Table 62.

4 In this context the question has been asked (not at all an irrelevant one for transport problems) at what time the snowshoe (mu ma, 'wooden horses'); according to some of the usual legendary datings (e.g. Mathys, 1). One of these was kindly brought to our attention by my colleague Dr F. P. Bowden in 1955. The texts, first studied by Lauffer (30), take a little digging out, but they indicate conclusively (cf. Needham, 49) that the knowledge of the Chinese had what snowshoe came from their contact with the northern Turkic peoples early in the -7th century. No earlier references have been found. In +649 the Pa-yeh-ku (Bayirk, a branch of the 'Thi-chi' tribe (Tolo) tribe, cf. Vol. 3, p. 612, Vol. 4, pt. 1, p. 49 and Feen, Needham et al., who 'riding on pieces of wood, hunt deer over the ice,' first brought tribute (Thang Tien, ch. 199, p. 317), that great range of mountains shutting off Chhang-an and the Wei Desert to the

28. Roads

Table 62. Lengths of Chinn imperial highways

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Length (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chhien and Chhien Han li</td>
<td></td>
</tr>
<tr>
<td>Hsien-yang (Chang-an) to Lo-yang</td>
<td>950</td>
</tr>
<tr>
<td>Lo-yang north-eastward to Chi (Yen)</td>
<td>2,000</td>
</tr>
<tr>
<td>Lo-yang eastward to Lin-tzu (Chhi)</td>
<td>1,800</td>
</tr>
<tr>
<td>Lo-yang south-eastward to Kuei-chi (Wu)</td>
<td>3,800</td>
</tr>
<tr>
<td>Hsien-yang southward to Ling-ling (Chhu)</td>
<td>3,300</td>
</tr>
<tr>
<td>Hsien-yang northward to Chiu-yuan</td>
<td>1,910</td>
</tr>
<tr>
<td>Total</td>
<td>13,750</td>
</tr>
</tbody>
</table>

Taking the Chhien and early Han li as equivalent to 0-309 mile, this amounts to some 4,250 miles—not very unlike the distance of 3,740 miles which Gibbon estimated as the length of first-rate Roman road running continuously from the Antonine Wall in Scotland to Jerusalem. Further comparisons will arise as we go on.

There is evidence that the imperial highways system was only part of the road-building activity of the Chhien State and dynasty. The city of Yung (51), its former capital, was certainly connected with Hsien-yang and Chhang-an by a road running north of the Yellow River through Fu-feng (22) and Wu-kung (21) on higher ground than the present line of the Lung-hai railway. By -509, when the dynasty fell, some kind of road was in existence connecting Heng-yaung (17) with Nan-hai (76, Canton) via Chhiu-chiian (69, Kukong) and Ying-te (97, Yingtak) just as the Yih-han railway does today. This must have penetrated the gorges of the Nan Ling and mountains. In later centuries it became a very important north–south route between Canton and Peking, though for long the bulk of the traffic went round by the canal near Ling-ling. But the really heroic test of the ancient road-builders was the challenge of the Chhing-shan (3), that great range of mountains shutting off Chhang-an and the Wei valley from the south-west. This we shall discuss in a moment, since the works of Chhien and Han cannot easily be separated; here it is only needful to recall that the State of Chhien made conquest of the Szechuan States of Shu and Pa as early as -316, and the work of its unknown engineers must have been a primary factor in the achievement. By the end of the century the Chhien rulers were pushing on their colonisation across the barbarian uplands of Yunnan. Ssuma Chhien says, iconically:

'Under the Chhien, Chhang An 3 planned and constructed the Five-Foot Way (Wu-chhih Taou).',

Starting across the Yangtze from Pa (84, modern Chungking), already connected by road with Shu (83), it ran down through the hills of Kweichow via Yeh-lang (102) and Lang-chou (103) to reach the Kunning Lakes and the Ehr-hai Lake.
at Tien (90), I-chou (104) and Yeh-yü (91) respectively. This was a traverse very similar to that of the present-day road between Kunming and Chungking, continuous with the Burma Road, which took so much traffic during the Second World War. The commentators add that the Si Five-Foot Way (K) got its name from the abundance of stretches where it could not be more than five feet wide, since it often skirted precipices and included many hanging galleries (chan tao), i.e. wooden balconies jutting out from perpendicular cliffs and carrying the road along. Here for the first time we encounter a method of construction about which there will soon be much to say.

If the Chhin capital had had five major imperial roads radiating from it, the same metropolis under the Former Han emperors, rulers of a still more closely knit subcontinental nation, had as many as seven. We may consider them best not by boxing the compass, but in ascending order of magnitude and engineering interest. To the northwest there was a further opening-up of the Kansu and Shensi hill-country north of the Wei valley, with new roads to An-t'ing (50) and Hui-chung Kung (53), the latter completed in -108. To the south-east the distance to Chhang-sha and points south was shortened by a road direct from the capital to Hsiang-yang (71) passing south of the Liu-ling and Hsin-k'ai Ling mountains. Northward the capital was newly connected with Chiu-yuan (5, now Wu-yuan) by a road through Shang-chhin (55) which, though more roundabout, probably traversed easier and more inhabited country than the Great North Road built by Meng Thien. More important than any of these was the use of the long Fen River valley in Shanhsi to throw a road north-eastwards through Chin-yang (66, modern Thien-yuan) to Yen (7, Peking), considerably shorter than the former one, though still necessitating a Yangte crossing near Thung-kuan (57). From Yen communications were pushed through to Korea about -129, on the occasion of the conquest of that country by Pheng Wu, the General Wade of the Chhien Han, whose road must have passed through the Wall in the neighbourhood of Shan-hai Kuan (101).

In the eastern region the Han road-builders were particularly active, laying down a network of highways all over the North China Plain. Han-tan (62) was connected eastwards to Lintzu (8), south-eastwards to Phei (10), and southwards to Chhen-liu (9), whence a road continued to Nan-yang (14) joined by one from Lo-yang (6). Another new road struck south from Phei to Chhi-chuang (66), after which it descended to Chhing-chiang (67) and linked west with Chhang-sha (10) just as the Nan-hsun railway does today. Phei was also connected with the coast at Lang-ya (64), a place famous from the time of Chhin Shih Huang Ti. Further extensions were made by the Hou Han engineers, as we shall see, but in ancient times no penetration was made of the Fukien amphitheatre, where the country was too difficult and the people still barbarous.

Out towards the far west the case was very different. The desert oases formed less barrier to intercourse than the forested mountains, and the moment has come to examine the Chinese end of the Old Silk Road (A), an incurably romantic subject. Here we may not repeat what has already been said about east-west communications at an earlier stage, but we must see how the Chinese highway network joined on to the caravan trails around the Taklamakan Desert in Sinkiang (Chinese Turkestan). Leaving behind the complex of ancient roads in the Wei valley at Pao-chi (23) the road to the West passes through the gorges of the upper waters by Thien-shui (24) and then lifts itself up over the Hua-chia Ling passes to descend to Chhin-chhia (27), modern Lanchow) on the Yellow River beyond the great bends, for two millennia the hub of routes in this western region. Then over the Wu-shao Ling Pass (29) to Wu­wei (30), anciently known, by mistake for Chhing-an, as Sera Metropolis. After Wu­wei comes Yung-chhanging (31), site of the settlement about -30 of captured Roman legionaries, and then after the crossing of many streams and avulsion fans coming down from the lofty Nan Shan (1) (Chhi-lien Shan) on the left to be lost in the Gobi Desert on the right, Chhi-chhian (35, modern Suchow) is reached. All this while, the road has been protected upon its right-hand side by the extension of the Great Wall also constructed in the Han period, and at the same time a road was made north-eastwards to the lost city of Chhi-yen (99) by the Edsin Gol, certainly another listening-post for tribal intentions. Now the road leaves the guardianship of the Wall and strikes off across wild desert country to An-hai (38, anciently Kua-chou, the Melon City), a fortified post marking the first fork of the Old Silk Road. All this 'Kansu Corridor' was settled after the victory over the Huns in -121.

Thenceforward we have to think of the circumnavigation of the Taklamakan Desert in the 'Wild West', through which China culture meets that of the nomadic peoples, and where every place-name in the sandy wastes, with the snowy ghosts of the Nan Shan or the Thien Shan shining in the distance, bears witness to the heroic deeds of the Chinese soldiers and administrators of ancient times, marking the outposts of a truly great civilisation.

a Road names, with their key letters, will be found assembled in Table 61.

b To the south is Mai-chi Shan, the site of later Buddhist cave-temples, so often referred to in this book.

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1. 笛道  2. 洗像  3. 新開圖  4. 新河  5. 影堂  6. 影象寶
of the lost city of Lou-lan (42) beside the doomed lake Lop Nor. West of Tun-huang and Yu-men Kuan (40) the routes were caravan trails rather than main roads, but up to those points the roads were fully equipped with forts, beacons and post-stations in -107, during the campaign against the Lou-lan State. By -101 the line of forts and beacons was continued to Lou-lan itself, and perhaps also to Yu-ni. Between -77 and -59 this was the only loop of the Old Silk Road open to traffic.

North of the Taklamakan Desert there was the Road South of the Celestial Mountains (Thien-Shan Nan Lu'), running along their foothills (M) towards Kashgar. It was the first reached in -101 through Lou-lan to Wei-li (48, K518), but closed by the hostile Lou-lan people, who had moved northward, during the period just mentioned. This was the route which the armies of Kan Yen-Shou and Chien Thang employed in -36 in their expedition against the Hun Khan (the Shanyu) in Sogdiana. The Thien-Shan Nan Lu was reached in quite another way towards the end of the Former Han period by a (P) which penetrated north-westwards at An-hai (38) and struck boldly across the Gobi to I-wu (41, north-east of modern Hami, K721). It then passed west to Kao-chhang (45, Turfan), rejoining the older Lou-lan route at Wei-li (48). This road, later known as the Liu-chung Lu (Road through the Willows), was not complete until about +5, and not in real use till +73, when the I-wu region was occupied by the Chinese. After this, it superseded altogether the old roads through Lou-Lan, where Lop Nor was drying up, and the city itself soon to be buried in the sands until the coming of modern archaeologists. This road, later known as the Liu-chung Lu, which penetrated their eastern end (L) by taking off from Harni (41) and running to the lake at Chui-mi (105, Barkol), thence westwards to Ti-hua (106, Urumchi) and so to Kazakhstan. Eventually, especially in times of general imperial peace, the bulk of the trade and migration moved this way, down to the days indeed when war supplies for China rolled from the Turk-Sib railway along the southern edge of the Tuungarian plain. But there is ground for thinking that this northern route was the ancient way in which rubarb travelled to Rome, passing through the hands of the imperial blood-vessels of the empresses of the Han.

- **Stein** (10) has given a graphic account of his explorations of ancient roads in this region. On the Han Great Wall which protected Tun-huang, see p. 49 below.

+ **All this region had been prospected in the travels of Chang Chhien, already described in Vol. 1, p. 173, between -138 and -126. Dr Lu Gwei-Djen and I had the pleasure of studying the Han beacons and remains of forts on the Suchow-Tun-huang road once again in 1958. Cf. Fig. 72(a).**

+ **These names are evocative. Certain inscriptions in this region are unforgettable. The central drum-tower at Chhi-chih-chun (Suchow) carries the words ‘The sound that both Chinese and Barbarians hear’ (Sheng chen Hua P). On the north arch: ‘Straight to the desert’ (Pei tung sha-mo). On the south arch: ‘Face to face with the Chhi-lien Shan’ (Nan wang Chhi-lien). On the eastern arch: ‘Straight to the holy mountains of China’ (Tung tung huu yao). And on the western arch: ‘Towards the outpost of I-wu’ (Hai chen I-wu)’. So I saw it first in 1943 with Dr R. Alley, Mr Sun Kuang-Chin, Mr Wang Wan-Sîgong and other friends.**

+ **The initial conquest had actually been in -68.**

+ **Cf. Wulfsperger (1, 2); Hisamura Yukari (1) and Lo Jung-Pang (6) have made detailed studies of this road-system.**

+ **Cf. Vol. 1, pp. 114 ff. and passim.**

+ **Hence its name, the Chhien-tang Tao (Chhien’s Granary Road), but it was also known as the Old Road (Ku Tao).**

+ **When this Section was first drafted (1955) the Chhien-tang–Po-chi railway was in full construction along a closely similar route, to join at Po-chi with the Lung-hai extension past Lanchow over the Old Silk Road. In 1958 both enjoyed a journey along the latter line. Cf. Lien Tien (1); Chang Ching-Chih (1); Wang Yu-Chi (1); Anon. (54, 55, 56).**

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28. ROADS

That lines of forts were established along the great roads in the neighbourhood of the northern and north-western times is most certain, and the same system was probably used in Yunnan and other parts of the wild south-west. But besides these there were also fortified causeways (yung tao) running for relatively short distances in and around Kuan-chung, where the defence of a line of communication seemed particularly important; perhaps they were something like the Long Walls of the Piraeus. One such work connected the Ao Granary, a vital strongpoint, with the Yellow River quays near Jung-yang (107). The greatest engineering work of the Chhien Han road-builders, however, was the consolidation of the passes through the towering Chhin-lung Shan (3), those routes which had been pioneered by the Chhin people as early as the -4th century. To explain this we must return upon our steps and take up the story again from that date. The problem was to find routes across the great mountain divide between Shen-shi (Kuan-chung) in the north, where the Chhin capital was located, and the Szechuan basin, where the half-barbarian States of Shu and Pa, occupying rich agricultural land in a key economic area, were inviting annexation by the aggressive Chhin State. A deep intervening valley, that of the Han River, permitted the surveyors to take their breath before finding their way down or across the head waters of the Chialing River and into Szechuan. First then there was the range which brings the Pai-Pai Shang with its snows in sight from every vantage-point on the northern slopes of the Wei valley, and afterwards there were the less grim ranges of Mi-tshang Shang and Ta-pa Shang. Even today, the modern motor-road which connects Szechuan with Shensi passes through remarkably scenic, but in ancient times it must have been even wilder and more difficult country. This region saw the most spectacular work of the engineers of Chhin and Han. The focal way-stations were three small cities on the upper reaches of the Han River, Mien-haien (72), Pao-chhêng (73) and Han-chung (74). All the roads which went through them were in existence when the First Emperor ascended the throne in -221, but they needed, and received, great improvement under the Han. The oldest road (F) started from Chien-tang (old Pao-chi, 23), crossed the Wei River, ran up a small tributary through the Ta-san? Pass and came to the little town of Feng-haien (75). Then it turned westwards to the upper waters of the Chialing before doubling back into the
mountains to find its way to Mien-hsien. The first Chin improvement (B) was to shorten the western detour by striking through the mountains directly from Peng-hsien by way of Liu-pa (76) to Pao-chheng; this was known as the Lien-yiin Tao\(^a\) (Linked-Cloud Road). The passes on this route did not exceed 7,000 ft., but no less than one third of its 430 li was composed of wooden trestles built over the beds of roaring torrents, or actually shovled into the cliff higher up by means of timber baulk brackets driven into holes in the rock face.\(^b\) An accidental parallel for this chan tao\(^c\) system was the mountain road-building of Tiberius (r. + 14 to + 37) and Trajan (r. + 98 to + 117),\(^c\) but it was rather limited in comparison, and both these emperors were, as we should look at it, Hou Han people. The southern portion of the Chhen-tshang Road now fell out of general use. It is interesting that still to this day the modern motor road follows approximately the route of the Lien-yiin Tao,\(^d\) which has been the principal line of communication through the mountains since the Sung dynasty.\(^e\)

The second Chin improvement (C) chose a still more easterly traverse. Starting from the town of Mei-hsien (77) on a road running south of the Wei River from Chhangan, not north, it ran up the steep valley of the Yeh\(^f\) tributary through the Yeh-yii \(^g\) Pass and came out on the high mountain country surrounding Thai-Pai Shan to the west. Here it found the southward-pointing valley of the Pao\(^h\) or Thai-pai\(^i\) River, where a place still bears the name of Thung-chhe-pa\(^a\) (Passing-place for Carta), and dropped down to Pao-chheng from near Liu-pa. It thus short-circuited the northern portion of the Lien-yiin Road just as that had cut out the southern portion of the Chhen-tshang Road.\(^j\) First constructed with innumerable trestle and gallery sections in the 4th century, it was extensively enlarged and repaired about —260, in. —120 and + 66.\(^k\) Geography gave it the name of the Pao-yeh Tao,\(^l\) but because of its engineering works it was also known as the Pei-chan Lu\(^m\) (the Northern Trestle Road). Early in the 3rd century Chuko Liang described the massive pillars and beams which upheld the road through the ravines which it traversed. About what happened in —120 we know a good deal. Sauma Chhiien says: \(^n\)

After this, someone presented a memorial to the emperor proposing that the Pao-yeh Road should be adapted for the transport of grain by boat. The matter was referred to the Censor-in-chief Chang Thang,\(^o\) who enquired into the matter and reported as follows: \(a\) in order to reach Shu (Szechuan) (traffic) goes through the Marches of the Old Road (Ru-tao)\(^p\) where there are many rocky descents and long detours; if now we pierce a (better) road between the Pao and the Yeh the gradients will be much less difficult and the distance will be shorter by 400 li. Since the Pao river flows into the Mien river,\(^q\) since the Yeh descends into the Wei, we should be able to use them for grain transport by boat. The grain would come up from Nan-yang along the Han, the Mien and the Pao; then from the point where the Pao becomes too shallow the grain will be transported in carts to the headwaters of the Yeh about 100 or more li, after which other boats will take it down the Wei (to the capital). Thus the grain of Han-chung will become available, and that from east of the mountains can come in unlimited quantities, much more easily than it does past Ti-chu.\(^r\) Lastly, the abundance of wood and bamboo, both small and large, in the Pao and Yeh valleys, useful for construction, is comparable to that in Pa and Shu itself.\(^s\) The emperor approved the project.

Chang Thang's son, Chang Ang,\(^t\) was (accordingly) appointed Administrator of Han-chung, and he recruited several tens of thousands of men who re-constructed the Pao-yeh Road over a total distance of more than 500 li. The road was in effect convenient and shorter (than the others), but the rivers proved to be too violent and too much encumbered with rocks to allow of the grain transport by boats which had been envisaged.\(^u\)

This passage is of much interest as it illustrates the close coordination between land and water transport which characterised Chinese planning for more than two millennia.

Between the periods of rule of Tiberius and Trajan, the Pao-yeh Road, incorporating the southern portion of the older Lien-yiin Road, was repaired again after some three centuries of continuous use, and what that involved may be estimated by the figures which have come down to us—766,800 man-days of work, carried out by 2,600 convict workers.\(^v\) Much of the information about these roads in Han times comes from still existing stele inscriptions, which Lao Kan (2) discusses.\(^w\) Dating, for example, from + 57 and + 63, they mention surveyors\(^x\) as well as corvee labourers. Besides the miles of trestles and galleries, there were 623 small bridge-spans and five large ones, which was (accordingly) appointed Administrator of Han-chung, and he recruited several tens of thousands of men who re-constructed the Pao-yeh Road over a total distance of more than 500 li. The road was in effect convenient and shorter (than the others), but the rivers proved to be too violent and too much encumbered with rocks to allow of the grain transport by boats which had been envisaged.\(^u\)

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Galeries, travel over them in a great deal of pain, afraid of some ill accident or other. But the People of the place are very hazardous; they have Mules used to these sorts of Roads, which travel with as little fear or concern over these steep and hideous precipices as they would do in the best or plainest Heath.

And a thousand years earlier, the great poet Li Pai, who passed over the Chhinling Mountain roads more than once, wrote a famous poem on 'The Road to Szehuan'.

. . . To the West, starting from the Great White Mountain, a it was said
There was a bird-track that cut across to the mountains to Szehuan;
But the earth of the hills crumbledc and heroes perished.
So afterwards they made sky-ladders and hanging-bridges—
Above, high beacons of rock that turn back the chariot of the sun,
Below, whirling eddies that meet the clashing torrent and turn it away;
. . . It would be easier to climb to Heaven than walk the Szehuan Road.d

The construction of cliff-galleries was also naturally adopted in Tibet. We hear of 'suspended roads' (hsüan lu) in the travels of the monk Hui-Chhao to and from India around +726 on his pious missions. The Chinese also used half-tunneling, i.e. excavation of half the cross-section of the road into the cliff-face with a rock overhang (k'ung tao or liu-ch'ien tao), just as the Romans did in the time of Tiberius and Trajan.

Sometimes the rock will support an almost full cross-section; astonishing examples of great length are seen in the paths of the trackers or haulers of boats through some of the gorges of the Yangtze (Fig. 880, pl.). A number of these galleries exist in and around the San-mên Gorge, where the rocks bear many ancient inscriptions; all this has been the subject of a valuable recent monograph. But the modern motor-roads have also made much use of the technique, as can be seen, for example, on the Szehuan—Shensi highway in the Chhinling Mountains just north of Kuang-yuan near Chao-hua (80). It is probable that the balcony roads of the Chinese were sometimes suspended from chains since, as we shall see, the invention of the iron-chain suspension bridge occurred so early among them (cf. p. 193 below); if so, it would have anticipated the use of the device in Europe, which is attested1 for the first opening of the Gotthard Pass through the Alps about +1236. This was surely well within the powers of the Taoist patron saint of hanging-gallery builders, Lu Phi Kung.1

It would be hard to over-estimate the importance of the Chhinling passes in

a Thai-Pai Shan.

b Anyone who has travelled much in the mountainous western regions of China will have made personal acquaintance with landladies (hsai shueh) and what they can do. Cf. p. 23.

d This refers to five envoys sent by an ancient king of Shu to fetch five daughters of the king of Chhin; they are supposed to have perished on the return journey.


f Mason (1), p. 577; Ediger (a).

g Anon. (22); we shall return to it in connection with the rock-cut canal at this place, pp. 277 ff. below.

h I knew this place well during the second world war. There are Buddhist cave-shrines in the cliffs here, recently described by Sladen Yin (1).

i Cf. Straub (1), p. 54; Imberdis (1).


k Cf. Fuchs (4).


m Sometimes they were constantly under repair, attended to by men such as Chia San-T'eh in the +6th century, and Kao Ti23 or Chia Han-Fu34 in the +17th.


q This refers to a bird-track that cut across to the mountains to Szehuan.

r Anon. (22); we shall return to it in connection with the rock-cut canal at this place, pp. 277 ff. below.

s Cf. Pucha (4).

t l I knew this place well during the second world war. There are Buddhist cave-shrines in the cliffs here, recently described by Sladen Yin (1).

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w It would be hard to over-estimate the importance of the Chhinling passes in
4th CHHIEH CHHIEH CHHIEH CHIH

Chinese history.³ Twice at least did these transmontane roads become the paths of flight of emperors seeking the sanctuary of mountain-battlemented Szechuan. But much more important was the assimilation of Pa and Shu by Chhin in the 4th century, since the vast natural resources of Szechuan were placed at the disposal of the rulers of the Wei Valley, and this, together with the great irrigation projects which they also completed, must have been a cardinal factor in the first political unification of all China. And later the Old Silk Road was fed by the Linked-Cloud Trestle Ways, for much of the silk exported to Rome was Szechuanese in origin.

We are now in a position to take a look at the far-winding roads in the Land of the Four Rivers and the Land South of the Clouds to which the reduction of the Chhiling was, as it were, the gate. Restored by a pause in the upper Han or Mien valley, the principal route to Shu (Chih-chung, 28) directed itself south-westwards from Chiao-hua (80), having quickly reached the head waters of the Chia-ling¹ River by the Yang- phing² Pass or taken a slightly easier route through the Chhi-pan³ Pass amidst magnificent scenery from the town of Ning-chhiang (79). After negotiating the impressive Chien-men (Sword-Gate) Pass (81) the way was clear along the edge of the great basin to the capital. This road (G) was known from Chhin times onwards as the

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this, a road would have to be made to the Tsang-kho River (92), a tributary of the northern branch of the Phan Chiang,¹ which falls into the West River.⁴ Accordingly in -130 the road was undertaken. The CHHIEH CHHIEH CHHIEH CHIH says:²

Thang Mêng and (the Szechuanese) Sauma Hsiang-Ju⁶ opened up for the first time (the territory of) the south-western ¹ peoples. Cutting through the mountains (to shan⁴), they constructed a great highway more than a thousand li in length, in order to extend (the territory of) Pa and Shu (Szechuan). In this (undertaking) the population of Pa and Shu became wearied. (At the same time also) Phêng Wu⁵ opened (communications to the north-east) right through to the Wei-mo⁶ and Chao-haien³ tribes (Korea) where (soon after) there was established the province of Tshang-hai⁸ . . . .³

Those who constructed the roads numbered several tens of thousands of (conscripted) men, for whom (supplies for) meals and provisions (for daily food) were carried on the backs of porters for a thousand li. Of the supplies sent, on an average, one picul (weight) out of more than ten chung (capacity) reached (its destination).

The new southern road was thus intended to transport men and supplies south-eastwards from Pho-tao (89, I-pin) in Szechuan through Yeh-lang (102) in Kweichow to Kuangsi and Kuangtung, but it had the effect of opening up Yunnan also. It was long and hard in the building, and the opposition of local princes at first prevented its use, but less than two decades later, boats of more than one deck, or their parts, were being carried along this road to help the forces fighting the southerners.² The second was the road already mentioned (p. 16) which opened up the Korean provinces, among which Lo-lang was later one. The information that only about 2% of the supplies reached their destination is interesting, but may not mean that all the loss was due to corruption en route, for the carriers and road guards had themselves to be supplied. Meanwhile the imperial roads of the Chhin dynasty were still being kept up, as we know from several statements in the same chapter of the CHHIEH CHHIEH CHHIEH CHIH, where repairs and maintenance (shao tao⁴) are mentioned. And the organisation of the south-west went steadily on, for a road was pushed up into the tangled mountain country [32, 33] of the upper Yangtze to Yüeh-sui (93), near the long north-south valley road through Hsi-chhing¹⁰ which formed the rear-most lateral line of communications during the second world war. About the same time, too, the Burma road was extended to Yung-chhang (Pao-shan, 100), between the Salween and the Mekong Rivers.

It only remains to sketch a few of the major developments of the Later Han period. In 28 a military engineer who also constructed many fortifications, beacon stations and

⁴ The story is told in Chhinh, ch. 116, pp. 26 ff. (tr. Watson (x), vol. 3, p. 291 ff.) and abridged in Cordier (ı), vol. 1, p. 255.


³ See further on p. 411 below.


³ See further on p. 411 below.


² Hán, 1, 1, 11, 12.

³ Hán, 1, 1, 11, 12.

⁴ Hán, 1, 1, 11, 12.

⁵ Hán, 1, 1, 11, 12.

⁶ Hán, 1, 1, 11, 12.

⁷ Hán, 1, 1, 11, 12.

⁸ Hán, 1, 1, 11, 12.

⁹ Hán, 1, 1, 11, 12.

¹⁰ Hán, 1, 1, 11, 12.
transport depots. Starting from the old city of Tai (61) on the Shanai road to Peking, it led up through the Fei-hu Pass, from which it gained its name (the Flying-Fox Road), over the uplands north of Wu-thai (so famous later for its mountain abbeys) to reach Phing-chhêng (86) near Ta-thung, a focal point for the guard of the Great Wall. This road (J) was more than 300 li in length over difficult country. Other + 1st-century Hou Han activities in the north we have already discussed—the opening of new routes in Sinkiang and the easternmost crossing of the Chhin-ling Shan (pp. 18, 22 above).

This was the region also that saw the activities of another engineer of note, Yü Hsü (l.ft. + 110 to + 136). When stationed at I-chou, somewhere between Lüeh-yang and Chao-hua (86) on the upper Chia-ling River over from the Han Valley, he found that the roads carrying traffic (in that district) were very difficult and dangerous. Neither boats nor carts could get through (the defiles), so donkeys and pack-horses were used, which cost five times the value of all that was transported. Therefore Yü Hsü himself led out his officers and clerks on tours of inspection through the river-gorges from Chhî down to Haia-pien, and he caused the rocks to be fired and the wood to be cut down for several tens of li, so as to open the road for boats to pass. He thus constructed what was probably a trackers’ path, able also to take some wheeled traffic, along a river made navigable. A commentator explains: He thus constructed what was probably a trackers’ path, able also to take some wheeled traffic, along a river made navigable. A commentator explains:

To the east of Haia-pien for more than 30 li there is a gorge, where the rocks formed great barriers in the way of the spring freshets. This led to floods in spring and summer, spoiling wheeled traffic, along a river made navigable. A commentator explains:

This is far from being the only mention of the fire-setting method in Han texts. The resolution of the old highway engineers, ill-equipped as they were, can be guessed from the description of Li Hsi directing the burning and splitting of rocks about 250.

But perhaps the most extensive Hou Han road-building took place in the south. In + 35 a road was thrown along the mountains north of the Yangtze from Pa (84, Chungking) to Tzu-huei (88) in order to by-pass the dangerous Wu Shan gorges [21]. A very much larger network took the form of a cross in Chiangsi, Hunan, Kuangtung and Kuangsi. The N.W.–S.E. limb, starting from Yuan-ling (old Kuei-yang, 98) which was in good communication with the Tung-thing Lake by water, came down to Ling-ling (18) and so to Han-kuang (96), after which it joined the old road to Nan-hai (70, Canton) at Chhâng-yen (97, Ying-tak). The N.E.–S.W. limb, starting from Chhing-chiang (67) on the Former Han road from Wu, struck south up the Gan River to Gan-haien (68) and thence to Chhî-chiang (69, Kû-tong), much as a good motor highway does now, joining there the old road to Nan-hai, but continuing also to Han-kuang. All this system was complete by + 31. Subsequent developments were more military in conception. The second limb was continued all the way to Chhiao-chou (95), i.e. Indo-Chinese Hanoi, the Kattigara of ancient times, by + 83, passing Têh'ang-wu (20), the water-transport way-station for traffic coming down from the ‘Magic Canal’ near Kwei-lin (19). A further mixed land-and-water route was opened in + 41, when the general Ma Yuan, campaigning against an Annamese rebellion, built a road 1,000 li long from Ho-phu (94) in the Lei-chou peninsula to Chhiao-chou. It is noteworthy that this southern road network of the + 1st century contrasts with the earlier road-building in Kansu, Szechuan, Yunnan and Kweichow, in that the sacrifices and suffering of the people seem to have been much less than in those regions of wilder nature, and the benefits of the new communications more quickly felt by the inhabitants.

We are now in a position to make a very rough assessment of the extent of the road-building in the Chhin and Han periods. The approximate distances measured with a cartographical perambulator on a map such as that shown in Fig. 711 may be listed as shown in Table 63. They amount to just under 65,000 li. Converted into miles by the appropriate factors this means a total mileage of some 19,500, but with such a method the error of under-estimation of circuitousness must be considerable, and we shall not be wide of the mark if we accept a final estimate of between 20,000 and 25,000 miles for the main roads in existence by the end of the Han period. Estimates of the greatest extent of the Roman roads vary considerably, but the Peutinger Tables and the Antonine Itinerary seem to indicate something of the order of 48,500 miles, with about 2,400 in Britain and some 9,000 in Italy.

It thus becomes tempting to try to compare the road-building of the Chinese and Roman empires in terms of mileage per 1,000 sq. miles of territory. But while we may reasonably take the drainage areas of the Huang Ho, the Yangtze and the Hsi Chiang as the oikoumene which Chinese civilization was organising, and accept a figure of 1,532,000 sq. miles for these three basins as an estimate of the empire, it is much more difficult to obtain a satisfactory figure for the extent of that of Rome. At its greatest length over difficult country. Other + 1st-century Hou Han activities in the north we have already discussed—the opening of new routes in Sinkiang and the easternmost crossing of the Chhin-ling Shan (pp. 18, 22 above).

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extant, towards the end of the reign of Trajan (+117) it seems to have covered well
night two million square miles, but this was a maximum not long sustained, and when
his successor Hadrian abandoned Armenia and Mesopotamia to the Parthians, the
area of Roman rule fell to approximately 1,763,000 sq. miles. It is interesting that
Gibbon long ago ventured a figure of ‘above 1,600,000’ sq. miles for the Hadrianc
period. a Table 64 shows then that the two road systems are quite comparable.
It may well be, however, that the Roman relative figures are too high, for one must
remember that on the outskirts of the empire, and especially throughout North Africa

<table>
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<th>Table 63. The extent of road-building in the Chhin and Han periods</th>
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<td>Old Shih Road (Chhang-an to An-hsi including Edsin Gol)</td>
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<td>New Chhin-ruan road</td>
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<tr>
<td>Hunan-Changi-Kuangsi-Kuangtung system, including re-building of the old road to Canton)</td>
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and much of the Near East, the Roman paved *viae militares* probably tailed off into
caravan tracks like those of Sinkiang and other ‘Western regions’, which we took care
to omit from our estimate of the Chinese highway mileages. Such factors are extremely
difficult to estimate, but their operation might bring down the Roman relative figure to
some 20 miles per thousand sq. miles or even less. a A full study of the problem would
involve comparative estimates of population in the two empires. While this would take
us too far here, it is at least quite certain that a high proportion of the area of the Roman
empire was very thinly populated as compared with the same regions at the present
day; b and the necessity of linking far-flung administrative and defensive centres across
deserted country would naturally have tended to stretch the mileage of the intercon­
necting roads. To some extent this must have applied in China too. If we knew more
about the population in particular provinces we could make a better guess about the
solidity of particular stretches of road.

Table 64. Road-building in the Chinese and Roman empires

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<td><strong>Roman Empire</strong></td>
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<tr>
<td>Trajanic (before +117)</td>
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<tr>
<td>Hadrianic (after +117)</td>
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<td>Gibbon’s estimate</td>
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<tr>
<td><strong>Chinese Empire</strong></td>
</tr>
<tr>
<td>Hou Han (c. +190)</td>
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</tbody>
</table>

Broadly speaking, however, it may be said that down to the +3rd century the Chinese
network attained from 55 to 75% of the size of the Roman. In this difference
geo-political circumstances may have been important. The lesser relative mileage of the
Chinese network most surely have had something to do with the greater naviga­
ability of the inland rivers and the greater use of artificial water-ways in China, as
compared with Europe. One must conversely reflect that the Roman road system was, in a
way, an exo-skeleton, for the heart of the empire was a vast (and potentially stormy)
body of water, the Mediterranean Sea, and while this certainly facilitated maritime
transport the Romans seem to have felt the necessity of laying down roads of great
length all round the basin. On the other hand the Chinese highway system radiated
out from a particular centre, Chhang-an, over a very large continuous land mass,
constituting, as it were, the endo-skeleton of the empire. In any case, we have every
reason to admire the planning and the construction of the ancient Chinese roads, the
firmness of which, to borrow agreeably from Gibbon’s page, has not entirely yielded to
the effort of fifteen centuries.

a Similarly the Chinese figure would rise to 16-9 if one adopted the estimate of area of the Khang­
Hai atlas (see Vol. 3, p. 582), just under 1.3 million sq. miles (cf. Barrow (1), p. 575). And see p. 35
below.

b Though the figures of Beloch are now universally considered too low.
The space for only a very brief treatment of the subsequent development of the Chinese highway system. Its rapid rise during five formative centuries has now been sketched, and broadly speaking it declined in importance relative to the water-ways during the successive ten. The pattern of government enterprise nevertheless persisted. In the Han, the planning, review and construction of all major roads was the charge of the Grand Secretary, or Minister of Works (Yü-Shih Ta-Fu’), but the building of post-stations, forts, rest-houses and bridges was under the control of the Director of the Imperial Architectural and Engineering Department (Chiang-Tso Ta-Chiang’).

Since the roads, like all other great public works, were manned by conscripted corvee labour, assisted by convict or ‘State slave’ labour, as well as that of military troops, the personnel and man-power problems were at first the responsibility of the Ssu-Li Chiao-Wei, but this office became gradually confined to criminal investigation and police affairs alone, so that the Minister of Works (Ssu-Khung’) and the Superintendent-General of Convict Labour (Thu Ssu-Khung) took over. We have glanced already en passant at some of the logistics problems involved, but it would be interesting to have some estimates of the costs of construction. To this matter Lo Jung-Pang (6) has addressed himself, with the result that a figure of some £55,000 per mile emerges for the Szechuan–Kweichow road of about +65. These estimates are curiously similar to some which have been made for the Szechuan–Kweichow road of about +65, and for official travel they were replaced by the post-horse system, carts being used only for the transport of goods and for the movement of families of the better sort. At the same time the Later Han suffered from a shortage of horses, Lo-yang having but one stable instead of the six (said to have housed ten thousand animals) which the capital of Chihang-an had had two centuries earlier. Wagons drawn by oxen, mules or donkeys came into more widespread use, and on the feeder roads and pathways the South Chinese custom of riding in litters borne on men’s shoulders prevailed more widely. Indeed, a connection with the invention of the wheelbarrow in the

Later Han is surmised, not implausibly, by some. Then there was a general tendency to replace civil by military control as the centuries went by, and though the use of corvee and convict labour continued, the highway management as well as the post-station system came under the Ministry of War (Ping Pu’) at least from Sui and Thang onwards.

Though the network had decayed, it should not be thought that the highways were despaired during the period of disunion of the Nan Pei Chhao (c. +350 to +580). There were notable road-builders in the +5th century, such as An Nan, originally a tribesman from Liao-tung, who built a number of roads for the Northern Wei dynasty which included cuttings and embankments like those of Meng Then of old. So far did this house appreciate its highways that we can find in the settlement of the official hierarchy of +493 the first mention of a Regius Professor of Geographical Communications (Fang I Po-Shih’), alongside those for Astronomy and Medicine in the Imperial University. The Sui were also active in road-building. Apart from a number of new highways in the central provinces, Yang Ti constructed about +607 a military road (yü tao) some 3,000 li long and 100 ft. wide running parallel with the Great Wall, which he also extensively repaired, from Yü-lin (56) to Peking (7). The road network of the Thang was very thoroughly organised, but if we may judge from the number of land-transport post-stations (1,297) each 30 li apart, giving a total of some 38,900 li, and take for computation the long Thang li equivalent to 0.348 mile, the total mileage was not more than 13,550, a distinct reduction from the late Han figure. It is interesting to compare a map of the chief Thang routes with that in Fig. 71. Apart from a new route into Yunnan south from Yüeh-sui (93), that province, together with Kweichow and Kiangsi, had almost reverted to nature, but on the other hand the upper and lower Yangtze Valley regions were connected by a road by-passing the gorges completely, and the Chiangsi–Hunan–Kuangtung network was well kept up. We also see, for the first time, a highway running down from Wu (11) in Chekiang to the great ports of the Fukien coast which were to be such famous centres of international trade in the Sung. North of the 32nd parallel there was little essential change—the Old Silk Road, the Chhin-ling passes, the Road of the Golden Oxen, the northern highways to the Wall and to Peking (7), the ways to Nan-yang (14) and to Shantung, all radiating from the eternal city, Chiang-an, remained very much as they had been in the youth of the Chinese empire.
The remarks of Lecomte and other early Western observers, accepted rather unwillingly by Adam Smith, on the responsibility of the central government for road-building as well as all other forms of public communication in feudal-bureaucratic China, were quite correct, and applied from the time of the first unification onwards as we have seen; but in many periods at any rate the government was interested in transport and the conveyance of official messages. The upkeep of a multitude of local roads and paved pathways, therefore, upon the people themselves, acting in their co-operative capacity under village elders and small-town worthies, a in this context religious associations, such as the Taoist Yellow Turbans about +180, later so politically important, b or the Buddhist fraternities afterwards, played a significant part. Making good ("shien tzu tao ho") was nothing less than a pious duty ("chi tsa", shan chi). c Thus in the course of time, quite apart from the ancient and medieval imperial highways, China's landscape became shot through with millions of well-paved paths, suitable chiefly for pedestrians, porters with carrying-poles, d pushers of wheelbarrows, e and men carrying litters. Rough unpaved cart-tracks predominated only in the eastern plains. Those who, like the author, have followed these paved ways past woods and rice-fields for many a mile cannot think of them without intense nostalgia. 

Quite a number of names of those who were responsible for the surveying and making of these ways have come down to us—one might mention Lu Min in the Tang, Li Yü-Chhing in the Sung, and Hu Shao-Chi in the Chhing. One of the most remarkable was a woman Taoist, known to us only as Chiu Ku Shan Shou (? (the Valley-Loving Mountain Immortal), who directed the building of a mountain road in Fukien in +1315. There was a long tradition of such privately initiated roads going back to the Han or even earlier, and their total mileage far outstripped that of the government main roads as the ages passed.

Foreigners were usually much impressed by China's land communication system. The Japanese monk Ennin, who travelled widely in the Tang between +838 and +547, had many things to complain of, but never depreciated the roads, with their milestones, sign-posts, watch-towers, ferries and bridges, b Though nineteenth-century travellers grumbled about the Chinese highways, c which fell into a decline under the Chhing while those of Europe steadily improved, they inspired the admiration of Westerners in the +17th century. After the gloomy accounts of missionaries and century travellers it is rather surprising to read Lecomte's words of +1696:

One cannot imagine what care they (the Chinese) take to make the common roads convenient for passage. They are fourscore foot broad or very near it; the Soil of them is light, and soon dry when it has left off raining. b In some Provinces there are on the right and left hand Causeways for the foot Passengers, which are on both sides supported by long rows of Trees, and oftentimes terrassed with a wall of eight or ten foot high on each side, to keep Passengers out of the fields. Nevertheless these Walls have breaks, where Roads cross one the other, and they all terminate at some great Town. e

And he goes on to speak of triumphal arches, c milestones, and 'little Towers... on which they set up the Emperors Standard' near lodges for soldiers or country militia—in a word, the post-stations and guard-houses to which we must turn in a moment. e

In the twentieth century a vast system of modern roads suitable for motor traffic has been constructed in China. On the Old Silk Road today lorries and landrovers speed back and forth. The network has spread to Lhassa and far afield in Tibet and Sinkiang, generating a subsidiary net in the formerly untraded Tsaidam Basin. In this context religious associations, such roads, too, have foreshadowed the extensive railway system which today unites the Indo-Chinese with the Korean border, stretching before long from Kuan-chou to Kazakhstan. Only those who have had the opportunity of seeing for themselves what

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a Generally speaking (cf. Monnier, i), but there were exceptions. Thus John Barrow, travelling with the Macartney embassy in +1799—not at all an indulgent observer—was well impressed with two mountain roads. He tells us (1), p. 530, that between the upper waters of the Chhien-thang River at Chiang-shan and those of the Hsin-chang at Yu-shan there was a 'very fine causeway, judiciously led through the defiles of the mountains'. Further south, through the Nan-ling range between Gan-haien (68) and Nan-haien, Barrow admired (p. 543) 'a very well-paved road, carried in a zig-zag manner over the very highest point, where a pass was cut to a considerable depth through a granite rock; a work that had evidently not been accomplished with any moderate degree of labour or expense'. Cf. Macartney himself, in Cramner-Byngh (a), p. 193. One must always remember comparative standards. Smiles (1), vol. 1, pp. 162 ff., on the state of the roads Manchester about +1750, is well worth reading. b This remark is interesting in connection with our estimate of the light and elastic nature of the Chhain and Han roads (p. 7 above). Even today, however, the prolonged rainy season of the monsoon climate plays havoc with the modern motor roads, as I know from many personal experiences—often without their compensations. The landslides on the Burma Road, so well described by Tsoi Pei-Ying (1), are paralleled in all the mountainous provinces; and most of China is mountainous.

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32 28. CIVIL ENGINEERING

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33 28. ROADS
a single trunk road or a single line of railway can mean in terms of enlightenment and benefit to a province of many million people theretofore almost medieval can truly appreciate the work of the highway and railway engineers of modern China. For more than two millennia their fathers before them had served the same civilising mission.

(2) The Post-station System

Once the work of the road engineers was completed, it remained to weld it into a great social institution by establishing and deploying a whole army of messengers, coachmen and station-masters along the lines of communication throughout the empire's length and breadth. Such a system arises naturally as soon as developing society attains an imperial level of organisation. We find it, perhaps for the first time, in the great apogee from the time of Augustus onwards. The length and breadth. The Empire ran everywhere from furthest Britain to uppermost Egypt and from Finisterre to the Persian Royal Road, e. - 495. By the time of the compilation of the Chou Li in the - 2nd century the system is taking the very definite shape which it conserved for two millennia. Referring to the Almoners-General (I Jen'), the text says:

In principle, along all the roads of the Empire and the (feudal) States there is a rest-house (lu) every ten li where food and drink may be had. Every thirty li there is an overnight rest-house (mut) with lodgings (lu shih) and a (government) grain-store. Every fifty li there is a market (shih) and a station (hou kuan) with an abundant stock of supplies. [Comm. The lu was like our yeh hou thu with tables, and the wu was like our thing. The hou kuan included a watch-tower. Between every two shih there were three lu and one wu.]

Thus the Han commentator introduces the terminology which proved through the centuries most persistent. Broadly speaking the main roads were equipped from Han to Sung times with a post-office (yu) every five li, a cantonal office (thing) every ten li, and a post-station (chih) every thirty li. These short distances were undoubtedly chosen so that flag and drum signals, or the fire and smoke of beacons, could readily give and receive information. The postal clerks (chheng yi li) kept records of the despatches which they transmitted — in Han times these hat were written on foot-long wooden strips contained in bamboo tubes closed with a spring lock contrivance — and the cantonal officers (thing chang) policed the road and its neighbouring districts with their guards. At the post-stations (chiu chu, chuan chu) there were tables and couriers in readiness for the relay service (i, jih) under the authority of a station-master (chuan li, chhu chang). Strategic points in the network had veritable sorting offices (yu thu, yu chu), centres where mail was collected and distributed. By - 77 the post-station system extended as far west as Lou-lan (42) and Pao-shan (100). By + 89

* Mention may here be justified of the first modern Chinese railway engineer, Chan Tien-Yu (1860-1916), who built the Ching-pao railway (Peking to Pao-thou via Kalgan). Biography by Hsi Hsien-Wei (1).
* Herodotus, V, 52 ff.
* It is always with some surprise that one finds it necessary to regard the Roman Empire as a relatively late, a Hou Han, institution. The best monograph on the Roman post-station system is probably still that of Hude (1), but more briefly see Friedlander (1).
* Wei Liuch, cit. Sun Kuo Chih, ch. 30, pp. 32b, 33a; tr. auct. adv. Hirth (1), p. 70.
* Cf. Kuo Mo-Jo (2).

28. ROADS

term yu' as 'a station on the border for the transmission of despatches'. In the fragmentary period of Chou feudalism each potentate had his own system of tracks, but in the heyday of the Chou High Kings there had been full centralisation; as we may see from the saying of Confucius, reported by his greatest exponent, that 'the radiating virtue is faster than the transmission of (imperial) orders by stages and couriers (chih yu)'. This remark would have been made, it is curious to note, at a time exactly contemporary with the functioning of the Persian Royal Road, e. - 495. By the time of the compilation of the Chou Li in the - 2nd century the system is taking the very definite shape which it conserved for two millennia. Referring to the Almoners-General (I Jen'), the text says:

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* Ch. 5, p. 80b.
* Meng Tuan, 11 (1), i, 12; tr. Legge (3), p. 60.
* Ch. 4, pp. 59, 6a (ch. 13); tr. Biot (1), vol. 1, p. 488; Lo Jung-Pang (6), p. 101.
* Sometimes two or more offices were present at one place (hence yu-thing, yu-chih).
* These words were of rather wide meaning, applicable to the riders as well as the horses, and to the relay system itself; usable also as verbal meaning to transmit, or to carry, government despatches.
* According to the sources collated by Lo Jung-Pang (6), there were 29,353 cantonal offices under the Chihen Han, and 12,445 in Hou Han times. If these were all about 10 li apart on roads, the total mileage would have been 266,150 li in the first case, and 124,450 li in the second: I.e. some 74 times the mileage presented in Table 61 above for the Chihen Han, and 1.93 times that for the Hou Han. This would raise the road mileage for the Chinese empire in Table 64 to 42,500 and the relative figure of miles per 1,000 sq. miles to 27.7, i.e. entirely equivalent to the Roman empire estimates. But the discrepancy is so
tropical fruits were sent with the aid of the relay service from Nan-hai (70) to the capital. The post-station rest-houses had washing and sleeping accommodation for officials and authorised travellers, restaurants—and also cells for prisoners moving under guard. Often the way-stations had some private inns or hosteries (kho shè), li ni for those who lacked the right to use government facilities. Our footsteps in these volumes have often led us to the rest-houses of ancient and medieval China, without our noticing it; for Liu Pang, the founder of the Han dynasty, was at the start of his career a things chang (7) near Phei (10), a piquant story of the 2nd century had Sauma Hsia-Ju in just such a setting (8), and was it not at the Chhen-chhiao rest-house that Chao Khuang-Yin, the founder of the Sung dynasty, was invested with the imperial yellow?

Though the post-station service reached a particularly high development in the Thang period, with a force of some 21,500 officers strung out along the roads and managed by 100 high officials in the capital, the terminology did not change. In the Sung, however, the post-station service has become the 'hot-foot relay' (chi chiao ti), and the stations ma ti, or ma phà. With the growing militarisation previously mentioned, the couriers appear in the Yuan dynasty as phu ping, serving in chan-chih (Mong. jamt) under controllers (tho-tho-ho-run), another Mongolian transliteration. Though corruption was prevalent at all levels, the 14th-century service actually attempted to work to a timetable. After this there was little change until the arrival of the telegraph and modern road-building in the nineteenth century.

We may glance at a few further points of interest concerning ancient times, however. The speeds attained by the couriers have been thoroughly studied by Lo Jung-Pang (6), who concludes that a fair average was some 120 miles in 24 hr., though large that we are reluctant to adopt the cantonal offices criterion as the best guide to total road mileage. It is surely probable that many of these offices, after all somewhat like police or gendarme stations, were located far off the beaten track of the great highways, and, at the least, a great many of them would have been on secondary roads not counted in the estimates of Table 63. If this is so, we can hardly assume, as Lo Jung-Pang (6) does, that the number of post-offices was double that of the cantonal offices, since the former were scattered along the main lines of communication. At the same time, the figures are prevalent at all levels, the +14th-century service actually attempted to work to a timetable. After this there was little change until the arrival of the telegraph and modern road-building in the nineteenth century.

In the Chhien Han period, when the roads were at their best, an elaborate service of government relay chariots, carts and carriages was also in use. Besides the holders of noble titular ranks such as Kung Chheng (Riders in Public Transport) and Sau-chhè Shu-chang (Quadriga Elders), the roads were full of officials in chariots carrying imperial commands, proceeding on tours of inspection, assuming or retiring from posts, or supervising the government monopolies and other enterprises, including the roads and canals themselves. The bureaucracy was always sensitive about the misuse of transport, and one of the crimes with which the general Yang Phu was charged in -111 was that of asking for a relay carriage to go to the frontier, but actually using it to go home instead. Public transport was correspondingly a mark of imperial favour, as we noticed at a very early stage in connection with the scientific-technological congress of +5 when government coaches were provided for the doctors. About eight years earlier, when an assembly of literati was convoked by the emperor Ai Ti, the eminent scholar Kung Shcheng, who had arrived first, suggested that government vehicles should be sent for them, for such transport had already been granted to physicians and sorcerers (i wu). The emperor said: 'Did you then, Sir, come by private vehicle?', and when Kung replied that he had, official carriages were ordered for all the others. About the speeds attained in the relay carriage system we know little that is certain, but to judge by an urgent journey of the Prince of Chhing-l in -74, it could rise as high as 9 miles per hour. Horses were changed every thirty & at the post-stations.

In the Han, carriages and mounts were under the control of the Thai Phu (Grand Keeper of Equipages), but another bureau, the Regulations Department (Ta Tshaö), looked after the post-system, and yet another, the Commandant's Department (Wei Tshaö), was responsible for the public vehicles. Each province or commandery had its Superintendent of Posts (Tu Yu) and was divided into a number of postal districts. Each provincial government had also its civilian Tso-chhian Yuan-l (Secretarial Aides for Highways and Bridges), its Chin Yuan (Fords Officers), and its military Kuan Tso-Wei (Commandants of Passes and Barriers). These last had to check the credentials of travellers and goods, collect internal customs, prevent smuggling, and rather more could be attained by men who galloped 12 hr. from dawn to dusk at an average speed of 11 miles per hr. The literature contains a number of exceptional records for the Liao and Chhing periods ranging up to 260 miles a day, explicable only by conditions which permitted continuous travel through the night. Beacon signalling alone gave faster results. In -74 the news of the death of the emperor Chao Ti was transmitted by this means at a speed of some 27 miles per hr.

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maintain general security. This reminds us that one of the more unexpected functionaries of the Ministry of Works was the Prefect of Credentials and Tokens (Fu Chieh Ling). All passports (chuan) had to bear the seal of this Minister. The corvee and taxation system always applied for the needs of the post-service, local people having to pay special taxes (ma khoi chien) for the horses, and to supply a tithe of food for the travellers. The service was thus exposed to trouble from two sides. On the one hand there was the perennial resentment of the Chinese population, which disliked passports, corvee and direct taxation, and which therefore showed in general a passive hostility to the road authorities and all their works. But on the other hand there was the armed resistance of the tribal peoples, who saw very clearly that the road network was a major factor in the expansion of the Chinese empire, and therefore cut the roads and destroyed the post-stations whenever they could. This was what the Chhiang did in Kansu in -41, and their example was well followed by the south-western tribes in -93. But in spite of everything, the Chinese highway network, and the post-station system which was inseparable from it, constituted a cardinal factor in the advance of East Asian civilisation. Those who are aware of the facts which we have here rehearsed know what to make of the commonly received opinion that ‘the Chinese have no great record as road builders’.

(c) WALLS, AND THE WALL

There can be no doubt that the most ancient form of walling in China, both for houses and un-roofed enclosures, was that of terre pise or tamped earth (thien ni). Removable elongated boxes or forms (pan or kan) without tops or bottoms are used, dry earth being rammed within them at successively higher levels as the wall rises (Figs. 719, 720, pl. 44). This shattering resembles that used today for confining concrete while setting. So

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Fig. 719. Tamped earth (terre pise) walling under construction; a drawing from the Erk Ya, ch. 7, p. 63. The caption says that the boards of the shuttering are also called yeh.

binding material as the foundation of walls, and to spread a layer of thin bamboo stems between each pise block so as to hasten thorough drying-out. The ubiquity of terre pise walling in Chinese culture certainly has something to do with two features which we shall later find characteristic of Chinese architecture, first that walls were not for compression, as in their own continent that they have thought of it as a Chinese invention. But the compression of earth in climbing shuttering, raised lift upon lift till the wall has reached its full height, was well known to Pliny, who wrote: But there are not, moreover, in Africa and Spain walls made of earth that are called ‘framed walls’, because they are made in a frame of two boards, one on each side, and so are packed or rammed rather than constructed; and do they not last for ages, undamaged by rain, wind and fire, and stronger than any cement? Spain still sees the watchtowers of Hannibal, and his forts of earth walling placed on the mountain ridges. Another interesting reflection is that the introduction of the iron reinforcement of concrete was a fresh illustration of the principle used so long in that natural material the bamboo (cf. Vol. 4, pt. 2, p. 61), the principle of two-phase components, now iron for tension and concrete for compression, as W. B. Wilkinson in 1854 was the first to recognise (Skempton, 6). Finally, we shall see later on in this volume (p. 72) how Chinese engineers of the 7th century anticipated in their stone segmental arch bridges the design brought to such exquisite perfection in reinforced concrete by Robert Maillart during the first decades of the present century.

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(c) WALLS, AND THE WALL
Indeed in rural England and France these techniques have never died out. In many English counties boundary walls with roofs of tile or thatch, looking extremely Chinese, can be found, and the old Devonshire saying about earth walling—"Give it a good hat and a good pair of boots and it will last for ever"—could have come straight out of the Lu Pan Ching.

In late Chou times bricks were mostly of adobe, i.e. sun-dried mud (mi phi, thu phi), such as may frequently be seen in China still, but by the Han period baked bricks (chaun) were becoming general (Figs. 721, 722, pl.a). Plaster (wuj) was then already used, and often covered with paintings. Many different brick sizes have been current through the ages, and now different shapes are found in different regions, e.g. in the north-east 12 in. × 9 in. × 6 in.; in the south-west 6 in. × 5 in. × 1 in., and this latter tile-like form is seen also in the Great Wall (15 in. × 7½ in. × 3 ½ in.).

Besides the bonds with which we are familiar in the West, the Chinese have long used a 'box bond', in which stretchers are placed vertically between layers of horizontal ones, the interior being filled with earth and rubble. Fig. 723 (pl.), a family temple in Szechuan, shows this. Or two horizontal layers may intervene (Fig. 724). Often bricks of two different thicknesses, but similar in other dimensions, are used. Then there is the Chinese cross bond, in which the stretchers are placed in groups of three.

Besides the ordinary baked bricks of the Warring States and Han periods, the Chinese craftsmen were the first to master the art of moulding and firing large hollow blocks of terracotta brick (khung hsin chaun) ornamented with very intricate scenes and patterns (Fig. 725, pl.). These were used mostly for tomb walling, as in the Warring States burials at the Erh-li Kang site near Chêngchou.

Adobe survives as 'clay-lump' buildings in East Anglia to this day.

a See Davey (1), pp. 20 ff., but especially the monograph by Williams-Ellis, Eastwick-Field & Eastwick-Field (1). Terre pisé is characteristic of the Lyonnais and Catalonia, but similar methods using a wetter mix without shuttering live on in Devonshire, South Wales and Wiltshire as what is known as 'cob' and 'chalk mud'.

b From this geographical distribution one would seem to be in presence of a technique which had spread both east and west from ancient Mesopotamia, but its presence there seems uncertain. Lloyd (1), pp. 456, 460, speaks first of 'solid walls of rammed clay, pise' from -4000 onwards, but then of pise 'prepared with a rectangular wooden mould, open at top and bottom'. That however is adobe, not pise. Since reading this I have been informed by Prof. Seton Lloyd, through the kind intermediation of Miss Munn-Rankin, that he knows of no Mesopotamian example of a wall made by ramming earth between frames. Sun-dried adobe bricks must therefore have been meant, and not pise at all. Thus it is strange that both China and Europe should have had the technique.

c Adobe survives as 'clay-lump' buildings in East Anglia to this day.

d Kelling & Schindler (1); Fischer (2).

e Mirmas (1); Spencer (1).

f See further Hommel (1), pp. 479 ff. and Arnald (1); but especially Liu Chih-Phing (1).

g Burnt or baked brick had been used extensively in Mesopotamia and the Indus Valley, and also, though not commonly, in ancient Egypt (Davey (1), pp. 22 ff., 34 ff., 76 ff.; Petrie (2); Capart (1); Lloyd (1); Briggs (2), p. 41). They seem to have been an innovation at Rome in the time of Vitruvius (late - 1st century), who worked mostly with sun-dried bricks. Thus they spread, like so many other things, both east and west. Cf. the quotation from Fang I-Chih in Vol. 4, pt. 2, p. 219.

h Cf. Davey (1), p. 89 and pl. XXXII.

i Anon. (23), pp. 50 ff. and pl. 20, fig. 1. Dimensions average here 3½ ft. × 1 ft. × 6 in. Openings are both round and rectangular.

j See fig. 724. A late Chihing representation of bricklayers at work. Box bond with the horizontal stretchers in double layers and a coping of five layers of headers. Plasterers are also seen. From SCTS, ch. 31, Tsu Tahai (Medhurst (1), p. 240; Karlgren (12), p. 48), whence the caption: 'Preparing the home of a family for roofing.'
from the scenes and characters depicted on them. It may be worth giving a curious passage concerning the use of baked bricks for fortification at the capital of a short-lived peripheral barbarian dynasty, the Hsia (547-550), whose Hsiung-nu rulers governed parts of Kansu and Shensi and were overthrown by the Thopa Wei people. The Chin Shu says:

In this year (541), the reign name was changed to Feng-Hsiang. (The emperor) Holien Pho-Pho chose Chhihkan A-Li to take office as Chief Engineer (Chiang Tso Ta Chiang), and to mobilise 100,000 workers of the Hsia peoples north of the mountains. They were to go to a place north of the Shuofang River and south of the Heishui River, there to build the capital. Pho-Pho himself said, 'As I have just united the world and attained the empire over ten thousand regions, I shall name it Thung-Wan.'

(Chhihkan) A-Li was extremely skilled and clever, but also cruel and violent. He caused the workers to bake bricks (ch'ung-ta) to make the city wall. (He used to test the bricks) and if a hammer blow would make a depression as much as an inch deep, he would have the worker (responsible) killed and buried inside the wall.

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We shall meet again with this disagreeable Hun technician in the manufacture of bricks and tiles. This was the prevailing among the workers and partly to avert the confusion of organisation which done little to refashion them or change their proportions.

Siren was writing several decades ago, and in fact the exigencies of modern life have now led to the disappearance of some parts of city and village walls, but it will be a long time before travellers cease to marvel at their size and ubiquity.

Even the ancient Asian nomads surrounded their camps with earthen ramparts, and there can be no doubt that the essentially settled agrarian culture of China erected walls round its earliest cities. As Crecel (2) has remarked, the character for capital (ching) has as its oldest graph (K 755) a picture of a guard-house over a city gate. And city walls we find as early as the 15th century. Those of the Shang city of this period, Ao, just north of modern Chêng-chou, some 65 ft. wide at the base, enclosed an area about 2,100 yards square. Similar excavations and studies have been made of Chou feudal capitals such as that of the State of Chao at Han-tan (62) in Hopei, founded in 398, where the main rectangular enclosure has sides some 1,550 yards in length, with walls originally as high as 50 ft. on a base again 65 ft. wide. All such walls consisted essentially of successive layers of tamped earth averaging from three to four inches thick. When Chinese city-walls are cut through today for modern transport improvements, these layers can still be seen. Whether or not the walls of Shang and Chou cities were always faced with sun-dried (adobe) bricks we cannot be sure.

* This applies, of course, only to the facings; the cores of many walls are very old. Also it is not true of the Great Wall.

b i.e. backward sloping.

c In north-west China in 1958 I found that the removal of city-walls was much welcomed as symbolic of the modernisation and pacification of a countryside which had known rebellion, ethnic strife and banditry for twenty centuries.

d Cf. Uchida (9).

e Ch'eng T'e-Khan (9), vol. 2, pp. 17, 19, 199; Watson (2), pp. 61 ff. Anyang was not founded till after 1400.

f Watson (3), pp. 121 ff.; Vol. 1, pp. 94. See also Ch'eng T'e-Khan (9), vol. 3, pp. 18 ff.

g Li Chi (3) has reckoned that of 163 city-walls built before 722 no less than ten were still in use in 1958. Of 589 constructed between 722 and 867 as many as 74 still remained.

h See the map.
By the end of the -3rd century the art of fortification had made so much progress, and the unification of the empire had afforded such abundance of men and materials, that the walls of the Former Han capital at Chang-an, still traceable some five miles north-west of modern Sian, were on an altogether greater scale. Along a circuit of some 16 miles arose a rampart wall some 50 ft. high and 40 ft. broad at the top, still devoid of enfilading bastions, but it did not stand alone; it was backed by a terreplein more than 200 ft. wide raised about 20 ft. above the surrounding land level, and protected by a moat 150 ft. wide with a depth of about 15 ft. The terreplein was once covered with buildings, perhaps garrison dwellings. Its inner face, as well as the berm outside the wall and the scarps and counterscarp of the moat, can still be made out. From the outer edge of the counterscarp to the foot of the inner face of the terreplein the total width of the works around the whole perimeter must have been of the order of 480 ft. All this was an effective reply to the poliorcetic arts which had developed during the Warring States period, such as fire-setting in mine tunnels to cause the collapse of walls, or the diversion of rivers to wash away their foundations. The traditional builder of these fortifications of Chang-an about -200 was Yang Chheng Yen.

The cores of Chinese city-walls were always of earth or rubble (hence perhaps the 'earth' radical in the word for city-wall or city, chheng3), but in later centuries they were usually provided with outer, and often also inner, facings made of large grey burnt bricks laid in lime mortar. Occasionally, where stone was plentiful, as in Szechuany they were revetted with dressed stone blocks in regular courses of equal height. A traditional Chinese representation of the foundation and revetment of a city wall is shown in Fig. 726, where we see also the infill of rubble. Fig. 727 (pl.) shows part of the walls of modern Sian, which run three miles from east to west, and which I remember seeming interminably long when I saw them for the first time as I arrived by train at dawn from Paoshan.

The foundations of the great Wei Yang Kung palace are also still to be seen at the west side of the Han city. They consist of a series of five superimposed rectangular terraces like the terreplein on a base of 450 x 145 yards with its long axis north and south, so arranged as to lead up a processional way to a small rectangular terrace at the northern end still over 50 ft. above the surrounding land level. I have vivid memories of a visit paid to this romantic but desolate site with Dr Dorothy Needham and Dr Tshao Thien-Chhin in 1945 when the rain beat down upon the Han paving-tiles still abundantly scattered about among the trees.

Like the Roman opus inluminum and opus reticulatum (cf. Vitruvius, ii, viii, 1, and Blake, 1), covered with stucco.

Like the Roman opus iodominum (cf. Vitruvius, ii, viii, 9).

In many dynasties there was the equivalent of the Royal Engineers, the chheng chiallg of the army, regular units of chin chheng3 artisans skilled in fortification as well as other branches of military technology. See further Yang Lien-Sheng (11), pp. 30 ff.

This is taken from the inward side and may be complemented by a splendid air photograph (probably von Castel's) of the succession of external bastions, reproduced in Gutkind (1), pl. 9.

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Cf. p. 17 above.
Chinese city-walls are never complete without their watch-towers and gate-towers, usually single structures in two or three storeys, with the up-turning roof-corners so characteristic of Chinese buildings, and set directly over the opening in the city-wall. The latter is sometimes protected by a curving curtain-wall which makes the gate a double one. The drum-tower in the centre of the city follows a similar pattern, for it is often a two- or three-storey pavilion set upon a solid rectangular fort tunnelled spaci­ously in both directions at right angles. An alternative type of city entrance, probably rather older, flanked the gateway by two such pavilion-bearing towers. But whatever may be the plan, walls and bastions are invariably battered, i.e. they slope markedly inwards to the top; contrasting thus with the perpendicular walls so often seen in medieval Western castles. To illustrate the style of Chinese defensive architecture,a Fig. 728 (pl.) shows a Thang-period fresco from Tunhuang, and Figs. 729 and 730 (pl.s) give different views of the Ming gate-fortress at Chia-yü-kuan (76), where the Old Silk Road passes out through the Great Wall. A typical wall of a small Szechuanese city is seen in Fig. 731 (pl.).b

The massive Chinese wall did not always rise straight out of the ground or the water-filled moat. It frequently had a supporting platform or plinth, just as if it were any other building (see on, p. 91). But since many of the plinth designs had re-entrant mouldings, the placing of the heavy wall above them gave a remarkable effect of elegance and lightness. As Mirams has pointed out,2 the battered line of the superstructure, instead of starting from the line of the inset die of the base, as is usually the practice in the West, starts from the face of the corona. Hence the spreading static effect of Western classical designs is altogether avoided.

The Great Wall (the 'Ten-Thousand Li City-Wall—Wan Li Chhah Chhêng,1 as it is called in Chinese) has of course been in the reader's mind during the previous paragraphs. It notably stirred the imagination of eighteenth-century Europeans. In + 1775 Dr Johnson talked with an uncommon animation of travelling into distant countries; that the mind was enlarged by it, and that an acquisition of dignity of character was derived from it. He expressed a particular enthusiasm with respect to visiting the Wall of China. I caughted it for the moment, and said I really believed I should go and see the Wall of China had I not confidence was not misplaced. Stretching from Chinese Turkestan to the Pacific in a line of well over two thousand miles (nearly a tenth of the earth's circumference), the Wall has been considered the only work of man which could be picked out by Martian astronomers. To visualise its equivalent in Europe one must think of a continuous structure reaching from London to Leningrad or from Paris to Bucarest. The Roman empire had its times or frontier fortifications covering stretches between rivers and other natural borders, but they never attained anything like this length. The longest was the Limes Germaniae et Rhaetiae3 which connected the Rhine and the Danube across South Germany, but it did not exceed 330 miles and its defences were confined to earthworks and timber forts.4 As for the walls across the British isles, the longest was but a fifth of this,5 while the Limes Syriacæ, though extending for some 625 miles, had no continuous line of defence at all.6

There is no lack of travellers' descriptions of the Great Wall,6 but studies based on modern historical scholarship are few and far between, whether in Chinese or Western languages.7 Figs. 732 and 733 (pl.s) give good impressions of its winding over the mountains of Hopei and Shensi, and Fig. 734 (pl.) shows its lesser glory along the western marches in Kansu, where it has lost its stone facings (if indeed it ever had them in those parts), and runs along as a ridge of compacted loess with numerous breaks. In some places it is almost overwhelmed by the desert sands (Fig. 735, pl.). We know of no accurate count of the number of wall-towers and isolated watch-towers in the Wall's neighbourhood, but those who have walked long distances along the line estimate that some 20,000 of the former and 10,000 of the latter are still standing, and that at the time of its maximum strength the Wall embodied at least 5,000 more of each of the two types.8

It will be worth while to examine briefly the component parts of the Great Wall as shown on the map in Fig. 711. Its present main line is, broadly speaking, that of the Ming period, but different parts of it are built along alignments of earlier walls dating from very different periods, as we shall see. Let us begin from the eastern end, Shan-hai-kuan (101),9 where one of the portals on the road to Manchuria and Korea bears the

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1. Shan-hai-kuan
2. The Vallum Antoninii Pi of + 81 (evacuated + 183) extended only 37 miles as an earthwork. The Vallum Hadriani of + 126 (evacuated + 185) was faced with stone but did not exceed 73 miles. For a sketch of present remains, cf. Mothersole (1).
3. It was established by Trajan about + 106 against the Arianes Parnicans, but had only gaurd-posts every 12 miles and forts every 38 miles, with connecting roads, but no rampart.
5. Indeed we have not been fortunate enough to find one. The work of Clapp (1), with its excellent chart, is perhaps the best, but it is strictly geographical. Beyond this there is Geil (3), well illustrated but the most anecdotal and chaotic of all his books; Hayes (1), more businesslike but small, and more recently the romanic history of Lumin (3) based solely on translated sources. Silverberg (1) we have not seen. Academia Sinica should produce a standard work. The monograph of Wang Kuo-Liang (1), though brief, is excellent on the historical side, but we had access to it too late to make the best use of it. Still more tantalising was my experience with a much newer study, that of Shou Pho-hu Pei (1) printed in 1961. This I purchased at Siam in 1964, only to find, before I could enjoy it, that it had been withdrawn from sale and could not be delivered. The reason for this remains a mystery. I saw only that it has good maps.
7. Numbers in brackets refer to Table 60. Those in square brackets refer to Table 4 and Fig. 35 in Vol. 1.
inscription Thien-Hsia ti I Kuaoi (The World’s First Gate). Ascending steeply on to the mountains overlooking the Hopei plain, the Wall snakes along ridge after ridge in a section broken by only one important gate, that of Ku-pei-khou (108), through which passed the road to Jehol, so important for its imperial summer residence during the Chhing. Then almost due north of Peking (7) at a point known as the Eastern Bifurcation, it divides into two, the Outer or Northern Wall running along the border of Shansi province, the Inner descending to a point some 125 miles further south among the mountains and then rejoining the main defence line some 30 miles east of the Yellow River. Within this lozenge are the important cities of Chang-chia-khou (110, Kalgan) and Ta-chung (86), both giving access to Inner Mongolia, and both reached through a famous check-point in the Inner Wall, the Chū-yung-kuan gate (Fig. 736, pl.) at the Nan-khou pass (109). Here came through the old road to Urga; and the new railway to Ulán-Bator, the modern reincarnation of the Mongolian capital, takes exactly the same route, issuing from the Outer Wall just north of Ta-thung and striking off across the Gobi Desert. Further south along the Inner Wall is the site of the old fortress of Tzu-ching-kuan (I I I) beside which no doubt passed the road from Tai (6 I) already described (p. 26). Similarly the great road from the south through Shansi pierced the Inner Wall at a more westerly point, Phing-hsing-kuan (I I 2). Besides the two cities already mentioned, the lozenge contained the important Han fortress of Yen-mên (I I 3).

The Outer or Northern Wall is undoubtedly based on an alignment dating from the + 5th and + 6th centuries. After Northern Wei tentatives the first construction was undertaken by the Eastern Wei in + 543, but it was carried on far more energetically by the Northern Chhi between + 552 and + 563, especially in a great effort of 3,000 li in + 556 which cost heavily in men and material and almost bankrupted the State.

The Inner Wall line is of uncertain time, and it has a very curious branch wall running south for some 230 miles along the edge of the Shansi uplands overlooking the Hopei plain. This is certainly somewhere near the site of the + 5th-century wall built by the feudal State of Chung-han, but the line is more probably of much later date, perhaps traced by the Shansi people of Western Yen about + 590 against the Later Yen State of Hopei and Shantung which soon afterwards annexed them, or alternatively the remains of the frontier between two transient States in the Wu Tai period (+ 927 to + 966). a  

a As this gate led to Loomiast regions, it was reconstructed in + 1343 with three storeys over the arch and an abundance of Buddhist carvings, together with inscriptions in six languages, Lantscha (Nepalese Sanskrit), Tibetan, ‘Phags-pa Mongolian, Uighur, Hsi-Hsia and Chinese. We owe to Murata & Fujieda (1, I) an elaborate monograph on this ‘pagoda-bridge’ (that chieh tha’), as it was called. Nanc-hou is today a favourite viewpoint for visitors from Peking (cf. Chū Shōu-Iken (i), Schultheiss (i), pl. 6a).

b TCKM, ch. 32, p. 59a.

c TCKM, ch. 33, p. 61a, ch. 34, pp. 62b, 64a.

d Pei Kuo Shu, ch. 4, p. 26a; TCKM, ch. 34, p. 20a.

e TCKM, ch. 34, p. 36a.

2 Wang Kuo-Liang (1) considers it also of Northern Chhi date.

2a Cf. Vol. i, Fig. 12.

2b Cf. Herrmann (1), map 29 (iii).

2c Cf. Herrmann (1), map 41 (i, iv), Wang (1) describes it also to the Northern Chhi but its purpose then is not obvious; cf. Herrmann (1), map 33.

The Outer or Northern Wall runs south-west across the Oordos Desert, choked and blown over with sand, rising north-west again to meet the river higher up in the vicinity of Ninghsia (114). The first part of this traverse is very ancient for it was essentially the line of a frontier wall built in + 353 by the State of Wei; it passes the outpost city of Yu-lin (56) and the vanished gates of the Chhin and Han imperial roads which led to the north of the great bend of the Yellow River (pp. 14, 16). In the neighbourhood of Lanchow (37) the layout again becomes complex. From Ninghsia the remains of an inner wall follow for a long way the right bank of the River, and from Lanchow north-westwards a wall in better preservation protects closely the Old Silk Road, but besides these an outer wall strikes off across desert country to rejoin the latter in the neighbourhood of Lanchow (36). The dates of these modifications are not clearly known. North-west of Lanchow the line continues as a loose wall with periodical stone towers, taking in the Pai-thing Ho 1 Valley which ends in lakes in the Gobi outside the Wall but rejecting the Jo-shui 2 which leads out to Edsin Gol, until it curls inward to the fortress of Chia-yü-kuan (36) and ends a few miles further in towards the Chhi-lien Shan. But although this was the ‘Last Gate of the World’ in Ming times and for many centuries earlier, it was not so in the Han (—2nd century). A further wall of loess, now completely missing where at right angles to the prevailing winds, but otherwise standing 12 ft. high at minimum, and dotted with many 30-ft. towers, continued along the Su-lo Ho 3 past An-hsi (38) to surround Tun-huang (39) in a protective embrace. 4 The roads to the West (cf. pp. 17, 18) passed out through Yu-mên-kuan (40) and Yang-kuan (116) respectively.

A very mysterious extension of the Great Wall exists in the form of the ‘Chhing-hai Loop’ in the neighbourhood of Lanchow. 5 Originating from the western junction of the Lanchow Loop with the Outer Wall, it passes south-westerly in an arc enclosing Hsiao-ning (115) and Kumbum, short of Lake Kokonor itself, crosses the Yellow River and returns in a curve to the neighbourhood of Lanchow giving off at least one major spur southward on the way. This seems to be a + 4th-century alignment, for the country it encloses is contrasted between the Chhien Liang and Hou Chao States (+ 314 to + 76), and became independent as Hsi Chhin (Western Chhin) between + 385 and + 556.

5 But not exactly, for the ancient wall ran more directly north-south, nearer the east limb of the Yellow River’s great detour.

6 The stretch, known as the North Shensi Frontier Wall, was the scene of the chief reconstruction work under the Sui. In + 585 a length of 700 li with ten fortresses connecting the eastern passage of the Yellow River with Ninghsia was completed (TCKM, ch. 36, p. 94; cf. TH, p. 1270). In + 607 and + 608 the line between Yu-lin and the Tsü-hung region was put in order (TCKM, ch. 36, p. 131a, ch. 37, pp. 26a, 45; cf. TH, p. 1278), thus linking the work of the Han and the Northern Chhi. The Sui Wall may have been rather more east-west, however.

6a Except for a short spur near Chin-tha, built doubtless to protect the road to Chü-yen (99), cf. p. 17 above.

6b Cf. Vol. I, Fig. 14.

6c This Han part of the Great Wall was first surveyed by Sir Aurel Stein; see his classical studies (1, 2, 3, 4, and especially 5). We showed it already in Vol. I, Fig. 16.

6d The Sui-fortress was already in existence before + 111 (Hsia Nai 4), pp. 76, 158. On the exact position of the two see Hibino Takes (1).

6e This was first surveyed by Geil (1).

4a 天下第一關 4b 戰馬關 4c 逃邉塔

4a 天下第一關 4b 戰馬關 4c 逃邉塔

4a 天下第一關 4b 戰馬關 4c 逃邉塔

4a 天下第一關 4b 戰馬關 4c 逃邉塔
Thus, in sum, the Wall has had periods of importance and periods of decay. After the Chhin and Han (—3rd to +3rd centuries) there was little maintenance. The Wei, Chhi and Sui accomplished major reconstruction (+6th and +7th centuries) but the seven centuries of Thang and Sung passed without upkeep or any fresh building. In the Yuan and Chhing the Wall lost all significance and this is why its present state is essentially Ming.

The sight that paternal preoccupations withheld from James Boswell became in due time the lot of Captain Parish of the Royal Artillery, Lord Macartney's military attaché, who in +1793 gazed upon the Wall at the gate of Ku-pei-khou when the ambassador's company was on its way to attend the Chhin-Lung emperor in Jehol. Parish measured and surveyed as much as he could of the walls and towers in that neighbourhood, and his estimate of the Wall's magnitude formed the basis of a famous statement by his colleague, Macartney's private secretary, John Barrow. The Great Wall, wrote Barrow, is so enormous, that admitting, what I believe has never been denied, its length to be fifteen hundred miles, and the dimensions throughout pretty much the same as where it was crossed by the British Embassy, the materials of all the dwelling-houses of England and Scotland, supposing them to amount to 1,800,000, and to average on the whole, 2,000 cubic feet of masonry or brick-work, are barely equivalent to the bulk or solid contents of the Great Wall of China. Nor are the projecting massy towers of stone and brick included in this calculation. These alone, supposing them to continue throughout at bow-shot distance, were calculated to contain as much masonry and brickwork as all London. . . .

The approximate dimensions of wall and towers in the eastern stretches along the Hopei and Shansi borders may be seen in the accompanying diagram (Fig. 737), based upon Parish and the data of many travellers subsequent to him. The granite blocks of the stone foundations are often as large as 14 ft. x 3 ft. or 4 ft., those of the stone facings for the rubble core some 5 ft. x 2 ft. x 1 ½ ft.; if the facing (always about 5 ft. thick) is of brick-work, it contains seven or eight thicknesses (cf. p. 45 above). There are eight to twelve towers per mile, at distances ranging from 100 to 200 yards. To compare the constructional methods of past ages with those which would be employed for a similar work today would lead us far into conjecture; one can only say that an immense amount of man-handling of the blocks on slides must have been used, with suitable tackle for laying in place.

Reinforcements of wood, and even of iron, appear to have been used occasionally in certain sections of the wall. The Kuei-Hsien Tsa Chih (Hsi Chi) of about +1298 tells us that people living along the Great Wall used to find within it, in places where it broke down after heavy rain, lengths (kun') of an extremely hard wood which had been used by the builders centuries before. These were good for spear-shafts. In view of the term used (cf. p. 58 above) these may well have been boards which had been part of the shuttering, but it is not excluded that they were baulks intended for reinforcement only, since Stein (10) found that the walls of Han forts in the Tarim Basin were generally formed of brushwood fascines and wild poplar trunks alternating with layers of tamped clay. Perhaps the same wood served both purposes. It could moreover have been piling. If you rain down piles of "thousand-year wood", wrote Fang I-Chih in his +17th-century technical encyclopaedia, "much energy is saved; pine and cypress wood can last for centuries without decay.”

For a brief biography of Parish, see Cranmer-Byng (2), p. 313. Macartney (1), p. 110 ff., gives the ambassador's own observations.

For a report on the excavation of the walls of Chhi-Shih, see Stein (10), p. 475.

If you rain down piles of "thousand-year wood”, wrote Fang I-Chih in his +17th-century technical encyclopaedia, "much energy is saved; pine and cypress wood can last for centuries without decay.”
There is every evidence that the first Great Wall of Chhin Shih Huang Ti took quite a different course from the present main line. How far north-west of Lanchow it started we know not, but it certainly passed Ninghsia (114) and then kept all the way north of the great bend of theYellow River, covering Wu-yuan (9), where there was a gate at Kao-chhiieh (117), a site now long lost. The surmise is that it then ran eastwards through the southern steppes of Inner Mongolia along a line some distance north of the present Wall, reaching the sea not far from Shan-hai-kuan. There is also evidence that the Chhin fortifications were extended, probably as an earthwork, along a different course from the present main line. How far north-west of Lanchow it found which can be recognised as Chhin work, except some of the foundations used by later dynasties.

Perhaps significantly, the Great Wall is not given as much prominence in the Shih Chi as one might expect. We are simply told that Chhin Shih Huang Ti built a wall along the north of the Yellow River, and ordered Meng Thien to set up a line of fortresses. This was in - 214. In the general's biography a little further information is given. We read:

After Chhin had unified the world (in - 221), Meng Thien was sent to command a host of 300,000 men to drive out the Jung and Ti (barbarians) along the northern (marches). He took from them the territory to the south of the (Yellow) River, and built a Great Wall, constructing its defiles and passes in accordance with the configurations of the terrain. It started at Lin-thao and extended to Liao-tung, encompassing a distance of more than 10,000 li. After crossing the (Yellow) River, it wound northwards, touching Mount Yang.

The building of the Great Wall can only be viewed in its correct historical perspective by realising that what was done in the Chhin was not so much the construction of a continuous wall entirely de novo, but the extension and linking of a number of walls which had been built previously by the various Warring States. Their purpose was to break the shock tactics of the nomadic horse-archers, or of cavalry belonging to feudal States which had adopted such tactics. This was first perhaps brought out by a Ming scholar, Tung Yüeh, in his Chhi Kuo Khaö (Investigation of the Seven States), and has been set forth by a number of modern authors.

But of the immense organisation which the task must have involved, of the supply trains, of the surveying and planning, no word has come down to posterity.

The Wall, as is well known, has remained for centuries a focal point of Chinese folklore and legend. The story that one of the workers (at least) was buried in it gave rise to the famous Ballad of Meng Chiang Nu (tr. Wyman, and Needham & Liao) on which see Ku Chieh-Kang (1); Hsiao (1); and Surna (1). The burying of objects in walls was only one department of builders' magic in China, on which Eberhard (20) has written, drawing from the La Pen Ching (cf. Vol. 4, pt. 2, p. 44). The building of the Great Wall can only be viewed in its correct historical perspective by realising that what was done in the Chhin was not so much the construction of a continuous wall entirely de novo, but the extension and linking of a number of walls which had been built previously by the various Warring States. Their purpose was to break the shock tactics of the nomadic horse-archers, or of cavalry belonging to feudal States which had adopted such tactics. This was first perhaps brought out by a Ming scholar, Tung Yüeh, in his Chhi Kuo Khaö (Investigation of the Seven States, and has been set forth by a number of modern authors.

And we have already sketched the pre-Chhin walls in Vol. 1, Fig. 12, based on a chart
constructed by Latimore. They began in the late 4th century with a number of works of defence against the steppe nomads. About -300 the Chhin State built one wall from the Thao River in Kansu north-eastwards to somewhere near the point in northern Shensi where the present Great Wall turns northward again, so that it joined an earlier Wei wall of -353 which ran further north-eastwards along the edge of the Ordos desert towards the descending loop of the Yellow River; this line was later followed more or less (as we have seen) by the Sui Great Wall. The State of Chao, under Wu Ling, also about -350, built another running from Kao-chhüeh (117) eastwards north of the Yellow River to somewhere between modern Kalgan and Peking. The State of Yen, about -290, built a third fortification from near the eastern end of the Chao wall to the lower valley of the Liao River in Manchuria; this was the precursor of the Willow Pale. Both these were very near, if not exactly on, the line taken by the Great Wall more than half a century later. But the walls were not only to keep out the barbarians or to prevent marginal Chinese from joining them, for some were built along the boundaries of individual feudal States. In -353 Wei built the north-south one in Shensi to protect its western territories from Chhin, and later, after this had proved useless, another one further back across the Yellow River valley somewhere near Loyang. Similarly Chhi, in northern Shantung, had long before (c. -450) built a wall running east and west north of Lu State, to protect itself from the growing force of Chhu in the south. At the beginning of the 3rd century, Chhu also set up a wall somewhere fairly high above Nan-yang (14) protecting the northern side of the Han Valley, as a defence against Chhin. It was as if, says Latimore, the "cellular" units of walled cities, each with its adherent population, were grouped in agglomerations of cells, each with a wall which identified it as a major unit compounded of minor units. One cannot suppose that the resources of these minor 'metazoan' social entities permitted of much more than a continuous dyke and ditch to aid defence; probably these early walls were something like the series of Romano-British "Devil's Dykes" between the ancient fen and forest with which we are familiar in East Anglia. It is very unlikely that they were faced with brick or stone as were large sections of the later Great Wall.

The best estimate of the Great Wall's length puts it at 3,930 miles if all its branch walls are counted, and 2,150 miles if the main line alone is taken. The distances divide (going westwards) as shown in Table 65. These figures are roughly correct when the relative primitive state of transportation in the Chhin and Han is taken into consideration, as Western historians of technology, for example Horwitz (6), have agreed.

![Table 65: Lengths of the divisions of the Great Wall](image)

As to the effectiveness of the Great Wall in keeping out the troops of nomadic horsemen, it was probably considerable. Any breaking-down of the wall, or building ramps up to it, would allow time for the arrival of Chinese reinforcements. At an earlier stage in this book, evidence was considered which suggests that the impenetrability of the Great Wall was a factor in the initiation of a series of shocks in tribal relations which transmitted themselves like a chain reaction to cause disturbances and invasions at the nomad-settlement frontier in Western Europe. Chinese engineering skill, and the genius of that people at that time for the organisation of mass labour projects, might therefore be said to have outplayed the protective capacities of the Roman Empire. For while the Romans were quite capable of building, in Hadrian's time, a wall and line of forts across the narrow neck of northern England, they never attempted to build what would have been the true counterpart to Chhin Shih Huang Ti's wall, namely one reaching from the mouth of the Rhine to the mouth of the Danube. For half a millennium the Great Wall fulfilled its purpose, and only after the end of the 3rd century, when imperial Rome had been very largely 'barbarised', did the contracting power of the Chinese central State permit in its turn the establishment of numerous Turkic and Hunnish principalities north of the Yangtze and south of the Wall.
The most ironical thing about the Wall was that medieval Europeans (and Arabs) were under the impression that their own forefathers had built it. The biblical characters Gog and Magog, according to many versions of the Alexander-Romance, had been driven eastwards by Alexander the Great, and confined, with twenty-two nations of evil men, behind an iron wall which divine assistance had helped him to build. In the last days they would break through his gate and overrun the world (Fig. 738). As de Goeje (1) maintained long ago, there can hardly be any doubt that this legendary engineering work (which constantly appears in Western medieval maps) was an echo of the real Great Wall itself. The story is mentioned in the Koran, in connection with 'Him of the Horns' (Dhul al Qarnain), i.e. Alexander the Great, so that it must have been contained in Syriac sources. Some Arab travellers were said to have seen the Wall of Gog and Magog, notably Sallām al-'Tarjamān (the Interpreter), who gave an account of it afterwards to the geographer Ibn Khurādādhbih (d. c. +912), and read to him his report to the Caliph. Sallām had seen an 'iron gate' in the Wall, and others averred that it was made of alternate courses, red and black, of bronze and iron or lead. Efforts have been made to identify this iron gate (after all, a rather common geographical name in all parts of the world) with passes in the Urals, but Togan (2) suggests more plausibly that it was the Talka pass in the Thien-Shan range. In any case both Franks and Saracens knew of a Great Wall, vague though their knowledge might be, and throughout the middle ages they ascribed its origin to the Macedonian world-conqueror. But by the time that His Excellency Ysbrants Ides, Ambassador from His Czarish Majesty to the Emperor of China, rode with his cavalcade through the Nan-khou Gate in October 1693, Europeans well knew who deserved the credit.

Fig. 738. Gog and Magog breaking through Alexander's gate in the last days to overrun the world, a page from the Revolutiones Pseudo-Methodicius (Furter ed.), one of the versions of the medieval Alexander-Romance corpus. After Cary (1). The caption at the top says: 'How Gog and Magog issuing from the Caspian Mountains shall obtain the land of Israel.' Below: 'Truly in the last days, the time of consummation of the history of the world, according to the prophet Ezekiel, Gog and Magog shall come forth into the land of Israel, for these are the peoples and the kings that Alexander the Great shut up in the extreme northern and eastern regions; Gog and Magog, Meneshech and 'Thabul, Anog and Aseg and . . . ' Cf. Ezekiel xxxviii and xxxix, where of course there is nothing about the Wall.
Though architecture (chien chu) is a subject which lies so near to the fine arts that it hardly comes within the scope of the present book, it has a technological basis which we could not dare to omit. This problem will face us again, as in ceramics, where the fundamental discoveries, such as that of porcelain, will concern us deeply, but not the reader must have recourse to the abundant literature which already exists on the aesthetic aspects of Chinese civilization; it lies off our course, and we can only glance at it.

To the first European visitors in the sixteenth and seventeenth centuries, Chinese buildings must have seemed very strange. They attracted more detailed interest and study in the Chinoiserie period of the eighteenth century, as witness buildings, and the like. For temple architecture, the early work of Combaz (4) on the imperial temples in Peking was extended by Boerschmann (2) and Prip-Møller (1) to imperial palaces have been described and photographed in luxurious style by Combaz (3); its illustrations, though few, were chosen with great care, and its text, though brief, is clear and helpful. It has been supplemented,

Recent studies, however, have partially made up for former neglect. There are the impressive folios of Sirén (1) and Boerschmann (1, 8) on Chinese architecture in general, largely devoted, of course, to the more important works, temple halls, palace buildings, and the like. For temple architecture, the early work of Combaz (4) on the imperial temples in Peking was extended by Boerschmann (2) and Prip-Møller (1) to Buddhist and Taoist temples in many parts of the country. The imperial palaces have been described and photographed in luxurious style by Combaz (3); Sirén (3); Ogawa (1); and Okuyama, Ito, Tsuichiya & Ogawa (1). Sirén (4) devoted a special work to the walls and gates of the city of Peking, while studies of its plan are due to Chu Chhi-Chhien & Yeh Kung-Chao (1) and Rasmussen (1) among others. A different kind of architectural complex is formed by the imperial tombs, with their huge embattled mound, and their sacrificial halls among the hills, preceded by long avenues of stone figures; the description of these was tackled first by Combaz (2) and afterwards by Boullard & Vaudescal (1); Grantham (1) and other writers. For the pagodas scattered throughout the country Boerschmann's account (4, 7) is the standard one, while Combaz (5) traced their origin and evolution from the Indian stūpa.

After some time the reader begins to feel, however, that he is suffering from a surfeit of beautiful photographs and too much archaeology and comparative religion, and would prefer more precise information regarding the functional basis of the building construction. At the same time he also feels that he would like to give less study to the highest flights of Chinese architecture, and more to the regular, common-place, but regionally diverse and often very attractive, dwellings of the townsman and the farmer. Thirdly, of looking at so many examples of the exquisite curving roofs, he would like some clearer ideas about the history of the remarkable style which produced them. These needs have evoked some response in the West, not as yet a wholly satisfactory one.

The first study which provided good drawings of the timber construction, roof supports, etc., of a Chinese Buddhist temple was that of Hildebrand (1), some sixty years ago, but it gave no Chinese technical terms. This gap was filled more or less well by the monograph of Kelling (1), who had the advantage of being able to study the great Sung compendium of architectural practice, the Ying T'ao Fa Shih (see on, p. 84), lithographically reproduced in 1920. Defects this monograph may have, but there is nothing else of the kind available, and among its merits is the fact that it devote particular attention to domestic architecture. So do the excellent papers of Spencer (1) and Skinner (2), more recent in date. On the historical side, there is little save the monograph of Bulling (2) (originally a thesis), but Kelling & Schindler investi­gated ancient building technique in China with philological methods, and in Japanese there is a noteworthy treatise by Ito Seizo (1).

The best all-round book in a Western language on Chinese architecture has for many years been that of Mirams (1); its illustrations, though few, were chosen with great care, and its text, though brief, is clear and helpful. It has been supplemented,
but not superseded, by the more extensive account of Sickman & Soper (1). 4 From the photographs of Boerschmann (3) an excellent idea can be gained, by those who have never been in China, of the way in which Chinese builders sited their constructions so as to blend into the scenery and topography in the most intimate way.

For those who understand Chinese, of course, a vaster field of literature lies open, albeit less well documented pictorially perhaps than the Western productions. Useful summaries have been written by the doyen of Chinese architectural historians, Liang Sus-Chhêng (3, 1). An enormous mass of information is contained in the Chinese Journal of the Society for Research in Chinese Architecture, recourse to which is indispensable for anyone wishing to penetrate beyond the surface of the subject. The Society has also published monographs and portfolios of plates, such as the contribution of Liang Sus-Chhêng & Liu Chih-Phing (1) on some of the most essential features of Chinese building construction. 5 Twenty-five years later the second author produced an invaluable systematic treatise on Chinese architecture and its development (Liu Chih-Phing, 1) 6. And in recent years there has been a spate of valuable publications on domestic architecture, 7 architectural detail, 8 and the like, which we may mention again as need arises. Lastly, a bookcase of modern Chinese architectural works would not be complete without some of the excellent albums of photographs now available (e.g. Anon. 37). And the study of the history of building technology has newly arisen in neighbouring countries of the culture-area. 8

(2) The Spirit of Chinese Architecture

In no other field of expression have the Chinese so faithfully incarnated their great principles that Man cannot be thought of apart from Nature, and that man is not to be divided from social man. Not only in the great constructions of temples and palaces, but also in the small structures of gardens and domestic buildings, the whole conception is in accordance with the view that "Man is Nature", that man is part of nature and cannot be separated from it. In the literature of the East these ideas have always been expressed in such manner as to be comprehensible to the people who lived and worked under the influence of such beliefs, and the Chinese were no exception. The idea that nature is the source of all is not new, but the Chinese have always been conscious of the fact, and have tried to express it in their art and architecture. This is evident in the way in which they have attempted to blend their buildings into the landscape, to make them part of the natural surroundings, and to create new landscapes in the process. The Chinese have always been aware of the beauty and power of nature, and have sought to make their buildings a part of it. This is evident in the way in which they have used natural materials such as wood, stone, and earth, and in the way in which they have designed their buildings to fit into the landscape. The Chinese have always been aware of the beauty and power of nature, and have sought to make their buildings a part of it. This is evident in the way in which they have used natural materials such as wood, stone, and earth, and in the way in which they have designed their buildings to fit into the landscape. The Chinese have always been aware of the beauty and power of nature, and have sought to make their buildings a part of it. This is evident in the way in which they have used natural materials such as wood, stone, and earth, and in the way in which they have designed their buildings to fit into the landscape.
Thus man is not isolated from Nature. As old Magalhaens wrote three centuries ago: *b*.

There are two things to be observed; the first, that all the Cities and all the Palaces...are so built, that the Gates and Principal Apartments look towards the South; the second, that whereas we build our Lodgings...the Chinese build upon the same Level one within another...so that we possess the Air and they the Earth.

The long rear wall is almost always unbroken by doors or windows, and forms, as it were, the ultimate statement of the plan, though not its climax, since the largest hall will be placed somewhere north of the central point, and there will be a diminishing of constructions behind (i.e. north of) it. For a concrete illustration in the Chinese style of draughtsmanship of how the system works out, we may glance at a plan of a Confucian temple (Fig. 744) taken from the Sheng Hien Tao Thang Thu Yuan (Comments on Pictures of the Saints and Sages, Transmitters of the Tao). Here may be seen the triumphal gateways (phai-lou; see on, p. 142), the succession of halls and avenues on the central axis, the arrangement of two subsidiary parallel axes, the enclosing walls, and divers pavilions for special uses. Even domestic architecture, moreover, has an informally liturgical character, which reflects the ancient prescriptions of the books of social ceremonial, such as the Li Chi. Fig. 745; well illustrating this, shows a bird's-eye view of a traditional home in Peking.

Another characteristic of the Chinese house, seen as soon as it rises above the level of importance of the simple thatched cottage, is that it is based upon a platform. This was presumably utilitarian from earliest times, to raise the living quarters and the passages between them above the mire of farmyard and caravaners. But with the passage of time this facility developed into one of the most majestic elements of the full style, joining with others such as the great emphasis placed on roofs, and the advantage invariably taken of sloping ground. In very important buildings, the terrace platforms may exceed 6 ft. in height, and may be constructed of white marble, access to them

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*a* One of my most dominant impressions for some time after first returning to Europe from China was the sense of loss of intimate contact with the weather. The wooden lattice windows covered with paper (often torn), the thin plaster walls, the open verandahs outside every room, the sound of rain-water dripping in the courtyard and small pavilions, warmth made individual by fur-lined gowns and charcoal fires—everything gave a consciousness of Nature's moods, of rain, snow, wind and sunshine, from which one is utterly isolated in European housing.

*b* (1), p. 771.

*c* A small Confucian tract put together by a local official, Huang Thung-Fan, in 1609.

*d* A particularly good perspective plan of this kind is seen on an inscribed stone stele of a temple at Jung-lo in Shanai (Wang Shih-Jen, 1).

*e* Rammussen (1), p. 6; Liu Tun-Chen (4), pls. 90-92.

*f* In some large compositions the main entrance is at the lowest point, so that the visitor wanders through the series of courtyards and halls ever ascending. This trait has been mentioned already (Vol. 2, p. 164) in connection with a Taow temple near Kunming, and it is found often also in Confucian temples such as that at Chhing-kung, Yunnan, illustrated in Fig. 37 (Vol. 2). My memories of these beautiful places are heightened by the fact that when I first began to explore them in 1934, no one in China had much time to spare for conducting foreigners around. Thus with solitary steps I penetrated into an enchanted world of exquisite ancient buildings, able in silence to receive their full message of Chinese cultural values incarnated in wood and stone.
being gained by two central stairways flanking a central inclined 'spirit-path' carved in high relief, besides which there will also be staircases at the sides of the courtyard.

'The wooden pillars', says Sirén (1), 'rise above the supporting terraces, which often reach considerable heights, like tall trees on mounds and hillocks. The lines of the far-projecting curving roofs suggest the long wavering branches of the cryptomerias, and if there are any walls, they almost disappear in the play of light and shade produced by the broad eaves, the open galleries, the lattice-work of the windows, and the balustrades.' This point is important, for the walls in Chinese buildings are indeed of secondary significance; it is the terraces and overhanging roofs which are decisive for all outer aspect. As we shall shortly see more fully, the walls of Chinese buildings are always curtain walls; they take no share as bearing walls in the support of the structure.

In contrast to Greek structures, Sirén goes on, the gables have no function but to terminate the long hall; they lack every architectural emphasis and in many cases are not even intended to be seen. This follows from the choice of the long side as the main façade and the transverse position on the axis of the composition.

The main features of Chinese building may be summarised then as follows: (a) emphasis on the roof, and its construction in sweeping curves, (b) formal grouping of buildings round rectangular courts, and marked attention to axis, (c) frankness of construction, the supporting pillars of the massive roof timbering being clearly visible, even when partly engaged in walls, (d) a lavish use of colour, not only in roof tiles, but on painted columns, lintels and beams, richly bracketed cornices, and broad expanses of plastered walls. Here the third item of this observer particularly arrests our attention. Indeed, as another modern Western architect has said, the quality of greatest interest in traditional Chinese building is perhaps that it was functionally and structurally direct and honest. The structural elements are distinct and explicit, all decoration being based on them. Clarity and rationality appears in plan, section and elevation, and in the high degree of harmony between the three. 'Chinese buildings, for all the sophisticated aesthetic that controls every part, have a look of being built by a master-craftsman or architect-engineer, as indeed they were.' And all was under the aegis of the element Wood. 'Though we shall ponder upon this again, we cannot forget it here. In spite of early knowledge of arch and vault, masonry and brickwork were always confined to terraces, defensive works, walls, tombs and pagodas. No Chinese house could be a proper dwelling for the living, or a proper place of worship for the gods, unless it was built in wood and roofed with tile. Immense consequences followed. The timber frame and the screen wall provided large span, compact supports, maximal unobstructed space, standardisation of planning, and flexibility of use. The timber structure blossomed into the elaborate roof which became the main feature of the building, and considerable height and monumentality, when occasion demanded, was not beyond its powers. As we shall see in more detail later, the most typical Chinese building was a rectangular hall on a terraced base, marked out by wooden columns joined together in a complex trabeate system. The heavy and overhanging roof was supported not by means of triangular trusses but by a network of beams of diminishing length, separated by struts and superimposed one over the other across the rectangle. Since the purlins were supported directly by this trabeation, any desired curve could be given to the roof. All round the building the

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\[\text{Ref.}\]

\[\text{Fig. 744. Plan of a Confucian temple taken from a roughly printed popular edition of the Sheng Hsien Tao Thang Thu Tam. It is that of Yen Hui, one of the 'four associates' of Confucius, and his favourite pupil, Watters (a), p. 2 (F), at Chihfou east of the temple of Confucius himself. Symmetry dominates in the placing of the subsidiary fasting pavilions, and the 'sage's distinguished pupil.' Cf. Watters (2), pp. 2-3.}\]
Fig. 745. Sketch of a traditional Chinese home in Peking (after Rasmussen).

beams were cantilevered outwards to form the generous overhang of the eaves, and as time went on there arose an extremely elaborate development of cantilever brackets piled up in tiers, enlarging thus the overhang to reach a maximum in Thang and Sung times, and embodying the most ingenious carpentry. The basic ground-plan was capable of expansion in all directions—lengthwise by unit-repetition, crosswise by verandah bays or ‘transepts’, and upwards by the addition of storeys in numerous forms, e.g. low verandahs with a high internal hall, or galleries in several storeys surrounding a lofty interior space. And marvellous polychrome ornament was added by the decorators.

The words ‘standardisation of planning’ may have caught the reader’s eye in the preceding paragraph, and perhaps they awakened a curiosity which deserves satisfaction. Modern architecture has indeed been influenced more by Chinese (and Japanese) conceptions than is usually supposed. One basic Chinese characteristic has always been the addition at will of repeating units keyed to the size and scale of human beings—pillar-intervals or bays (chien) in buildings, and spaces in open-air courts. Such ‘modules’ occur in the theory and practice of modern architects such as le Corbusier, some of whom (e.g. Frank Lloyd Wright) themselves worked in Japan, as Murphy did in China. Le Corbusier’s ‘modulor’ is a series of predetermined lengths intended for use as building measures, and generated by the application of the recto aquarea (c.618) to the height of a man taken as 6 ft. It thus derives from Pythagoras through Fibonacci and Dürrer. But the harmonious assembly of units each fixed to the human scale is even more deeply Chinese, because it was universally, not occasionally, practised in that civilisation, a working norm rather than an aesthetic theory. Unit-repetition flexibly available for a variety of different purposes is now acclimatising itself in the West on other grounds also, having proved its value for example in the architecture of modern scientific laboratories. In Chinese tradition faithfulness to the human scale doubtless had some connection with the natural limitations of timber construction without geometrical trusses, but contemporary builders all over the world, though now far more capable than medieval Europeans of erecting structures entirely out of scale with individual men, are coming to appreciate more and more the sober humanism of the Chinese style, which was certainly not conditioned by the materials alone. Its multiplication of relatively small spaces horizontally is in many ways more satisfying than the attempt to bridge ever larger and loftier spaces, only to dwarf their human inhabitants.

In this connection it is significant that the traditional Chinese architects and builders were extremely conscious of standard dimensions and right proportionality. Soper remarked in passing that the Sung manual of about +1100, the Ying Tao Fa Shih, which we shall study in detail presently (p. 84), uses a particular proportion as a modulor, namely the end elevation (huang, kuo tu) of the horizontal corbel bracket arm (the hua hong), cf. pp. 93, 95. Actually, this had been the discovery of Liang Ssu in (9) when he was studying the Tu-Lo Tsaw temple at Chi-Hisen, a Liao...

a Who can forget, having once seen, the corner pavilions high on the grey walls of the Forbidden City at Peking (Fig. 746, pl.), their roof-tiles of imperial yellow surmounting their fretted walls and doors of a faded murrey colour?
dynasty (late +10th-century) structure. This module was called a *tshai*, an area measured in Chhing times as $2 \times 1$ *tou-khou*, a *tou-khou* being a relative dimension from 6 in. down to 1 in. in all of eleven different sizes (6, 9, 15, 18, 25, etc.). The height of one corbel arm (*hunny*), plus that of the wooden blocks (*tan-tshai*) carried on each end, was $2 \times 1$ *tou-khou*, and the thickness of the corbel arm was $1$ *tou-khou* making 1 *tshai*. The corbel arm alone had the height of $1/4$ *tou-khou*, and this was called a *tan-tshai*. All other measurements of the building were derived as multiples of these.

In Sung times the module system was a little different. One *tshai* measured $10 \times 15$ *fen*, where *fen* was a relative dimension ranging from 0.6 in. down to 0.1 in. The height of corbel arm plus block ($10 \times 21$ *fen*) was then called *tou-tshai*, the corbel arm alone raised ($10 \times 15$ *fen*) was the *tan-tshai*, and the block height alone ($10 \times 6$ *fen*) was the *chihi*. Although the term *tshai* had this special technical significance, its use was certainly related to the fact that the timber beams and baulks came then. Thus the entire Chinese building was designed in terms of standard modules, proportion was thus safeguarded, and relational harmony preserved, whatever the standard Chinese modules, but he does not adequately explain them.

This system was undoubtedly inherited from Thang practice, probably not new even in Sung times as 2 *x* I

As for the roof-structures of houses and halls, everything depends on the standard size of the materials chosen (*chih i tshai wei tou*). There are eight standard sizes (of the height and thickness of timber baulks), and these are used in accordance with the size of the building. [Measurements follow, ranging from 9 x 6 in. to 4 5 x 3 in. Notes specify the type of buildings, party in terms of numbers of rooms, for which each grade of cross-section is suitable.] When the measure called *chihi*, six standard parts (*fen*) in height and ten in thickness, is placed on top of the *tou-tshai*, the whole is called the *wu-tshai*. The height (*bunng*) of each standard beam is divided into 15 standard parts, and the thickness (*hou*) (always) corresponds to 10 of these.

Thus the height and depth of the roof, the length, curvature and trueness of the members, and the ratios of column and post heights (*chihi*), lit. raising and cutting (in the structural cross-section adopted for any particular ground plan), together with the right use of square and compass, plumbline and ink-box—all proportion and rule depends on the system of standard timber dimensions and the standard divisions of these.

This system was undoubtedly inherited from Thang practice, probably not new even then. Thus the entire Chinese building was designed in terms of standard modules, and modulors of variable absolute size, none ever out of scale with man himself. Right proportion was thus safeguarded, and relational harmony preserved, whatever the magnitude of the structure.

To unravel the moulding of the various building patterns of China by the concrete needs of the different parts of the social order at various stages would constitute a special task in itself, and an important one. By Western historians of Chinese architecture it has been strangely neglected, and only now are the Chinese themselves beginning the task, as in the monograph of Liu Tun-Chêng. For example, the large joint-family system, in which the sons did not quit the ancestral compound on marriage, must have evoked powerfully the differentiation of a multiplicity of halls and courtyards within the single enclosure. So also the tendency of great families in the Han to establish what were almost factories in their large dwellings must have worked in the same direction. Although the Thang the wealthy family was not so often a centre of production of commodities, but then the effects of artisanal family production on urban buildings could certainly be studied in Chang-an and Hangchow as well as the great cities of subsequent times. Rural building must always have centred round the farm as an agricultural production-unit, and domestic architecture must have waxed and waned in accordance with the prosperity of countrysides and the particular social strata (poor peasants, rich peasants, scholar-gentry, etc.) in question. As for the formative influence of the bureaucratic-feudal State on Chinese public architecture, it was evidently capable of large-scale planning from the start, and its splendid works were always essentially secular in spirit. Immanentist, ethical, hierarchical, liturgical, axial, symmetrical—these were the qualities of Confucian architectonics. Taoist influence was on the side of immanence too, of course, but it tended to softer less severe, formulations, finding architectural expression in beautifully sited buildings and romantic ensembles, developing the garden and the artificial landscape. Buddhism went along with the Taoists in these matters, adding however the pagoda derived from the Indian *stupa*, and the *phai-lou*, the triple or five-span gateway derived from the Indian *torana*, familiar from Śrīnāchi. Typically, the enceinte wall of the compound turned into long cloisters facing inwards, the gates held their place on the main south-north axis, the pagoda, at first central, was duplicated symmetrically, or pushed to one side or northward, and finally exiled to the outer grounds; north of its primitive mid-

any particular human being of whatever age depended upon the length of a particular bone in the hand. This sophistication application of a relative measure threw at once into relief disorders of normal proportionality, and facilitated the location of desired points in the anatomical pattern. How characteristic these ideas and practices were, whether in building or biology, of a culture saturated with the organic view of the universe! a Cf. Vol. 4, p. 3, n. 26. b Here a special case was constituted by the *great towers of stone* which Marco Polo saw, solid and moated. In fact these buildings were fireproof warehouses (*the fang*), caravanserai with more than a thousand rooms rented to nomads for their goods according to need on monthly leases. The descriptions in Tu Ch'êng Chi Shêng, ch. 13 (p. 100) and Ming Liang Lü, ch. 19 (p. 290) have been translated and discussed in Moule (11), (18), pp. 24 ff. and Gernet (a), p. 38. For an eye-witness account of the Canton towers in 1903 see R. D. Thomes (1), p. 3. Cf. p. 90 below. c Cf. what was said in Vol. 4, pt. 1, p. 53, about the organisation of the meridian arc survey early in the 4th century. d On these see pp. 142 ff. below.
line position came the worship-hall, north again the lecture-hall, and still further north the dormitories and living-quarters.

As Soper (2) has emphasised, in his luminous discussion of Chinese and Japanese temple planning, there was never any disjunction or dividing line between the secular and the sacred in East Asian architecture. Temple buildings were repeatedly compared with those of palaces, palace buildings were often converted into temples, and temples once again secularised for use as schools, hospitals, or government offices. The very word 70 line position came the worship-hall, north again the lecture-hall, and still further north the dormitories and living-quarters.

For the temple itself, the sacred grove (often extensive woodland) was generally sufficient protection, but lay folk sometimes felt the need of more, and thus the element of security also had its effects on Chinese building. No one who has travelled in China's north-west can forget the fortified villages (pao) surrounded with their crumbling walls of loess, hardly distinguishable at a distance from the circumambient hills.

Elsewhere, as in the far south-east, migrations of people in times of disturbance led to the construction of veritable fortified apartment-houses, some fairly conventional in their rectangular planning but others with great originality making use of vast cylindrical edifices with inward-opening dwellings of many storeys (cf. p. 134 below). So far the social significance of the infinite variety of China's building patterns has been studied insufficiently whether in east or west. Though the historian of science and technology cannot do the job, he can at any rate voice the need for it.

Whatever the forces which moulded the Chinese building trade, its achievement was truly extraordinary. It mirrored in hard structural materials the outstanding genius of this people for combining the rational and the romantic. Harmonising intellect and emotion, it wedded the science of the erection and disposition of edifices to the art of landscape design in such a way that Nature remained dominant, free from subjection to an imposed architectural pattern, and rather uniting with the works of Man in a larger synthesis.

(3) The Planning of Towns and Cities

If the individual family dwelling, the temple, or the palace was so elaborately and attentively planned, set out, indeed, as a highly integrated organic pattern, it would naturally be expected that urban planning would also show a considerable degree of organisation. The question is not however quite so simple, for in China there was a rather marked difference between the spontaneously growing village or rural settlement and the town planned from above. It would not be desirable here to anticipate what will have to be said later on about the Chinese town in its social and economic context, but a few words on the subject cannot be avoided.

As Gutkind has pointed out, in the only review we have of Chinese town and village plans, the villages tended to grow up, as elsewhere in the world, along roads, paths and other lines of communication, according to a sort of 'ribbon development'. They arose at cross-road points, or where three ways met. At all times they possessed a great deal of unofficial self-government, and formed integrated community groups, dominated by one or more homogeneous clans. The sense of community was very real, especially when the village grew up far away from a line of communication at some point most convenient for the working of an agricultural area surrounded by upland or forest.

The Chinese town, on the other hand, was not a spontaneous accumulation of population, nor of capital or facilities of production, nor was it only or essentially a market-centre; it was above all a political nucleus, a node in the administrative network, and the seat of the bureaucrat who had replaced the ancient feudal lord. Originally, before the first millennium, the proto-feudal chieftains appropriated the centres of assembly where the people exchanged commodities and came together for the seasonal festivals. There was therefore no distinction throughout Chinese history between the feudal castle and the town; the town was the castle, and was built so that it could serve as the protection and refuge, as well as the administrative centre, of the surrounding countryside. Towns and cities in China were not the creation of burgheers, and never achieved any degree of autonomy with regard to the State. They existed for the sake of the country and not vice versa; they were planned as rational fortified patterns imposed from above upon carefully chosen portions of the earth's surface. Hence they did not necessarily grow, indeed they shrank as often as they expanded, while the esoxkeleton of walls remained in being to be refilled with flesh perhaps during a later dynasty. Their population was merely a sum-total of individuals, each of whom was closely linked with the village from which the family had originated, and where its ancestral clan temple still stood. While the European city or borough

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8 See Soper (3), pp. 23 ff., on the 'Kudara (i.e. Pakche) Plan', so called because the Japanese obtained it about + 590 from that Korean country. It was broadly that of older Chinese temples such as Hio-Tung Sun's founded at Chianghow in + 350 and Yung-Ning Sun's at Loyang (+ 310). Much about this type of foundation can be gleaned from the writings of the monk Tao-Hsian (+606 to +667), who described an imaginary temple in India in his Chung Thuem-Chu Shii-Wai Kao Chii-Yen Sun Thu Ching (Illustrated Description of the Jeyavana Monastery in Srvasti in Central India), and real ones in China in his Li Hoing Kan Tung Chon (Miscellaneous Temple Traditions according with the Vinayas Regulations) and his Kaum-Chang Choung-Li Chii-Chen Thu Ching (Illustrated Treatise on the Method of setting up Ordination Altars used in Kuan-Chong). He himself used earlier records, especially Ling-Yu's Shii-Chu Chii (Records of Holy Places), c + 581. The oldest Buddhist temple architecture in China can be dimly visualised from what Chai Jung 1 erected between +189 and +193 (Hou Han Shu, ch. 101, p. 138, Shin Kao Chii, ch. 49 (Wu, ch. 4), p. 26). This certainly had a court enclosed by cloister galleries, with apparently a combined pagoda and worship-hall at the centre. Cf. Soper (4), p. 39.


10 Here another special case would be constituted by the lofty towers of stone found attached to domestic buildings in the Tibetan marches among the mountains of Sikang (cf. Stein, 3, 4). These served the same purpose as that of the round towers of old Ireland, protection for the inhabitants in case of raid and rape.

12 T'ai Shan, Tai Shan, T'ai ch'ii, Tai Ch'ii.
13 Ling-chi, Ling-ch'ii, Lin-ch'ii, Lin-ch'i, Ling-ch'i, Lin-ch'i, Ling-ch'i.
14 Ch'ii Shan, Chin-ch'ii, Ch'ii ch'i, Chin-ch'i, Ch'ii ch'ii.

15 Cf. all that has been said concerning the universal tendencies of Chinese philosophy towards the organic as opposed to the mechanical (esp. Vol. 2).
16 Sect. 47 below.
17 Cf. also Haverfield (1); Miyazaki (2, 1).

A typical plan is given in Gutkind (1), fig. 27, due originally to J. L. Buck.
developed from within outwards, centred on its agora, forum, cathedral, market-place, and halls of municipality and guilds, the external fortifications were of the essence of the Chinese city (the same word 殿 1 still means both), and the key points were the central drum-tower (鼓樓) and the offices (衙門) of the governors, civil and military.

It is probable that all Chinese cities were laid out, since the Chou period, in a rectangular manner closely resembling that of the Roman castra. There was the great east-west street corresponding to the via principalis, and the great north-south one cutting it at right angles like the via decumana. Some indeed have thought that certain ancient forms of characters betray an older circular type of wall. This is argued for by the word 安 (K683) which means a 安邑 city, and appears on bones and bronzes as a ring-wall with a human figure kneeling beside it. So also 蒯, later meaning a suburb, shows (K774) an outer wall, apparently circular, with two well-drawn gate-towers. This came to be written in later times with the addition of the abbreviated form of the radical 安 just mentioned, generally used in combinations.

A number of existing derivatives of this radical have meanings connected with urban build (K76). Many Chinese drawings and paintings give life to this pattern; see, for example, the most, yang, in which (K1184) it is combined with water. But these arguments assume that in the difficult media of bone and bronze the Shang or Chou scribes were really capable of distinguishing clearly between the round and the square, which may perhaps be doubted. It is true, however, that the word 陽 宮 to build (K6457), which originally meant the demarcation of an encampment (hence the fires at the top of the character), is related to 城, a palace, which in its ancient form (K1006) shows distinctly two square rooms under a roof. The word 宮, written like it is composed of the phonetic 宮 completion combined with the radical 地 earth.

Dr Trevor Hodge points out a certain parallel in the Greek acropolis of Mycenean times, a fortified hill that held the king's palace and the main temples but served also as a stronghold for all the peasants of the surrounding districts in time of war. The agora was something quite different, connected with democratic life, and outside the acropolis.

We have not come upon specific technical town-planning terms for these, but there is a close parallel with the terms for the paths, balks or headlands running between fields—下田 generally north-south, and 西 generally east-west. These will come into some prominence at a later stage (pp. 258, 261, 267 below).

E.g. Herrmann (12).

This term, which has denoted the lowest rank of city possessing a magistrate since Chhin times, may be connected with a cognate word 亚洲, meaning to hang, e.g. the plumb-line, for buildings, and metaphorically for justice. It is also the custom in ancient China to hang up boards bearing written laws outside the government offices in towns (cf. Chou Li, ch. 1, p. 168 (ch. 2); tr. Biet (1), p. 34). The District Commissioner administering the law on the verandah of the only building for many miles around is thus the image of the Chinese magistrates of the -2nd millennium.

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Dr Trevor Hodge points out a certain parallel in the Greek acropolis of Mycenean times, a fortified hill that held the king's palace and the main temples but served also as a stronghold for all the peasants of the surrounding districts in time of war. The agora was something quite different, connected with democratic life, and outside the acropolis.

We have not come upon specific technical town-planning terms for these, but there is a close parallel with the terms for the paths, balks or headlands running between fields—下田 generally north-south, and 西 generally east-west. These will come into some prominence at a later stage (pp. 258, 261, 267 below).

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external walls (tu chéng). The word tu (capital) was written in some of its earliest forms with the city radical already mentioned, combined with mouths and the foot-steps of people walking in the streets (K.45g²). Chihang-an had no less than nine main streets in each direction.

Still at the present day, the principal walls of cities in China form a square or a rectangle (cf. Fig. 731, pl.), though there are many exceptions. The very long walls of Nanking follow the local topographical configuration, and some large cities such as Fuchow have very irregular outlines. Occasionally there occurred a circle or ellipse, as in the case of Sung Shanghai. Nearly all cities still have wide empty spaces left within the walls, available for kitchen-gardens and even farms. Sometimes ribbon-development occurring along an important road outside the city-gates became later incorporated within the walls, forming an elongated protrusion, as we see in the Tungkuan² district at Lanchow. Another Kansu city, Thianshui, came thus to consist of five walled towns joined together in a row.

In Chinese cities, a rather large population was sometimes packed into a confined area. In general the builders did not resort to multiple storeys, party walls were constantly used to separate dwellings of different families, and even the wealthy had rather restricted space, but every courtyard, no matter how small, became something of a garden by the use of plants and small trees in pots, no 'grounds' being provided. This meant that population density could reach high levels. And yet a sense of seclusion was preserved. In Peking, figures for residential areas reached 55,000 per square mile, and for working areas 85,000. But the city maintained a garden character owing to the abundance of trees, which paradoxically were more numerous within the walls than outside, and to this day Peking seen from some vantage-point resembles a forest, with only the roofs of the most important buildings visible above the tree tops (Fig. 748, pl.).

The Chinese garden is a goodly subject of enquiry and instruction in itself. Though its motive throughout the ages was of course primarily aesthetic, our own preoccupations will bring us back to it later on in connection with botanical and zoological collections.

* Sects. 38, 39 below. Musukami Yoshimi (1). It is not easy to find traces in China of the layout of Han gardens, but one formal plan of the 5th century still exists below the great rock of Sigiriya in Ceylon, crowned by its palace-temple.


* Lancelot Brown (+1715 to +1783), protagonist of naturalism in landscape-garden design, as at Kew and Blenheim.

* See the historical account of Chu Chi-Chihén and Yeh Kung-Chao (1), and general descriptions by Brettechneider (5); Favier (1); Fabre (1) and others. The names of many of the architects who contributed to it are known. Their line might be said to begin with Khung Yen-Chou, who rebuilt the capital with Kew and Blenheim.

* See Vol. 4, pt. 2.

* Of the literature on city planning a brief account will be given shortly (p. 87). It is a commonplace to say that the Chinese capital was copied by all the peoples of the surrounding culture-area for their centres of government, notably Japan (cf. Sansen (1), p. 108, (2), vol. 1, p. 82), but it is literally true.

* See the great work of Ĥu Tso (6), besides some shorter writings (11). Wilson (1) is also valuable, and the Chinese garden writer Li Shao-Chhang (1) and the writer on Chinese gardens Li Shao-Chhang and Li Shao-Chhang (1). The Chinese garden has perhaps been some what overshadowed in the European mind by those of Japan (cf. Harada, 1), but unjustly. Cf. Sugimura Yuzo (1). On miniature gardens, which began in China, and their symbolism, see Stein (2).

* Sect. 28, BUILDING
Chin Chhêng\(^1\), a with extremely broad roads transecting the capital in both directions, and with the superb axis leading from the centre to the cosmic temples near the southernmost gate,\(^7\) it has excited profound admiration in modern architects and writers such as Murphy, Gothein, and Rasmussen.\(^8\) The first speaks of this axis as the greatest in the world today. Southward it runs from the Bell Tower through the central pavilion on the Coal Hill, through the main transverse buildings of the Forbidden City with their magnificent yellow roofs, and through the towering wall-gate of Chhien Mên,\(^6\) to end five miles away, at the South Gate, Yung-Ting Mên,\(^5\) between the Altar of Agriculture and the Altar of Heaven (Fig. 752). The formal grouping of buildings, says Murphy, is marked not by rigid symmetry, but by that nice feeling for balance which is characteristic of all Chinese art. By avoiding exact duplication on each side of an axis, sufficient variation to avoid monotony could be introduced. This is seen, for instance, in the handling of the beautiful artificial lakes with which Peking is so well provided.\(^4\) A stream was led in at the north-west corner of the present city, and then expanded into a series of lakes (Pei Hai,\(^4\) Chung Hai,\(^4\) Nan Hai\(^4\)) forming, as it were, a parallel but sinuous western axis subsidiary to the main one which runs north-south through the centre of the Forbidden City, indeed through the imperial throne itself. All three lakes lie within the confines, formerly walled, of the Imperial City (Chhi Huang Chhêng\(^7\)), the next largest of the concentric rectangles which constitute the whole capital.\(^6\) The moat of the Forbidden City is supplied by a branch canal from the northern lake, and the moat in turn feeds the Stream of Aureate Water which is crossed (at no. 9 in Fig. 753) by the five marble bridges (Fig. 753, pl.) between the Meridian Gate (no. 8) and the Gate of Supreme Harmony (no. 10). Similarly the southern lake provides the ceremonial stream under the marble bridges which give access from the south to the grand entrance at the Thien An Mên.\(^8\) The water finally finds its way out at the south-east corner of the city. To give an idea of the grandeur of the view which lies before the visitor who passes northwards through the Gate of

**At the middle of the southern wall of the Forbidden City is the finest architectural unit in the country, the great Wu Mên (Meridian Gate), a central building some two hundred feet long, on a balustraded terrace, flanked by a pair of square, sixty-foot pavilions. The four-hundred-foot composition is raised on a wall base fifty feet high, plastered in dark red, and pierced by five arched tunnel entrances. Projecting three hundred feet south are two flanking wings of the wall base; at the outer ends of these, a second pair of pavilions repeat those of the main group. The effect is one of overpowering majesty and breath-taking beauty.\(^6\)**

To sum up, then, we find (in the words of a contemporary English architect)\(^9\) a series of demarcated spaces, each opening into the next but screened and stopped from it each time by walls, gateways, buildings overhead, and the tension heightened at chosen points, as some climax is approached, by such incidents as the bow-shaped stream with its marble balustrades and five parallel marble bridges. Between the constituent parts there is remarkable balance and interdependence. The contrast with the Renaissance palace is striking, for there the open vista, as at Versailles, is concentrated upon a single central building, the palace as something detached from the town. The Chinese conception was much grander and more complex, for in one composition there were hundreds of buildings, and the palace itself was only part of the larger organism of the whole city with its walls and avenues. Although so strongly axial, there was no single dominating centre or climax, but rather a series of architectural experiences. Hence the bathos of an anti-climax had no place in such designs. Even the Thai Ho Tien\(^1\) is not the climax, for the composition flows on northwards past it and behind it. The Chinese conception also shows more subtlety and variety; it invites a diffusion of interest. The whole length of an axis is not revealed at once, but rather a succession of vistas none of which is overpowering in scale. Sometimes, in the approach to the final objective, the visitor is brought back to ponder a stretch of the approach which has just been negotiated—as in the case of the imperial Ming tomb of Thai Tsu at Nanking.\(^c\) Thus the Chinese form of the great architectural ensemble, which attained its highest level already in the early 14th century with the Temple and Altar of Heaven in Peking (Fig. 755, pl.),\(^4\) combined a meditative humility attuned to Nature with a poetic grandeur to form organic patterns unsurpassed by any other culture.

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\(^1\) Chin Chhêng, 1282-1355, 13th-14th century architect, founder of the Yuan dynasty.  
\(^2\) The reader will be reminded of the ancient schematism which depicted the radiation of Chinese culture in the form of a series of concentric rectangles; cf. Fig. 20a in Vol. 3, p. 50a.  
\(^3\) The base of the main building is penetrated by a staircase in a barrel-vaulted tunnel, which brings the visitor to a terrace at the far side against the mountain, whence he returns round either end of the building up ramps or stairs to reach the top terrace which faces back along the main approach axis. Finally the main hall is entered through one of three arched openings. Similar arrangements exist, for example, at the tomb of the Yung-Lo emperor (Chhêng Tsu) north of Peking. Cf. p. 144 below.  
\(^5\) J. de Siren (3) likens it, with diagrams, to a zigzagur in one plane.  
\(^6\) As it did in one of the greatest of its adopted sons, Antoine Gaubil, in his description of the Temple of Peace, we may quote the excellent description of Murphy (cf. Fig. 754, pl.).  
\(^7\) Mr Andrew Boyd, in a private communication (cf. Boyd, 1) on which the first part of this paragraph is based. The second part draws upon the impressions of Mr Francis Skinner.  
\(^8\) A stream was led in at the north-west corner of the present city, and then expanded into a series of lakes (Pei Hai, Chung Hai, Nan Hai) forming, as it were, a parallel but sinuous western axis subsidiary to the main one which runs north-south through the centre of the Forbidden City, indeed through the imperial throne itself. All three lakes lie within the confines, formerly walled, of the Imperial City (Chhi Huang Chhêng), the next largest of the concentric rectangles which constitute the whole capital. The moat of the Forbidden City is supplied by a branch canal from the northern lake, and the moat in turn feeds the Stream of Aureate Water which is crossed (at no. 9 in Fig. 753) by the five marble bridges (Fig. 753, pl.) between the Meridian Gate (no. 8) and the Gate of Supreme Harmony (no. 10). Similarly the southern lake provides the ceremonial stream under the marble bridges which give access from the south to the grand entrance at the Thien An Mên. The water finally finds its way out at the south-east corner of the city. To give an idea of the grandeur of the view which lies before the visitor who passes northwards through the Gate of

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\(^1\) C. Hu Chia (1). Wu No-Sun (1) likes it, with diagrams, to a zigzagur in one plane.  
\(^2\) See Siren (3), and on the symbolism Ayscough (2). Air photographs in Mirams (1), opp. pp. 35, 38, 39.  
\(^3\) Mr Andrew Boyd, in a private communication (cf. Boyd, 1) on which the first part of this paragraph is based. The second part draws upon the impressions of Mr Francis Skinner.
Fig. 752. Plan of the capital city of Peking to show its axial pattern; north at the top (after Hu Chia, i).

28. BUILDING

Explanation of Fig. 752
1 South Gate, Gate of Everlasting Stability (Yung-Ting Mên) of the outer city (formerly called the 'Chinese' city)
2 Bridge of Heaven (Thien Chhiao) market, traditional centre of folk entertainments
3 Front Gate (Chhien Mên) of the inner city (formerly called the 'Tartar', i.e. Manchu, city)
4 China's Gate (Chung-Hua Mên)
5 Square of the Gate of Heavenly Peace, to which five marble bridges give access
6 Gate of Heavenly Peace (Thien-An Mên), entrance of the Imperial City (Chiu Huang Chhêng)
7 Gate of Correct Deportment (Tuan Mên)
8 Meridian Gate (Wu Mên), i.e. Noon Gate or South Gate, entrance of the Purple Forbidden City (T'au Ch'in Chhbêng)
9 The five marble bridges over the Stream of Aureate Water (Chin Shui Ho)
10 Gate of Supreme Harmony (Thai-Ho Mên); to the left the Gate of the Floribundant West, or Western Floriate Gate (Hsi-Hua Mên); to the right the Gate of the Floribundant East, or Eastern Floriate Gate (Tung-Hua Mên)
11 Hall of Supreme Harmony (Thai Ho Tien), the throne-hall, backed by the Hall of Central Harmony (Chung Ho Tien) and the Hall of the Preservation of Harmony (Pao Ho Tien)
12 Complex of inner palace apartments (Ku Kung), having the Hall of Reverence for Peace (Chhin An Tien) at their northern end, behind which the Gate of the Warlike Spirit (of the North, Shen-Wu Mên) terminates the enclosure. Now the Imperial Palace Museum
13 'Coal Hill' (Ching Shan) gardens and pavilions
14 Site of the Gate of Earthly Peace (Ti-An Mên)
15 Drum Tower (Ku Lou)
16 Bell Tower (Chung Lou)
17 Imperial Ancestral Temple (Thai Miao), now People's Palace of Culture (Lao-Tung Jen-Min Wên-Hua Kung)
18 Temple of the Altar of the Land and Grain (Shê Chi Thân), now Sun Yat-Sen Park (Chung-Shan Kung-Yuan)
19 Temenos of the Altar and Temple of Heaven (Thien Than)
20 Altar of Heaven, the Orbêd Concentric Platforms (Huan Chhiu Thai); cf. Vol. 3, p. 237
21 Hall of the Infinite Canopy of Heaven (Huang Chhiung Yu)
22 Hall of Prayer for the Year (Chhi Nien Tien), the blue-tiled circular edifice built in +1420 and rebuilt in +1550 and +1711, commonly called the Temple of Heaven
23 Gate of Veneration of Letters (Chhung-Wen Mên)
24 Road leading to the Imperial Observatory (Kuan Hsiang Thai) on the eastern wall of the inner city; cf. Vol. 3, p. 453 and passim
25 Northeast Gate, Gate of Peaceful Stability (An-Ting Mên) of the inner city
26 Temenos of the Altar and Temple of Agriculture (Hisen Nung Thân)
27 Gram Flour Factory Street (Liu-Li Chhang), famous centre of bookshops, art and antique shops
28 Gate of Peace and Harmony (Ho-Phing Mên)
29 Gate of the Proclamation of Military Might (Hsuan-Wu Mên), like gates 3, 23 and 28, between the inner and the outer cities
30 Southern Lake (Nan Hai)
31 Central Lake (Chung Hai)
32 The Round Fort (Thuan Chhêng), perhaps the throne-castle of Khubilai Khan; behind it, on the island to the north, the prominent White Stupa (Pai Tha) built in +1665
33 North Lake (Pei Hai)
34 Back Lake (Hou Hai) with the Front Lake (Chhien-Hai) to the south of it
35 Northwest Gate, Gate of Victorious Virtue (T'ê-Shêng Mên) of the inner city

N.B. The plan covers only a north-south strip sufficiently wide to include the two inner concentric rectangles of the capital city. The Purple Forbidden City (T'au Ch'in Chhbêng) is seen at the centre surrounded by its moat. Outside it and enclosing the string of lakes, south of the Gate of Earthly Peace (Thien-An Mên, no. 14) and north of the great east-west road in front of the Gate of Heavenly Peace (Thien-An Mên, no. 6) is the Imperial City (Chiu Huang Chhêng). It is substantially square save for the indentation of its south-western corner. Of the people's cities only parts of three east-west boundary walls can be seen, enclosing the so-called 'Tartar' (Manchu) city above the middle one, and the 'Chinese' city below it.
28. CIVIL ENGINEERING

(4) BUILDING SCIENCE IN CHINESE LITERATURE

Presumably owing to the fact that architectural employment was not considered a very suitable occupation for a Confucian scholar, Chinese literature is relatively poor in writings on the subject. However, the earliest dictionary, the Erh Ya, dating from the Chou and early Han times, has a special chapter devoted to matters connected with building (Shih Kung; Explanations Concerning Palaces and Halls). In this we find a good many technical terms which retained their meaning afterwards with little or no change. Later encyclopedias often have similar sections. In Chihing times a number of scholars made useful studies to elucidate the meaning of ancient architectural words and expressions.

The chief literary tradition which involved actual architectural plans was that of the San Li Thu (Illustrations of the Three Rituals). Two books of this name were composed in the Later Han period (+2nd century), one by Chêng Hsian, the famous commentator, the other by Yuan Shen, his contemporary. At some subsequent time they were probably combined under the editorship of Liang Chêng, and an important series of illustrations was added about +600 by Hsiahou Fu-Lang, whose authorship the book was ascribed in the Sui bibliography. Then in or around +770 a further revision was made by Chang I. All this work was afterwards lost, but not before some of it had been used by Nieh Chhung-I in the definitive text of +956, made down to us, having been re-edited for the last time in +1676 by the Manchu prince Nalan Chêng-Tê.

The reason why this material was preserved even as well as it was lay in the desire of scholars to interpret the rubrics in the ancient liturgical and ceremonial texts. Many books of the Sung and later simply illustrated these as their authors saw fit, without any traditional basis. The plans of architectural interest are found in ch. 4 of the San Li Thu, and include the Ming Thang (cosmic palace-temple).

Ching Chiin

There are also 'maps' of the schematic sites of the feudal lords (Chiu Fu, cf. Vol. 3, p. 502 above), the Ching Thien system (see pp. 256 ff. below), and the theoretical irrigation arrangement (Kou Hsü, discussed on pp. 4-254).

Reviews by Demieville (4), probably the best account, and Yets (10). See, e.g., the Miao Chih Thu Kuan, written about +615 by the famous scholar Wan Sau-Thung. The reader will remember the traditions associated with the name of the patron saint of artisans, Kungshu Phan (La Fan), described at some length in Vol. 4, pt. 2, pp. 43 ff. His effigy in Fig. 729, p. 15, suitably opens this story.

A modern interpretation of this kind of material will be found in Kelling & Schindler (1), p. 102, taken from Couvreur (3). A similar work was the Shih Kung Hsiao Chih (Brief Record of Buildings and Palace Halls), by Chih Ch'eng-Chun (HCCC, Hsi pien, ch. 525).

The ancient fragments contained in this have been assembled by Ma Kuo-Han, HYPF, ch. 28, pp. 444 ff. See, e.g., the Miss Chih Thu Kuan, written about +615 by the famous scholar Wan Sau-Thung. The reader will remember the traditions associated with the name of the patron saint of artisans, Kungshu Phan (La Fan), described at some length in Vol. 4, pt. 2, pp. 43 ff. His effigy in Fig. 729, p. 15, suitably opens this story.

It is interesting that etymologically 'architect' (chief of the workmen) is identical with its Buddhist name for an abbot. "Archimandrite" (director of the enclosure) parallels this.

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a marvel of art, but struck by lightning and destroyed about +1040. The fact that his book was not recorded in the official bibliography is significant as showing that building technique was regarded as too ‘mechanical’ for inclusion among scholarly works. There was probably also a social barrier, for Yu Hao was a Master-Carpenter (Tu Liao Chiang), while the man who built upon his work to produce the greatest architectural book in Chinese history was a ‘white-collar’ Assistant in the Directorate of Buildings and Construction (Chiang T’ao Chien Chhêng)³.

Shen Kuei, the great Sung scholar of scientific and technical interests, so well known to us, wrote about Yu Hao in a passage which is worth quoting in full. He said:

> Methods of building construction are described in the Timberwork Manual, which, some say, was written by Yu Hao.

(According to that book), buildings have three basic units of proportion (fen)⁴ what is above the cross-beams follows the Upperwork Unit, what is above the ground floor follows the Middlework Unit, and everything below that (platforms, foundations, paving, etc.) follows the Lowerwork Unit.

The length of the cross-beams will naturally govern the lengths of the uppermost cross-beams as well as the rafters, etc. Thus for a (main) cross-beam of 8 ft. length, an uppermost cross-beam of 33 ft. length will be needed. (The proportions are maintained) in larger and smaller halls. This (2:8) is the Upperwork Unit.

Similarly, the dimensions of the foundations must match the dimensions of the columns to be used, also those of the (side-) rafters, etc. For example, a column 11 ft. high will need a platform 48 ft. high. So also for all the other components, corbelled brackets (heng), projecting rafters (shih), other rafters (chhui), all have their fixed proportions. All these follow the Middlework Unit (2:11).

Now below of ramps (and steps) there are three kinds, steep, easy-going and intermediate. In palaces these gradients are based upon a unit derived from the imperial litters. Steep ramps (chhùn tao) are ramps for ascending which the leading and trailing bearers have to extend their arms fully down and up respectively (ratio 3:35). Easy-going ramps (sun tao)

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² Kuo T’ien Lu, ch. 1, pp. 1a ff.; Mu Ch’i (Things Silently Recorded) by Wang Chih (11th century), p. 482; MCPT, ch. 18, par. 15.
³ It is paradoxical (and perhaps significant) that from the brush of Li Ao ² (c. +775 to +844), one of the philosophical precursors of Neo-Confucianism (cf. Vol. 2, pp. 452, 494), there has come down to us a small tractate with a very similar title, the Wu Mu Chhêng. It is listed among various books on technical subjects about +1135 in Yü Chien, ch. 7, p. 46. But in fact it only concerns the game of dicing, and its title could be translated ‘Manual of the Five (Throws of the) Wooden (Dice)’. Nevertheless, Yu Hao was greatly admired by some of the outstanding scholars of the early Sung, such as Ouyang Hsiu.
⁵ Here equivalent to fen. Cf. p. 68 above.
⁶ It will have been obvious that the first two units of proportion are derived by simple division. The three now given for the ramps represent in the same way the relation between the heights above ground of the two ends of the emperor’s litter during its ascent. The proportions of the human body are taken from standard figures given in the Huang Ti Nei Ching Th’ii Su of +678 (ch. 13, p. 87.2) and the I Thiang Chhien Chhêng of +1742 (ch. 71, p. 14.4) as follows: trunk and legs 6:1 ft., upper arm 1:7 ft., lower arm 1:95 ft. Such data came from long before the Th’ang and changed little or not at all afterwards. To determine the absolute gradients it would be necessary to know the lengths of the standard litters, but we have not gone into this. It is interesting to find here yet again a modular unit based upon the proportions of the human body (cf. pp. 68, 69).
are those for which the leaders use elbow length and the trailers shoulder height (ratio 1:38); intermediate ones (phing tao) are negotiated by the leaders with downstratched arms and trailers at shoulder height (ratio 2:18). These are the Lowerwork Units.a

The book (of Yu Hao) had three chapters. But builders (tshu mu chhī kung) in recent years have become much more precise and skilful (ser stan) than formerly. Thus for some time past the old Timberwork Manual has fallen out of use. But (unfortunately) there is hardly anybody capable of writing a new one. To do that would be a masterpiece in itself!

This passage would have been written about +1060. Within twenty years the man capable of doing the job which Shen Kua saw as necessary had arisen and completed it. This was Li Chieh,4 and the title of his book was Ying Tso Fa Shih4 (Treatise on Architectural Methods).b

The date of Li Chieh’s birth is not sure, but he was already a subordinate official in the Bureau of Imperial Sacrifices when Shen Kua was about to produce his Mêng Chhi Pi Tham. Moving to the Directorate of Buildings and Construction in +1092, he must have shown immediate and outstanding promise as an architect, for his revision of the old treatises was commissioned in +1097, completed by +1100, and printed three years later. He was a distinguished practising builder as well as a writer, for he erected administrative offices, palace apartments, gates and gate-towers, and the ancestral temple of the Sung dynasty, as well as Buddhist temples. Li Chieh says in his preface that he studied long and minutely the practices and orally transmitted rules of the master-carpenters and other responsible artisans.c

It is of much interest that Li Chieh never quite succeeded in fusing the scholarly and the technical traditions. His method was to quote many ancient and medieval texts, with great reverence, in the earlier chapters, then to describe the practice of his time, and finally to enunciate rules (thiau), which are always based on practice and have little or nothing to do with the texts. Introductory sections (including a Khan Hiau),d are used to discuss meanings of old terms, and are followed by the Rules and Regulations (Chih Tu) which form the main body of the book. These deal systematically with one department after another, comprising:

- Completion of a job of upperwork and lowerwork is seen in Fig. 757.
- A more artisanal tradition is represented by a Japanese monk, Gikai, in +1259, and entitled Wu Shan Shih Chha Thu.15 But its technological detail is not very impressive. A more artisanal tradition is represented by a Ming book, Ying Tso Chhing Shih (Right Standards of Building Construction), evidently closely related to the Lu Pan Ching discussed in Vol. 4, pt. 2, pp. 44 ff.
- No work by another individual ever took the place of the Ying Tso Fa Shih, but subsequent dynasties issued more or less official technical compilations. In the Yuan there was a Yuan Nei Fu Kung Tshen Chh Ta (Regulations for (Construction) Work on Palaces and Public Buildings, authorised by the Imperial Directorate of Architecture), but it is lost. Similar material existed in the Ming, and in the +18th century there was a Chinh-Ying Kung Fu Kung Chheng Tso Fa (Official Manual of Woodcarving and other crafts)17

a His explanatory notes are printed in red. The willingness of Li Chieh himself to learn from experienced artisans and craftsmen is worth emphasising a little further. It had been a long tradition in Taesam, as witness the story of Pien the Wheelwright (Vol. 2, p. 132 above), and Liu Tsung-Yuan’s old gardener (Vol. 2, p. 577 above). In the Thang, Han Yu, though so Confucian a scholar, had written a famous essay on what he had learnt from the master Wang Chhing-Fu (Ku Whn Hii 1, ch. 12, pp. 89 ff. on the wheelwright).b Cf. des Rotours (1), pp. 105, 178. Cf. p. 311 (Fig. 18).c The last chapters deal with Job accounting (Kung hsien14); Materials (Lao li11), including some interesting paint compositions; and the Classification of crafts (Chu tso teng tu18).

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Constitutional Engineering drawn up by the Ministry of Works upon Imperial Order. A bulky MS. without title, but containing regulations for building and furnishing imperial palaces, which (from internal evidence) covers the dates +1727 to +1750, has been described by Hummel (20) and Malone (1). It deals largely with the Yuan Ming Yuan summer palace (started in +1709 and destroyed by foreign troops in 1860), but has more to do with the economics than the technique of building.6

A quite different tradition of literature which is relevant here is that of the descriptions which have come down to us, in prose or poetry, of cities, palaces and temples. From the Later Han period onwards haphazardical odes on the successive capitals became a distinct literary genre, and so it came about that when the great collection called the Wen Hsian (General Anthology of Prose and Verse) was brought together by a prince of the Liang in +530, the section entitled Ching Tu1 took pride of place in the opening chapters.6 A pair of odes on the western and the eastern capitals, Chhang-an (Sian) and Loyang (Hsi Tu Fu3 and Tung Tu Fu4), was written by the famous historian Pan Ku4 about +8756 and there followed soon afterwards (in +107) a second pair by the eminent astronomer and mathematician Chang Hêng5 (the Hsi Ching Fu5 and Tung Ching Fu8). Since the two capitals symbolised the ethos of the Former and the Later Han respectively these odes have attracted the close attention of modern historians of thought and culture (notably Hughes, 9) interested in their differentiation; but the poetical phraseology is notoriously difficult, the technical terms obscure, and the descriptions of buildings and layouts naturally somewhat vague. Still, a careful study by a historian of Chinese building technology would be well worth while. Chang Hêng also left a third ode, the Nan Tu Fu,7 on his birthplace, the ancient city of Wan9 (Nanyang10), long a centre of the iron and steel industry; this was written during a period of temporary retirement. In the following centuries the tradition continued and about +270 Tso Ssu11 produced a set of poetical descriptions of the capitals of the Three Kingdoms, Shu, Wu and Wei.8 Panegyrics of Han palaces also exist, for instance Wang Wen-Khao’s12 Lu Lung-Kuang Tien Fu,13 written about +140, an elaborate account, but more of the ornamentation than the building.5 The Ying Tsao Fu Shih quotes judiciously from these sources in its opening chapters. All in all they constitute a valuable quarry for architectural history not yet fully exploited.

The San Fu Huang Thu1 (Description of the Three Metropolises), attributed to Miao Chiang-Yen,4 may date from this time, but more probably from the +3rd century; it had originally drawings and charts, and is considered a fairly reliable source for details about the Later Han capital, Chhang-an.10 Then in the +6th century came the famous Lo-yang Chhieh-Lan Chi1 (Description of the Buddhist Temples and Monasteries at Loyang).5 In the Sung the city was still so beautiful that it merited another monograph, the Lo-yang Ming Yu’an Chi (Record of the Celebrated Gardens of Loyang), written by Li Ko-Fei14 about +1060. But the time was soon coming when the victories of barbarians would act as a powerful stimulus for the reminiscent description of cities and their buildings as they had been before the storms burst. Thus it was that the Tung Ching Ming Hua Lu6 (Dreams of the Glories of the Eastern Capital), dealing with Khaifeng, was written just twenty years after its fall. The pattern imposed by the Chin Tartars was repeated a century or two later by the Mongols, giving us at least four books about the Sung capital at Hangchow, among which we need mention here only the Tu Chhing Chi Sheng’7 (The Wonder of the Capital) of +1235, and the Ming Lung Lü6 (The Past seems a Dream) of +1275. Finally, we have descriptions of the palaces and public buildings of both Yuan and Ming. Hsiao Hsin’s book on the former, Ku Kung Lü,19 has already more than once been mentioned, and the same category might include the Yuan Shu Tzu Chi11 written about Peking by Shen Pang12 in +1593, and now newly republished from a lone copy preserved in Japan. Not long afterwards came the Ming Kung Shih13 of Liu Jo-Yü,14 written about +1620 and dealing with Peking also. It would certainly be possible to derive from these graphic accounts of the appearance and life of the great cities matter of interest both for architecture and town planning, but an exposition of it would require specific researches not yet complete, so that here we can do no more than call attention to the field.

A third great class of literature gives further opportunities of reconstructing the architecture and layouts of medieval Chinese cities and public buildings, namely the indefatigable researches of archaeologists and local antiquarians. Nearly every city
28. BUILDING

has its local gazetteer (feng chih), a work often in many successive recensions on the history and topography of the place, always including traditions of buildings and building plans. But most attention, of course, was given to the capitals. The line could begin with Wei Shu's Liang Ching Hsin Chi (New Records of the Two Capitals), written during the first half of the 8th century. Though only one chapter of this work has survived until now, it laid the foundation for the subsequent work of Sung Min-Chhu about 1075 entitled Chhchang-an Chih (History of the City of Eternal Peace). About the same time Liu Ching-Yang and Lü Ta-Fang were commissioned to make a historical map of the city, and this they did on a scale of 2 in. to the mile, identifying and marking the sites of ancient buildings. This Chhchang-an Thu Chhi was served in turn as the basis for more elaborate plans produced about 1130 by Li Hao-Wên, an imperial tutor, in his Chhchang-an Chih Thu (Maps to Illustrate the History of the City of Eternal Peace). Chinese traditional archaeology laboured on continuously into the modern period, as may be seen by the work of Hsi Sung in 1810 with the title Thang Liang Ching Chheng Fang Kha (Studies on the Districts in the Two Thang Capitals).

Recent studies have shown, however, that any reconstruction of ancient and medieval buildings in the light of textual evidence only is extremely difficult. For interpreting the texts correctly iconographic evidence, whenever it can be obtained, is indispensable. Fortunately we are not entirely without it. From the Warring States period, from the Han and Chin dynasties, there are carved vessels, moulded bricks and tomb models, all making a considerable contribution; presently (pp. 126 ff.) we shall be better off, for we have the iconographic wealth of the fresco paintings of the Tunhuang period, from the Han and Chin dynasties, there are carved vessels, moulded bricks and temple plans. There may be something in this, but we are still more reluctant to accept her view that the Thang Chiao Chien. Before the Sui, architectural officials were appointed only when there was need of palace or government buildings, at other times the posts were left vacant. Gradually changes of meaning occurred, and apparently in the Yuan period, the Chiang Tho Yuan was no longer a building department, but rather a part of the imperial workshops connected with the working of precious metals, and the weaving of valuable textiles. Here again we can see how useful a monograph on the general history of the imperial workshops would be.

A picture of one of these orchestras has already been given in Vol. 4, pt. 1, Figs. 313, 314. The work thus begun needs systematic extension. Only in this way will it be possible to assess some of Bulling's themes, for example that the accent on axiality is missing from pre-Thang and early Thang temple plans. There may be something in this, but we are still more reluctant to accept her view that the crowds in the paradise pictures represent living people vested to play the parts of Buddhas and Bodhisatvas at the periodic temple festivals.

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doen interesting designs, often including a peripheral cloister studded with small pavilion towers. As for the parades, the settings where Buddhhas and Bodhisatvas are assembled to witness sacred dances, acrobatics, the births of new souls from lotuses, and so on, to the accompaniment of orchestral music, invariably comprise halls, pavilions, galleries, forecourts, pools, platforms and bridges in elaborate ensembles. Here again everything can be translated into accurate ground-plan and precise elevation. We reproduce in Fig. 758 (p.l) a picture of the Western paradise of Amida, painted about 1000, from cave no. 127.

A further source of information about the position of architectural science in the different periods would be the titles and powers of officials concerned. The Chou Li, in its account of the Artisan-Carpenters and Engineers (chiang jen), says that they have to construct capital cities (ying huo) and buildings (ying shih). It includes some schematic information about the plan of a standard city, with its three gates on each side, nine transverse main streets, central palace, northern market, and so on. It also indicates that buildings were measured in 9-ft. mat-lengths (chiu chih chih yen), and street breadths in 6-ft. chariot-gauges. The Sung Sii Wu Chi Yuan tells us that in Chhin and Han there were officials called Chiang Tso (Directors of Workmen) but no special bureau. A Directorate of Buildings appeared in the Northern Chinn dynasty (+550 to +570) as the Chiang Tso Tso, and in the Sui and Thang it became the Chiang Tso Chien. Before the Sui, architectural officials were appointed only when there was need of palace or government buildings, at other times the posts were left vacant. Gradually changes of meaning occurred, and apparently in the Yuan period, the Chiang Tso Yuan was no longer a building department, but rather a part of the imperial workshops connected with the working of precious metals, and the weaving of valuable textiles. Here again we can see how useful a monograph on the general history of the imperial workshops would be.

* See the more extended discussion in Vol. 3, pp. 571 ff.
* We have met with Wei Shu already in Vol. 4, pt. 2, p. 471.
* Most of what survives of these maps and plans has been collected in Anon. (2).
* On Hsi Sung, vol. 3, p. 525. Besides the systematic scholarly works here mentioned, one must not forget the remarks on buildings in the desultory notes of Chinese writers of all ages—for example, in the Chheng Wu Chi (Notes on Life's Staples) written by Wu Chen-Heng about +1593.
* On this panorama see a special paper by Hibino Takeo (2).
* A picture of one of these orchestras has already been given in Vol. 4, pt. 1, Figs. 313, 314.
* The work thus begun needs systematic extension. Only in this way will it be possible to assess some of Bulling's themes, for example that the accent on axiality is missing from pre-Thang and early Thang temple plans. There may be something in this, but we are still more reluctant to accept her view that the crowds in the paradise pictures represent living people vested to play the parts of Buddhas and Bodhisatvas at the periodic temple festivals.
(5) PRINCIPLES OF CONSTRUCTION

In what has gone before we have been able to catch a glimpse of some of the essential principles of Chinese building, the use of walls as pure screens and partitions which carry no weight; the dependence on firm geometrical grids of pillars and beams, allowing great emphasis to be placed on the roof; the employment of raised platform foundations which balance the roof aesthetically; and the fact that buildings are nearly always meant to be approached from their sides rather than their ends. The moment has come to penetrate further into the matter. We shall find that certain obvious questions are capable of illuminating answers, while to others there is still no satisfactory solution.

Of this second class is the problem of basic materials. Why was it that the Chinese throughout their history systematically built in wood and tile, bamboo and plaster, never making use of the stone which in other civilisations such as Greece, India and Egypt left such durable monuments behind? I have often felt that if a full answer to this question could be obtained, it would throw light on many wider aspects of cultural difference. It certainly cannot be said that China had no stone suitable for great buildings analogous to those of Europe and Western Asia, but it was used only for tomb-construction, steles and monuments (in which typical woodwork details were frequently imitated), and for pavements of roads, courts and paths. Perhaps further knowledge of social and economic conditions might throw light on the matter, for the forms of slavery known in China in different ages seem never to have paralleled those occasional usages which could despatch thousands of human beings at a time to hard labour in the quarries. In Chinese civilisation there is absolutely no parallel to those large sculptured friezes of Assyria or Egypt which depict the harnessing of large numbers of workers in the transportation of enormous monoliths for carving or building. It might indeed seem that no rule could have been more absolute than that of a Chhin Shih Huang Ti, the builder of the first Great Wall, and of course there is no doubt that in ancient and medieval China very great labour forces could be mobilised by corvée, but what matters is the state of society in which the characteristic forms of

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1. For instance, there seems certainly to be some relation between aspiring monumentality in stone and the influences of mystical religion. But the Chinese mood was essentially secular, loving life and Nature. Hence the gods had to conform, to sit and be worshipped in buildings identical with the halls of families and palaces, or not to b. worshipped at all.
2. Cf. the frank imitation in stone of bundles of reeds so common in the Maya architecture of Yucatan.
3. Exceptionally also for forts and strongholds. A particularly interesting exception (noticed already on p. 69 above) was constituted by the fireproof warehouses (thu-lang) of the city of Hangchow, described in + 13th-century books. These caravanserais were stone towers like castle keeps surrounded by waterways. See the discussion of Mode (11), as also (§, 15).
5. Cf. the famous fresco at al-Bersheh showing the mode of transporting a colossal from the quarries, figured by Wilkinson (1) as the frontispiece to his second volume. Or Klebs (3), fig. 40, p. 61. Cf. too Vol. 4, pt. 2, pp. 74, 92.
7. In the discussion of Mode (11), as also (§, 15).
8. Cf. Sect. 30 in Vol. 5 below for another correlation between a profound cultural trait and the circumstances in which Chinese civilisation crystallised. An alternative way of putting the matter would be to relate it to the specific agricultural methods of China, so extravagant in man-power and time, and so dangerous for rulers if interfered with. Of course heavy building in stone does not always imply the use of slave labour; the Greek temples were built almost entirely by freemen.
10. See the discussion of Mode (11), as also (§, 15).
11. It is the wrong kind of answer. What we need to know first is how (i.e. by what constructional method) the Chinese roof succeeds in getting its curve. This can be appreciated by examining Figs. 733 and 706. The former gives a schematic cross-section of a hall, based upon the drawings in the Ying Tso Fa Shih.
12. The great supporting columns rest upon plinths which form part of the platform foundation, and they are fixed together by massive tie-beams at various heights above the floor. Above them rise in tiers the main cross-beams which carry the roof; these are upheld by many queen-posts arranged at suitable positions, with usually only one

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Chinese architecture were originally determined, and it may well be that some connection exists between the timberwork style and the absence of mass slavery. On quite another plane, the ancient symbolic-correlation philosophy was perhaps also involved, for if stone was regarded as belonging to the element earth it would have been proper for use only upon and under the ground, while wood was an element in itself, occupying a middle position between earth and the fiery ch'i of the heavens, hence the only fitting substance with which to build. Such a philosophy might have been but the expression of that genial sobriety and sensible dislike of extravagance so characteristic of Chinese culture. Why try to dominate posterity? One can create something, it is true," said Chi Wu-Fou, China's greatest writer on gardens (+ 1634), "which will last for a thousand years, but no one can tell who will be living after a hundred. Let it suffice to create a spot for pleasure and ease, which envelops the dwelling with harmonious stillness." Lastly, we must not lose sight of the fact that nearly the whole of China was, at one time or another, subject to earthquakes, so that experience may have shown the flexibility and elasticity of wood to be preferable to the unyielding but collapsible weight of stone. But all these notions are speculative, and the question remains.

Much more fruitful is that other question which so many foreigners in China must have asked themselves: what can be the nature and origin of the curving roof, that most characteristic and beautiful feature of Chinese buildings? The idea that it derives from an ancient desire to imitate the catenary curves of tents and mat-sheals has been a popular cliché of tourists for centuries. No one, however, has found any authority for this, either literary or archaeological. Besides, it is the wrong kind of answer. What we really need to know first is how (i.e. by what constructional method) the Chinese roof succeeds in getting its curve. This can be appreciated by examining Figs. 733 and 706. The former gives a schematic cross-section of a hall, based upon the drawings in the Ying Tso Fa Shih.

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central king-post at the top under the ridge-pole. Longitudinal beams or purlins are placed at any desired points towards the ends of these cross-beams, and to these purlins the rafters are fixed. A closely similar arrangement is used for aisles, galleries or verandahs, built in a lean-to manner. The fundamental unit is thus a 'two-dimensional' framework capable of endless variation and adaptability; this is known as the Method of Frame Construction (Ku chia chieh hou fa 1). Based on the platform of rammed earth (chu thu wei thai 2) it goes back in essence, as archaeological discoveries have shown, to the Shang dynasty (-2nd millennium). In ancient times only the cross-beams (chia liang 10) were used, but as time went on it was found that this placed

* An assembly of two cross-beams, being decorated before put into position, is shown in SCTS, ch. 31, p. 70.
* Various cross-sections noted by Spencer (1) are shown in Fig. 266 f-n.
* Liang Ssu-Ch'ing (J). See further on p. 122 below.

19.7. The sketch is purely schematic and takes no account of the sizes and strengths of the various component timbers. The proportions of the building as shown in the diagram are rather inelegant, but have been chosen for convenience of demonstration on the page of a book. At the same time it is true that Chinese monumental buildings always tended to be much larger in length than in depth, and the cross-section here depicted is not unlike that of the famous hall of the Hōryū-ji temple in Japan, built in 670.

Fig. 759. Timberwork construction of a Hall (schematised from Ying Tao Fu Shih, ch. 30, pp. 8a ff.).

Key:

- a platform chu, 1 chieh chi 2 (with balustrade hou lam 3)
- b stone plinths for the wooden columns chu chu
- c principal columns chu, 1 ying chu, 6 chin chu
- d principal columns supporting eave supports
- e short external principal column supporting saddle supports kiao yen chu 11
- f main tie-beams tai ying 12 ('forehead beam')
- g other tie-beams fang 13
- h lowest main tie-beam houa houng fang 14
- i ridge-pole (uppermost purlin) chi houng 15
- j ridge-pole (middle purlin) fang houng 15
- k ridge-pole (lowest purlin) thu houng 15
- l ridge-pole (main beam stands)
- m upper outer queen-posts (or blocks) thu tou 16
- n lowest outer queen-post thu chu 17
- o flat boards for coffer ceiling ping pao fang 18
- p purlins houng 15, lin, 16 lin chiao tou 17
- q false purlins fang houng 15
- r kua bu 18 (false cantilever principal rafters (see on, p. 95)
- s kua bu 18 (can be purlins in general)
- t false tie-beams fang 13
- u lowest corbel bracket unit thu chiao tou houng 19
- v corbel bracket units (both parallel with, and at right angles to, the beams) tou houng 19
- w canterlever principal rafters (see on, p. 95)
- x king-post chu ju chu 18
- y false corbel bracket units (only in Sung and Pre-Sung buildings)
- z king-post chu ju chu 18
- a inverted V-brace supporting the king-post tou houng 19
- b side braces connecting either cross-beam with cross-beam or cross-beam with purlin (only in Sung and Pre-Sung buildings) chu shou, 20 chu shiao 20
- c canterlever principal rafters (see on, p. 95)
- d main beam stands
- e king-post chu ju chu 18
- f false tie-beams fang 13
- g false purlins fang houng 15
excessive tension at the junction between columns and beams, failures tending to occur there. The improvement was therefore introduced of inserting a number of corbel brackets (tou hung)\(^1\) between the top of the column and the cross-beam. The tou was so called because it was a block of wood resembling a capacity-measure (tou\(^2\)) in shape, and the hung or bow-piece was the double elbow-shaped arm supporting one of these on each side. Corbel brackets successively longer were then piled on top of one another at the capital of the column, so as to form what were essentially corbelled arches of wood supporting the cross-beams. The tou hung branched forth not in one direction only but in both, i.e. as well parallel as transverse to the long axis of the building, thus supporting both longitudinal and crosswise beams (see Figs. 760a, b and 761, pl.). The original name for them was lu\(^3\) or lian,\(^4\) words which afterwards came to be applied occasionally to the king-post.\(^5\) The Ying Tao Fa Shih has many illustrations of them (Fig. 762), showing how they were fitted with tenons and mortises (shun mao\(^1\)), pegs and dowels (kan,\(^5\) chhiuan\(^7\)) (Fig. 763). Sometimes they are hidden by panelling.

The typical arrangement of roof and subsidiary roof for an aisle or verandah is shown in Fig. 760 (c), but during the Tang and before, it was usual to support the eaves with their rafters and flying rafters by means of purlins on brackets (Fig. 760a). There then developed another system, that of placing eave purlins upon 'cantilever principal rafters' or 'lever arms' (ang), Fig. 764 (pl.), fixed to the interior framework and piercing the bracket-arm clusters in a direction approximately parallel with the slope of the roof above (Figs. 760e and 765).\(^6\) This system died out during the Yuan period,\(^7\) but

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\(^{1}\) It may be noted that in the Chun Li, ch. 11, p. 230 a, the word lian is applied to the sharply curving ends of bells of oval cross-section—we do not know which usage was the older. Cf. Vol. 4, pt. 1, p. 196.

\(^{2}\) Most eavestrough buildings of the +7th century onwards have them, both in China and Japan (cf. pp. 100, 109, 135). For other drawings see Mairans (1), opp. p. 58.

\(^{3}\) This is true only of China; in Japan the ang has lived on down to our own time. On a visit to both countries in 1954 I was able to compare and photograph successively temple roof construction at close quarters. In China I was impressed by the prominence of the cantilever principal rafters, first in the +9th-century woodwork of Fo-Kuang Ssu\(^8\) (cf. p. 130) then in half a dozen temple halls dating from between +1030 and +1180 (Shan-Hua Ssu\(^8\) and the two Hua-Yen Ssu\(^8\) at Ta-thung, Chin Tzhu\(^8\) near Bai-yuan, all in Shansi, the Hsin Miao Kuan\(^8\) at Suchou (Chiangsu), minutely described by Liu Tun-Chen\(^8\), and Chih-Thai Ssu\(^8\) near Peking. No trace of ang is left, of course, in any of the monumental Ming or Ch'ing buildings in Peking or elsewhere. Then in Japan I admired the expected ang in the +9th-century Honjyoji\(^8\) buildings near Nara, as also those in the exquisitely beautiful Byodoin\(^8\) beside its little lake at Uji (+17th century). But they could still be seen in full employment in the gatehouse of the Engakuji\(^8\) at Kamakura, not earlier than +14th or +15th century, and before long I found them in double rows in the main halls of the Shinyo-do\(^8\) and Hysukumon of Chionji\(^8\) temples at Kyoto, rebuilt in the +18th or even the +19th century. Finally, by the kindness of the Rev. Yamasaki Teruo, I was able to inspect the gallery and interior of the gatehouse of the Komyoji\(^8\) temple at Kamakura, rebuilt in the early 19th century, and to see how the upper of the two rows of ang still retained its original structural function while the lower was 'false' and purely decorative. A consistent difference between the ang of the two cultures is that in China they end prismatically while in Japan they are cut off at right angles and the flat surface painted in contrasting colour. I owe much gratitude to my friend Dr Nakayama Shigeru for his kindness in helping our studies in Japan.

\(^{4}\) For other drawings see Mirams (1), opp. p. 58.

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Fig. 760. Diagrams to elucidate Chinese and Western building construction (explanations in text).

a The principle of corbel brackets (tou hung)
b A more complex example
c Typical arrangement of roof and subsidiary aisle roof in a Chinese building. No principal rafters; longitudinal purlins supported on the transverse frameworks in any desired profile
d Eave rafters and flying rafters on bracket-supported purlins
e Eave purlins supported from the ends of cantilever principal rafters or lever arms (ang)
f Characteristic structure of a Chinese building
g Characteristic structure of a European building
h Corbelled half-arches of an English hammer-beam roof
i Inverted V-braces of early medieval Chinese buildings (see tou hung)
j, k, l, m, n Typical Chinese transverse frames of columns (chu), tie-beams (fang) and cross-beams (long)
o, p Comparison of the fundamental Chinese building design with that of Greek and Gothic building (see pp. 62, 65, 102). Normally the Greek gable covered the perimetral colonnade.

'Forked hand' struts forming a trapesoidal truss (see p. 101).
left permanent traces in the form of 'birds'-beak' ends on the corbel brackets (as indicated in Fig. 759e); these may be called 'false cantilever principal rafters'.\(^a\) In most regions it was customary to raise up the four corners of the roof above the main roof edge line (cf. p. 128 and Fig. 766, pl.), and in the south the roof ridge itself was sometimes made to rise towards each end of the building in a graceful curve (chhui chi; shou chi).\(^b\) Main roofs may be either hipped or gabled, but in important buildings the gables seldom reach down to the eaves; they are cut at half their height or less, the slant of the roof continuing below and around them.\(^c\) This combination, as one of the pundits has justly remarked, is most imposing and harmonious.\(^d\)

Whatever the details of the roof-supporting system might be, it is important to bear in mind that the skeleton of the building as a whole stood up of itself, needing neither base, walls nor roof. The two-dimensional trabeate frames with their cross-beams and tie-beams were connected longitudinally by tie-beams below as well as other tie-beams\(^e\) and purlins above, so that a three-dimensional continuum almost like a cubical crystal lattice came into being. As we shall see (p. 103), this was the veritable ancestor (collateral if not direct) of the steel-frame lattice of modern building technology. Far different was it from the solid casing walls of ancient and medieval Europe.\(^f\)

We are now in a position to understand another radical difference between Chinese and occidental architecture. The curved roof and all that that implies was impossible in the West because the West was wedded to straight and rigid sloping principal rafters, that is to say, a transverse slanting element; while in China, on the contrary, the most important element was the longitudinal purlin, groups of which could be assembled according to any profile desired, by adjusting the framework itself.\(^g\) Some of the European principal rafters, of course, actually formed sides of the triangular roof-trusses, which, though they have their internal king-posts and queen-posts, present

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\(^a\) Cf. Siren (3); Mirams (1), opp. pp. 59; Sickman & Soper (1), p. 265.
\(^b\) Cf. Mirams (1), opp. pp. 85, 74.
\(^c\) The technical terms for the various types of roofs are given in Anon. (37), p. 6, simplified in Hsi Ching-Chih (1), pp. 38, 220. The roof of a building with plain gables is called 'hard-edged' (ying shou), one where the purlins project to give 'eaves' 5 to 8 rafters deep is called 'hanging' (hsieh shan). A hipped roof covers a 'verandah hall' (wu tien), and a hipped gable roof, as here described, is called 'curtailed' (bitou shou). The pyramidal roof of a square pavilion is called shou chi chien. All these have one tier of eaves (tai yen), but often a second tier is added below a short clerestory; this is called chhui yen.\(^h\)
\(^d\) Siren (1), vol. 4, p. 22.
\(^e\) Named pheng shou,\(^i\) and the highest under the ridge-pole chi shou\(^j\) (cf. Liu Chih-Phing (1), fig. 219).
\(^f\) Cf. Siren (3); Mirams (1), opp. pp. 85, 74; Sickman & Soper (1), p. 265.
\(^g\) To some extent the European medieval 'half-timber' building (cf. Briggs (2), pp. 131 ff.; Davey (1), pp. 40 ff.) was a structure inherently stable, even when the upper storeys overhung, as they often did. But the individual timbers employed were always so small relative to the whole building that there was no possibility of any wide openings, and the walls were still weight-bearing, with the disadvantage of being half composed of inflammable material.
\(^h\) This is well seen in the roof assembly for a small gate-house which I photographed at Chhien-fong in 1958 (Fig. 767, pl.). The single cross-beam carries a ridge-pole and four purlins by means of king- and queen-posts of different lengths. Fig. 768 (pl.) shows the skeleton of a larger construction, the framework of a new commune headquarters, at Ho-thang near Lo-phing in north-eastern Chiangsi. The columns, tie-beams, king- and queen-posts, and posts for the purlins are clearly seen (1964).

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\(^3\) 裳 衣 \(^4\) 營 衣 \(^5\) 極 衣 \(^6\) 釘 衣 \(^7\) 裳 衣
\(^8\) 營 衣 \(^9\) 極 衣 \(^10\) 釘 衣 \(^11\) 裳 衣

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**Fig. 762. Diagram of three corbel bracket assemblies, from a cross-section of a hall (Ying Tao Fa Shih, ch. 31, p. 44). The curving profile of purlins and the consequent curve of the roof line is well seen. Lever arms (àng) are present (see pp. 95, 99).**
only a superficial similarity with the Chinese transverse frame (Fig. 760f, g). The corbelled half-arches of English hammer-beam roofs (Fig. 760 h) were to some extent analogous with the tou-kung construction of China, but in no way liberated the West from its dependence on the sloping principal rafter. So long as that dominated, the purlins could never be in any relation other than that of a straight line, and therefore the common rafters which they carried were also necessarily straight, and often single. In China, on the other hand, the common rafters, though individually straight, were multiple, ending at every third or every fourth purlin if not more often, and thus permitting the tiles to descend in a smooth curve. Curiously, when the European roof did take on a curve, it was convex, not concave, as in the Mansard roof, where the queen-posts of the trusses are placed very much towards the sides of the building. It will be seen that the Chinese roof never had any principal rafters at all. The most obvious analogues were the cantilever 'principals' already referred to (Fig. 760 e), but these, though lying indeed under the purlins, served only as a support for the purlins of the eaves, which could take their due place in the curve of the cross-section. The cantilevers never dominated the cross-section and indeed died out after a time, leaving only the downward-pointing beaks of some of the corbel brackets as a kind of vestigial organ. In the Ming and Chhing periods even the brackets themselves tended to become more and more ornamental, their functions being less necessary because of a greater use of horizontal joists projecting from the pillars and a much increased size and strength of the main beams. Originally only in clusters over the columns, they ended by forming a kind of decorative frieze all along the outer beams under the eaves.

What was the origin of the 'cantilever principal rafters' or 'lever arms' (ang), constituting as they did a seemingly intrusive triangular element amidst the stalwart rectitude (Fig. 760j-n) of the characteristic Chinese transverse frames? To answer this one has to go back into history. In ancient times Chinese building technique had made considerable use of double slanting joists meeting at a point like the European roof-truss (cf. Fig. 760 j). But these inverted V-braces (jen tou hung 1 or chia shou 2) had at first little constructional importance; they were used mainly as an ornamental device between the longitudinal tie-beams, diversifying the appearance of the building as seen from the front. They must have been in use as early as the +1st century.

1 See here the excellent monograph of Hodge (1) on Greek roofs, and also particular papers, e.g. (2). Before about -460 the Greeks sometimes dispensed with principal rafters over certain parts of their temples (as in the Megaron at Gaggera), laying purlins directly from transverse wall to wall, but they never departed from the straight line laid down by the triangular roof-trusses over the cella. Sometimes also the tiles were laid directly on the purlins.

2 There were various ratio methods of plotting this, e.g. the chia chou 3 system in the Sung and the chia che 4 system in the Chhing.

3 Convex roofs for a Yang culture and concave ones for a Yin one? But see also p. 249 below.

4 There is argument about the first appearance of this member. The word certainly appears in the Ching Fu Tien Fu (mid + 3rd century), but some commentators gave it a different meaning. Li Chieh in the YTFS accepted it here in the normal sense, however (cf. Soper (4), pp. 99 ff.).
Fig. 765. Bracket-arm clusters containing ang canaliavers; drawings from the Ying Tsao Fu Shih (ch. 30, p. 6a).

because the Shih Ming dictionary defines them under the name hsieh chu (slanting struts). They appear not infrequently in Northern Wei buildings as depicted in the Yuan-kang cave-temples (dating between +450 and +535). In a famous design of about +650 (or +700) on a lintel of the Ta Yen Tha (Great Wild Goose Pagoda) at Sian. Other examples of similar dates occur in Korean tombs and cave-temples as well as in China. There was one employment, however, in which these inverted V-braces made a significant contribution to structural stability, for sometime they were used between the uppermost cross-beam and the ridge-pole instead of a king-post. One can see this still today in the +7th-century cloister galleries at the Horyuji temple in Japan, and (as part of a much more complex roof construction) in the +9th-century Po-Kuang Saih hall on Wu-thai Shan (Fig. 769, pl.). The curve of the roof was of course quite unaffected by the subjacent triangle. This system is extremely rare, if not unique, in Chinese buildings still extant, for by the end of the Thang period the king-post had universally superseded it. Nevertheless this did not mean that the chha shou (forked hand struts) disappeared entirely; they continued to exist for some time as strengthening elements for the king-post. Not only that, but they could be repeated at each end of the lower cross-beams, connecting sometimes beam with beam, sometimes beam with purlin, and forming thus a true kind of trapezoidal truss (Fig. 760); but because of their multiple character never in any way dictating the profile of the roof curve, which continued to depend solely on the layout of beams and purlins. One can...
now see how easily the idea of the ang or 'cantilever principal rafters' could have arisen; they were nothing but an extension of the principle of the chha shou or 'forked hand' struts to solve the problem of the widely overhanging eaves.

It may well be that the curving roof is ultimately referable to the fact that from the most ancient times the 'front' of a Chinese building was the longer side, instead of (as in Egypt, Greece, and medieval Europe) the shorter one (cf. Fig. 7600 and p). It was therefore natural enough to use complicated transverse framework partitions, since they would not spoil the perspective. They would be seen, if at all, end on. On the other hand, if the perspective had to be through the longitudinal axis of a building, roofing was necessary, whether of beams or trusses, which would leave that axis free. The desire for a vista found its ultimate expression in the Gothic vault. The natural tendency was to have rafters springing straight from the top of the side-wall to the ridge-post, following the geometrical pattern set by the end-wall or gable. The importance of end-walls in Western architecture is of course obvious; one has only to think of the pediment of the Greek temple and the west front of the Gothic cathedral. Even when European buildings were meant to be approached towards their longer sides, a pediment and columns were felt to be necessary as in the Palladian villa, or dormer windows in Dutch and Danish town houses, recalling pediments. On the other hand, the Chinese building, with no longitudinal vista, could fashion its transverse networks of wooden beams, and their upper contours, at will.

Whatever we may now think about the 'tent-theory', it is clear that the upturned roof-edge in China had the practical effect of admitting the maximum amount of slanting winter sunlight and the minimum amount of downpouring summer sunlight. It also reduced the height of the roof while keeping a steep pitch for the upper part and a wide span at the eaves; and thus it reduced the lateral wind-pressure. This property must have been very important in reducing movements about the bases of the columns which simply rested on their stone plinths and were not generally taken into the ground. Another practical effect of the curving concave roof may have been the shooting off of snow and rain-water well off the eaves into the courtyard away from the edge of the platform. But of course it must always have given the greatest aesthetic satisfaction, and Lamplrey was probably not far wrong in his suggestion that it was the

a The process can be traced in the sketches of Liu Chi-hsüeh (1), figs. 315, 316. The relation between the chha shou and the ang can be appreciated from diagrams such as those in Ying Tsao Fu Shih, ch. 30 spp. (pp. 216, 219, 220, 221). Cf. Liang Ssu-Chheng (3), pl. 4.

b Attention may be drawn here to a striking parallel between Chinese building construction and Chinese naval architecture. Just as the house or hall depends upon a series of transverse frameworks supporting the roof, so the junk or ship depends upon a series of transverse bulkheads, there being neither keel, stempost nor stempost. This will be explained in detail below, pp. 390 ff.

c Cf. Rasmussen (1), p. 73.


e Cf. Siren (1), vol. 4, p. 19: 'The marked development of the roof on Chinese halls is due to the fact that the entrance is not placed at one of the gable ends but in the middle of the south façade, the importance of which is brought out, not only by the gallery or open porch of free-standing pillars, but also by the wide sweep of the roof.'

f One of the problems of medieval European builders was how to prevent the drip of water from the roofs, which injured the foundations (Briggs (2), p. 210). Hence the proliferation of parapet-gutters, spouts, gargoyles, etc. print of a particular taste and genius upon a structure intrinsically capable of responding.

While examining the foregoing diagrams it has been repeatedly seen that no part of the weight of the roof or structural beams was taken in China by the walls. They are but membranes clothing a well-shaped structure of bone. Complete freedom was thus permitted for placing of doors and windows, and, for their construction in delicate woodwork and lattice. A building could be remodelled without any danger of collapse, and all openings in walls could be as large as desired; indeed in the hot climate of the south, one whole side of the hall could be, and often was, left open. Liang Ssu-Chheng (3) and others have drawn attention to the fact that this style of building followed exactly the same principles as those of modern steel and concrete construction; the skeletal framework is the essential thing, and the walls with their openings simply clothe it. Medieval European buildings, with their buttresses and flying buttresses, showed a tendency towards the same solution. It remains to be demonstrated, however, that Chinese building methods had any direct influence on the European escape from bondage to weight-bearing walls. This was perhaps more probably a slow intrinsic development, occurring first because of the resolve to build ever higher with ever greater daylight illumination of the interior (as in King's College Chapel and other buildings of the Perpendicular style); and then in a later phase for the availability of metallic building materials with which fireproof construction could be attained.

d deficit of iron columns and beams goes much further back historically than is generally thought; we shall see some unexpected examples in Chinese bridges (p. 151). Later on (in Sect. 200), we shall read of a hall built at Canton about + 050 on twelve pillars of cast iron each 12 ft. long. Iron tie-bars were used fairly frequently to secure lime and Renaissance vaulting. Cast-iron beams were then employed as furnace lintels in + 17th-century England, and the strengthening of monumental buildings by inserted wrought-iron armature systems ('reinforced masonry') was carried out extensively in France from + 1667 onwards. Enormous wrought-iron roof-trusses were installed in certain French buildings just before the Revolution. But the real break-
forming the first multi-storey iron-frame building. Here lateral stability was still provided by massive external walls, and it took forty years before portal bracing could be achieved so that a three-dimensional iron lattice would stand up of itself—as the comparable wooden lattices of China had done for so long. This was the period of the Crystal Palace and the Sheerness Boat Store. Cast iron, wrought iron and steel were all used in the first buildings of ‘skyscraper’ type, such as the ten-storey Home Insurance Building put up in Chicago in 1884, but the complete steel skeleton followed very soon afterwards. One effect of these developments was to make it possible to replace the walls of buildings almost wholly by transparent sheets of glass. The rebuilt cathedral at Coventry shows today how dramatic the result can be. But probably very few of the architects and engineers who participated in this great movement realised that a definitive escape from weight-bearing walls had already been accomplished by their Chinese predecessors during the previous two or three years.

(i) Drawings, models and calculations

Any history of Chinese building technology, however brief, should devote some attention to the records which exist of the preparatory work carried out by the builders and architects of old. Here we can give only a few examples from the surviving literary and graphic material.

The + 5th-century Shih Shuo Hsin Yu, speaking of a complex of buildings erected by the emperor Wen of the Wei State (+ 220 to + 226), says:  

The Ling Yün Thai had towers and temples most elaborately and ingeniously built. All the pieces of timber were first weighed, so that there was a perfect balance (between the sides of the buildings). This was why the high buildings showed no sign of leaning over or collapsing, though some of the storeys were quite lofty, and often shook and vibrated in strong winds. The emperor Ming (+ 227 to + 239), on mounting some of the towers, was alarmed at (what he thought was) a dangerous situation, so he caused one of them to be supported by an additional large column. (Some time after this was done) the tower collapsed and was destroyed. People talking about this result said that it was due to getting the weight unbalanced (ching chung li phien ka yeh).

The commentary of Liang date adds further details about these buildings from the Lo-yang Kung Tien Pu (Notebook on the Halls and Palaces of Loyang), since lost. The story gives a glimpse of the preparatory experiments of the early builders, spolt, not for the first or last time in history, by the interference of highly placed laymen.  

Pilot projects were also used to evaluate costs. About + 1137 the Neo-Confucian philosopher, Huang Kan, found himself charged with rebuilding the walls of An-ching, a city of which he was governor; so he began by constructing a trial length which enabled a fair estimate to be made of the expense in man-power and materials. After that he pushed on the work with all speed, and it was successfully completed before the Jurchen Chin armies could attack the city. Similar methods must have been used in hydraulic engineering works (cf. p. 333 below).

In the Liu Chiao period drawings and models also appear. About + 491 (according to the Nam Shih).

Tahui Yuan-Tsu said to the emperor that his nephew Tahui Shao-Yu was coming to the capital, and that he was exceptionally skilled in coloured architectural drawings (fan chiu). Tahui suggested that the emperor should order him to make a model (mu) of (new?) palace buildings, and retain him. But the emperor did not feel able to follow this suggestion, and so, after making painted diagrams of the palaces, Tahui Shao-Yu went home.

One would give a good deal to have these late + 5th-century drawings and models now, so that we could see how much progress had been made beyond the simple designs seen in the tomb-models of the Warring States and Han periods (cf. Figs. 783, 784, 786, pl.). Miniaturisation was evidently coming into use. Models are often heard of in the Sung. For example:

Certain workers made for Sun Chheng-Yu (a + 10th-century general) a small model of Li Shao (mountain), complete with streams, bridges, houses, pavilions and paths, made of a kind of cake mixed with camphor. Subsequently a model in wax was made.

This would have been one of those landscape designs, such as must have been prepared for the summer palaces which we can visit today. The same source tells also of a maker of architectural models (yang) who prepared one of some kind of grotto-pavilions for Kuo Tshung-I about the same time.

It was just at this period that miniature buildings were greatly employed as a sort of interior decoration. When the Japanese monk Jojin visited the capital Khaifeng in + 1072 he noted that the great hall of the chief abbey of the Chian school there had a...
ceiling that was 'all set out with (model) treasure-halls'. Libraries especially were treated in this way, the bookcases being crowned with whole temples
in piccolo. We can gain an excellent idea of what Jöujin saw because there still exists at Ta-thung in the north a splendid library at the Lower Hua-Yen Saü temple built under the Liao in +1038. Round the ends and the back wall of a building 85 ft. long run two double-storeyed roofed wall-cupboards for the stūras, diversified with higher pavilions and connected together over a central doorway with a magnificent model pavilion on a flying bridge of cantilever type (Fig. 771, pl.).

Beautifully modelled buildings have also often been used as reliquaries.

In the +17th century Chiang Shao-Shu wrote an interesting note on men who had specialised in drawings and paintings of architecture. Though these were not plans, they doubtless helped clients and builders alike. The style was called 'sharp-edge painting' (chieh hua), distinguishing it from that of the vaguer forms of misty landscapes.

The painting of palaces and houses is a very difficult thing. It requires great precision to be satisfactory. General Li was widely acknowledged as a great expert in this, but people do not know that there have been many others. In the Thang there was Yin-Chh-choo; Hu I and Wei Hsien worked in the Wu Tai period. There was no one to equal them. Later on, Kuo Shu-Hsien had an outstanding personality; though fully acquainted with the use of the compass, carpenter's square, water-level and plum-line, he was in no wise embarrassed by these instruments. Once he saw his Pi Shu Kung Thu (Drawing of the Summer Palace); there were hundreds of (eave-rafters) and chihti (rafters), yet none was missing from the drawing. Another expert, Wang Ku-Yün, flourished in the late defeated (Ming) dynasty; he also was successful, but not as good as Kuo. The masterpieces of the latter were the Hsien Shan Lou Ko Thu (Towers and Halls of the Mountain of the Immortals), and Tsun Yang Ching Tu Thu (Sailing Races at the Fifth Month Festival). The compositions of these paintings are very elegant, and every stroke is refined, fitting its place exactly....

The commentary adds that artists who wished to succeed in this specialty usually became skilled also in building calculations (mu ching tsuan fa). The paintings of Kuo and Wang were apparently devoted entirely to architectural constructions and details, without any extraneous figures or landscape. The importance attributed in China to drawings of buildings may be seen by the fact that this class of picture was one of the ten divisions of the catalogue of all the drawings and paintings in the collection of the emperor Hui Tsung, c. +1120 (Hsien-Ho Huu Phu). What kind of perspective was used in Chinese architectural paintings will engage us presently.

Of Chinese city-maps and plans we have already spoken in various connections, but this is perhaps the place to reproduce the most famous, that of Suchow (Fig. 772, pl.), carved on stone in +1229 and still preserved there. Also of the Sung, but rather earlier (+10th or +11th century), are the plans of the Thang palaces still to be seen engraved on stone in the Pei Lin Museum at Sian. When the sites of the Hsin-Chhing Kung and Ta-Ming Kung palaces in that city were being excavated in 1934, specialists found on the palace plans (thu shih) were found, with the positions and elevations of buildings on them clearly drawn to scale with ruled lines. As these certainly derive from Thang originals they are quite comparable with the oldest European architectural plan, that of the Abbey of St Gall, made with red ink on parchment about +820 and still treasured in the Stiftsbibliothek at St Gallen in Switzerland. Still more venerable is the plan of the Todaji temple at Nara in Japan, drawn on hemp cloth and dated +756. The dating of architectural drawings and models has much comparative interest, because Salzman (1) and other historians have drawn attention to their singular absence in early times in Europe. Few if any architectural drawings have reached us from before the time of Villard de Honnecontre (+1240), and Salzman finds no model before +1390.

This is why the Ying Tsao Fa Shih of +1103 is such a landmark. The excellence of its constructional drawings raises an issue of some importance. Nothing so far mentioned in this discussion constitutes (or could have constituted) what we would now call 'working drawings'. But the shapes of the component parts of the frameworks are so clearly delineated by Li Chhieh's drawing-office clerks (cf. Figs. 773, 774) that we can at last almost speak of working drawings in a modern sense—perhaps for the first time in any civilization. Engineers of our own time are often inclined to wonder why

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8 This was the period of activity of another celebrated architectural painter, Chao Po-Chhit ( whence Tronsdale (1) has written. He translates an amusing passage from the Thu Huu Chien Wch Chhih (Observations on Drawing and Painting) written by Kuo Jo-Hsiu (+904 to +974) which describes the daunting technological expertise necessary for success in this field. From +1180 we have the Japanese scroll-painting Shugian Engi Etsuki, the architectural drawing and perspective in which has been discussed at length by Arbruster (1).

9 Pf. 63, 80, 87, 88 above, and Vol. 3, p. 547.

10 See Chavannes (8); Moule (15), pp. 51 ff.; Chhien Yung (1); Liu Tun-Chhin (5), and Vol. 5, pp. 728, 551. It was made by Liu Yen, Chang Yün-Chhih (10) and Chang Yün-Ti (11). Moule also demonstrates the extraordinary accuracy of the city-maps of Hangchow, which date from at least +1274 (p. 13). I had the pleasure of studying the original stele of the Suchow map at the old Confucian College there (now a Middle School), with Dr Dorothy Needham and Dr Lu Gwei-Djen in 1954.


12 The illustrations were probably much better originally than they are now, for some of the details cannot be correct, and it is reasonable to attribute this to the work of the Chhing copyist, who was not in the trade. The awaited studies of Dr Else Glahn will, we are sure, throw more light on this.

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the technical drawings of ancient and medieval times were so extremely bad. A What
remains from the Hellenistic world is so distorted as to need much interpretation, b and
the machine drawing of the Arabs is notoriously obscure. The builders of the medieval

Sociological reasons probably had an important part to play in this. We have touched already
(p. 8a above, and Vol. 4, pt. 2, pp. 1, 2, 37) upon certain relevant factors in the Chinese situation.

Consider, for example, Drachmann (7, 9).

European cathedrals were no better draughtsmen, and the +15th-century Germans,
even Leonardo himself, produced little that was clearer than sketches, brilliant though
these sometimes were. If then there was no Western parallel to the Ying Tsao Fa Shih

There are two standard histories of technical drawing for the West, that of Feldhaus (5a) and that of
Neduloha (1); the former concentrating on instruments and materials more than the latter, but both
mainly occupied with post-Renaissance developments. See further Heymann (1); Booker (1).
we must face the fact that Euclidean geometry (which Europe had and the Chinese did not), vital though it must have been for the development of Renaissance optical perspective, and fundamental too for the rise of modern experimental science, had no power to give Europe precedence over China in the appearance of good working drawings, at least in building construction. The very reverse was true.3

Of the computational work necessary before any building was even started many traces remain in the work of Li Chieh. But before leaving the question of building calculations, attention must be drawn to a point which was already apparent at an earlier stage, namely the derivation of perhaps the majority of Chinese technical terms for solid geometry from the preoccupations of builders. Examples of this are numerous and interesting. The parallelepiped with two square surfaces was called *fang pao thano,*1 pao meaning (as still today) a fortified village, and thano a rampart of tamped earth. This figure is of course just that of each block of *terre pisé* within its shuttering. By extension, the word for cylinder was derived (*yuan pao thano*). The term for a parallelepiped with no square surface (*tsiang*) was taken directly from 'granary'. Sometimes the appellations seem to have originated from tools, as in the case of the pyramid (*fang chai*4 and cone (*yuan chai*5), *chui* by itself meaning a carpenter's boring tool, awl or gimlet. The lower corners of a pyramid6 were called *yang ma,*7 this the *Ying Yao Fa Shih* uses8 as a technical term for the eave corners or horns; perhaps the original significance was phallic.1 It is certainly as old as the +3rd century.9 Then the word 'pavilion' occurs in the terms *fang thing,* the frustum of a square-based pyramid, and *yuan thing,* the frustum of a cone. The frustum of a pyramid with a rectangular base of unequal sides was known as *chua*9 (really *chua*10 *thung,*11 chua having reference to the straw of thatched roofs, and thung to a flat top like the shaven head of a boy. Similarly, in the wedge with rectangular base, *chui meng,*12 both words refer to roofing, and the latter means the ridge-pole. The curious expression for a wedge with a trapezoid base, *yen chua,*13 comes undoubtedly from the under-

* Cf. pp. 113 ff. immediately below.
* Cf. Needham (44) and the accompanying contributions.
* Drawings of machines and their parts in China did not match up to the standard set by Li Chieh, but even Europeans could not produce good drawings of this kind until the +16th and +17th centuries.
* We shall find a striking parallel to this in Sects. 38 and 45. Accurate illustration of plant forms in China preceded the work of the western +16th-century European pharmaceutical botanists by some four hundred years. But that is more understandable since geometry was less necessary for it. The content of this paragraph emerged in conversations with my colleagues of the Newcomen Society, Mr Hugh Clausen and Mr Rex Wailes, with a background of Brixham shipwrights.
* Cf. the mathematical Section, Vol. 3, p. 97 above.
* Some of these interpretations were recognized by the Sung mathematician commentator, Li Chi, in his *Chiu Ch'ang Sun Shu Yin* (Explanations of Meanings and Sounds of Words occurring in the Nine Chapters of Mathematical Art).
* And hence sometimes, by extension, the pyramid as a whole.
* E.g., ch. 5, p. 6a.
* Cf. "male" and "female" in modern electrical technology.
* One finds it in the *Chang-Pu T'ien Pu*16 of Ho Yen (1682), *Hsüeh* (San Kuo sect., ch. 39, p. 5b).
* In the *Ch'in Shih Lu,* p. 10a, and *Chien Ch'ing Suan Shu,* ch. 9 (1682).
* See the full discussion, in Vol. 4, pt. 2, pp. 166 ff., and here especially Hirth (9).

28. BUILDING

Architectural draughtsmanship raises the question of the Chinese attitude towards perspective. Post-Renaissance European drawing has studiously followed the rules of convergent perspective, based upon the science of optics, according to which lines and planes on each side of the observer's position, though in fact parallel, appear to meet at a vanishing-point upon the horizon. It has commonly been held that this is the only possible kind of perspective, and that it was not known to the Chinese nor used by them until its introduction by the scientifically minded Jesuits early in the +17th century. The second of these statements is undoubtedly true, but the first, if we take the word perspective in its broad sense, is certainly at fault; for the Chinese were necessitated to introduce a sense of distance into their pictures, and did so successfully by a number of conventions which were not those of Europe.

The introduction of convergent or optical perspective into China has been considered in detail by Pelliot (27, 28), Hirth (9), Lauffer (28) and others. There is no question that Louis Buglio, S.J. (Li Lei-Ssu;4 +1606 to +1682), made the Western methods known by giving to the emperor three pictures in which the rules were perfectly followed. Gradually there appeared a mixture of styles: European missionary painters5 began to paint Chinese subjects in semi-European manner or themselves learnt the Chinese ways; Chinese artists began to paint in European style. The efforts of the Westerners were at first modified by the fact that to the Chinese the Western perspective seemed wrong.6 Fig. 775 (pl.) shows a painting which suggests that the drawing was modified to suit the Chinese taste in this matter.7 Among the earliest Chinese to draw in the Western manner were Tsung Chhi-Chang8 (+1555 to +1676) and Wu Li9 (+1632 to +1718), but convergent perspective was not fully incorporated in the traditional Chinese style until the famous set of drawings for the *K'eng Chih Thu*10 by Chiao Ping-Ch' en11 in +1666. In +1629 already Francisco Sam' isi (Pi Fang-Ch'i) 

ground passages made to give access to tombs, or in the recesses of imperial palaces.8 *Chhien tu,* a prism, combines words for moat and a low wall. The wall motif is also obvious in the terms for the frustum of a wedge, *chheng,*12 *yuwan,* and again *chhien.*1

This derivation of geometrical terms from building operations illuminates once again the practical and empirical genius of the Chinese people.
had issued a small tractate on the laws of perspective. Later on (+1729) came the Shih Hsieh (Science of Seeing), written by Nien Hsi-Yao. Yet it is clear that from the Han period onward, Chinese draughtsmen had had a great sense of distance in pictures. They had been conscious of the problem of the representation of space, how to represent three-dimensional space upon a plane surface. The terms kao yuán (high distance), shen yuán (deep distance), and ping yuán (level distance), not lightly to be equated with background, middle distance, and foreground, had been in use among Chinese painters for centuries (March, 3). One of the canons of Hsieh Ho, the great theoretician of painting in the +5th century, had been 'the right distribution of space' (ching ying wei chih?), which must have meant perspective of some kind (Hirth, 12). Certain Sung painters such as Li Chihýng have remained notable for their handling of distances, and in the Yuan, one of the great mistakes of beginners was said to be 'not distinguishing between the near and the far' (yuán chin pu fen). In general it may be said that in Chinese drawing distance had always been represented by height, so that one object standing behind another had been drawn above it, and not necessarily smaller. This has the result of giving to many Chinese pictures the character of bird's-eye views. Everything is seen as if from a height. The style is already present in the oldest Chinese landscape pictures still existing (-1st century). Might this not be one reason why the word thu has always retained an ambiguity, being applied equally to maps and charts and to drawings and paintings? A curious consequence of this Chinese style has been pointed out by Wells. In the European scene, the spectator feels that he has the scene thoroughly under control. He looks into it, it is all before him, and even if it is seen from a great height, it is seen, so to speak, from the top of a solid cliff. With the Chinese style the ground surface starts from the distance and slips past under the spectator's feet to a goal infinitely beyond, i.e. below and perhaps behind him. In some cases this produces a feeling of uncertainty, of falling into the scene. Sometimes, too, as Bachhofer (1) has pointed out in his elaborate studies of perspective in Chinese art, there seem to be a series of plane ground-surfaces, each with its own vanishing-point; for example, in the terraces which form the setting for the assemblies of Buddhhas and Bodhisattvas in the Tunhuang frescoes. But this is rather unusual.

Let it be accepted, then, that on the whole there is no true vanishing-point in Chinese drawing, and no exact rules of foreshortening. The horizon boundary was not felt to be important; the spectator was not compelled to participate in the drawing by his very physical position. How then was it possible for the Chinese to delineate, as they did, the 'sharp-edge' quality of buildings? What they employed was 'parallel perspective'; i.e. a system in which lines which were parallel in fact remained so in the drawing. Many of our illustrations show how this works out; many more could easily be added. The convention, reduced to its simplest elements, can be appreciated by comparing it with the same drawing in convergent or optical perspective: Fig. 778. March (1) has noted the paradox that while the European system depended tacitly on the non-Euclidean postulate that parallel lines meet at infinity, the Chinese, who had little or no Euclidean geometry, remained faithful to the postulate that parallel lines never meet at all, even in pictures. It is clear, too, that the Chinese convention could never show more than three surfaces of the interior of a paralelepiped, while the post-Renaissance convention could show five. The three surfaces are often referred to in Chinese writings on painting. For example, by Ta Chung-Kuang 1 in his Hua Ch'ien (The Painting Basket), a Ch'ing book, where he speaks of shih khan san miin (seeing three sides of rocks). That the Chinese never attempted to solve the problem of showing five surfaces is simply another result of the fact that they lacked geometrical optics. There remains a further paradox, namely that the projection which they did adopt is closely similar to some of those which architects and engineers use today for

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*a* Curiously entitled Shui Hua Erk Ta (Replies to Questions on Sleep and on Painting).

*b* A scholarly painter, the pupil of the Jesuit artist Ioseph Castiglione (Lang Shih-Ning); but better known as one of the Directors of Potesties at Ching-te-chen, hence the term Nien Yao for certain excellent wares produced under his authority.

*c* Cf. Wiley (18). His book, the Ku Hua Phin Lu, was continued c. +550 by the Hua Hsii Phin Lu. See Wang Po-Min (1).

*d* Rasmussen (1), p. 30, compared this system with the top-to-bottom arrangement of Chinese written or printed characters. He clearly appreciated the bottom-to-top succession of objects receding in space in Chinese pictures, but it would be impossible to sustain his statement that they give no impression of a third dimension. He is also wrong in supposing that the Chinese did not make the details of the far distant parts of their landscapes smaller and the colour lighter. Wang Wei (1) in the Thang distinctly stated these principles (Elisséev, 1).

*e* The so-called 'perspective cavalière', sometimes spoken of as 'azimuth perspective'.

*f* Bulling (11) discusses the two hollow-tile door-panels of a tomb excavated near Ch'ing-hua. C had been 'the right distribution of space' (ching ying wei chih?), which must have meant perspective of some kind (Hirth, 12). Certain Sung painters such as Li Chihýng have remained notable for their handling of distances, and in the Yuan, one of the great mistakes of beginners was said to be 'not distinguishing between the near and the far' (yuán chin pu fen).

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1. *Ch'iin Hua* (painter).
2. *Shih Hsiieh* (painter).
4. *Ch'ing Hua* (painter).
5. *Li Chihýng* (painter).
8. *Hua Chuan* (painter).
10. *Yao"* (painter).
15. *Chieh Ras* (painter).
18. *Yao"* (painter).
22. *Kuo Mo-Jo* (painter).
mechanical or structural 'working drawings'. It is therefore unlikely that the absence of convergent perspective was a limiting factor at any time in China during the eotechnic phases of mechanical invention.

Parallel perspective can be found already in the drawing of the scenes carved in relief in the stone tomb-shrines of the Han period (Chu Wei, Wu Liang, etc.). Diagonal lines strike off from the front line of the picture, with figures or buildings along them. This is also to be seen in many of the Han reliefs from Szechuan published by Rudolph & Wên. The convention continued in the works of the famous +4th-century painter, Ku K'ai-Chih, but with subtle modifications. Thereafter it was never relinquished. It has been justly pointed out that in early Chinese drawing there is no single point of view at which the spectator is supposed to stand, and from which his glance radiates from right to left. In all cases he has to be imagined as standing point blank in front of that part of the surface on which the object is presented. One comes back again, therefore, to the impression that Chinese conventions of draughtsmanship involved a 'minimum of subjectivity'. There was a 'multiple station-point',

«• Representations in parallel or non-diminishing perspective have been found extremely useful in modern technology, because, though planes therein do not diminish where they are supposedly receding, the drawings provide an adequate pictorial view of an object, and the distances in three principal directions can be scaled. Such drawings are called in general 'axonometric' projections, and they are either 'isometric', 'dimetric' or 'trimetric' depending on whether one, two or three different scales are used for height, width and depth. As long as two setting-out lines for principal directions are 90° apart (the others can be any division of 360°) one side of the recilinear object depicted can be projected directly in plan or elevation, which makes the representation advantageous, and quick to draw. Also not only distances but angles and curves are 'true' on that plane. Such axonometric drawings, sometimes also called oblique parallel projections, were the type used in the traditional Chinese system, the front elevation being always chosen as the 'true' plane.

»• His biography has been translated by Chhen Shih-Hsiang (a).

Western man, we write, because the beginnings of convergent or optical perspective can be traced back to the Greek — 5th century, with Aegaearchus of Samos and his scene-painting (Sarton (1), vol. 1, p. 95; Frankfurt (3); Schäfer (1), chs. 4, 5, esp. pp. 34 ff.). The beginnings of the deliberate use of optical perspective in western Europe are indeed seen in the works of Ambrogio Lorenzetti of Siena (Sarton (1), vol. 3, p. 111) he had mastered not only Euclidean geometry but the optical discoveries of the Arabs such as al-Haitham. Or someone else had mastered them and explained them to him. Convergent perspective developed slowly; pictures by Paul of Limbourg, for example (+1416), do not show it. The work of Albrecht Dürer (+1471 to +1528) in this connection is well known (cf. Rasmussen (1), p. 30). It is important to note that the earlier medieval European works seem not to have followed any system; they did not, for instance, develop parallel perspective and then give it up. On the history of perspective drawing in the West see Poudra (1); Wolf (2).

There was Li Chhêng, who when he depicted pavilions and lodges amidst mountains, stored up buildings, pagodas and the like, always used to paint the eaves as seen from below. His idea was that 'one should look upwards from underneath, just as a man standing on level ground and looking up at the eaves of a pagoda can see its rafters and its cantilever eave rafters.' This is all wrong. In general the proper way of painting a landscape is to see the small from the viewpoint of the large (t a kuan tiao), just as one looks at artificial mountains in gardens (as one walks about). If one applies (Li's method) to the painting of real mountains, looking up at them from below, one can only see one profile at a time, and not the wealth of their multitudinous slopes and profiles, to say nothing of all that is going on in the valleys and gorges, and in the lanes and courtyards with their dwellings and houses. If we stand to the east of a mountain its western parts would be on the vanishing boundary of far-off distance, and vice versa. Surely this could not be called a successful painting? Mr Li did not understand the principle of 'seeing the small from the viewpoint of the large'. He was certainly marvelous at diminishing accurately heights and distances, but should one attach such importance to the angles and corners of buildings?
Thus the small viewpoint of the stationary individual eye was condemned in favour of the large scanning view-area from which the artist, embodying in himself the insights which otherwise he would not have had. Similar examples of divergent perspective can be traced in less marked form on Han reliefs. It has been suggested that the motivation was similar to that of the child when it draws a human being with arms and fingers wide outstretched, though persons are rarely seen in this position (Wells, 2). But in view of the creative discoveries of modern graphic and plastic art, the wise will not be hasty to condemn these liberties which ancient and medieval Chinese artists took with bald reality. Besides this, we also find examples of marked divergent perspective drawing in certain geometrical frieze motifs in the Tunhuang cave-temple frescoes from the Northern Wei to the Sung periods. Lastly, it is interesting that both parallel and divergent perspective radiated from China to many other parts of Asia, especially to Tibet and the countries of the South Seas such as Java and Siam.

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Beyond this stage of analysis sinology and comparative art history have not penetrated. It is possible, however, that experimental psychology may be able to illuminate the problem from quite a different angle, for current investigations are revealing what may be physiological differences in distance perception between different peoples. Appreciation of depth and perspective may not be quite the same for all human beings. Although we cannot hope to do justice to these studies it would not be in accord with the spirit of a book on the history of science to ignore them.

If a square white card of 6 in. side is placed at a distance of 8 ft. from an observer, and a number of smaller cards are presented to him alongside it at a distance of only 4 ft., he may be asked to choose which of them appears to him to be of exactly the same size as the more distant one. It has been found that practically no subject ever chooses the 3-in. card, though in fact this is the one which produces a retinal image of exactly the same size as the further card. A card of intermediate size is always selected. In other words no one (of whatever culture) chooses the card which would be correct according to the laws of optical perspective, but a larger one instead. 'Mathematical' perspective is thus generally felt to be too drastic. This tendency is known as 'phenomenal regression to the "real" object', an effect defined by one of its first discoverers, Thouless (1), as 'the general tendency in perception for phenomenal (or apparent) characters to be intermediate between the characters indicated by retinal stimulation and the "real" characters of the perceived object'; and it holds good not only for size, as in the example just given, but also for shape. Alternatively stated, in the perception of objects, every subject sees (i.e. immediately experiences) not the sensory characters indicated by peripheral stimulation (such as the image on the retina), but a compromise between these and the 'real' characters of the physical object itself, provided he has adequate perceptual cues as to what these 'real' characters are.

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* Reproduced e.g. by Binyon (1), pl. 1; Waley (10), pl. v.
* Waley (10), pl. iv.
* And in very many later pictures strikingly, for instance the silk banner painting from Tunhuang (the Paradise of Bhaisalajugur, the Buddha of Healing), c. 9th century, figured in Waley (10), pl. xx.
* Cf. Fig. 303 in Vol. 4, pt. 1; here, Fig. 737.
* Drawing a picture more true than one's visual impressions, says Frankfurt (3), pp. 58 ff., expounding the views of Schäfer (1), pp. 332 ff., on the absence of optical perspective in ancient Persian art. It may well be, as says, that the Greek invention of this way of drawing was connected with a sharp philological distinction between the world of appearance and the world of the mind—the 'physiological' versus the 'ideological'.

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The well-known Ponzo figure and the Muller-Lyer line are examples of this. Compare also Baltraudtis (3); Escher (1); Gombrich (1); Campbell (1). In the same way we may judge as different the size of two apparent objects which can be proved to give exactly the same-sized retinal image, magnifying too much the thing which we think is the further away. This is the case with the apparent gross enlargement of the sun or moon seen near the horizon—a phenomenon discussed in ancient China (as we have seen in the amusing story of Confucius and Hsiang Tho, Vol. 3, pp. 225 ff.) and recognised already in the Vishnu Purana.

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* For helpful discussions on the subject of the following paragraphs I am indebted to Mr F. J. Pedler, Dr. Richard Gregory and Miss Charriean Shopland.
* As when one looks through a lensless pinhole camera. Distant objects seem curiously small and near one uncommonly large.
* Though not always for colour or brightness.
* A universal accompaniment of 'phenomenal regression' is 'size constancy', the fact that if we look at a small object such as a wristwatch or a seal-stone within a considerable range of distances, it always appears to be the same size, though the images which it forms on the retina are much smaller when it is further away than when it is near. Cerebral-mental compensation is in fact going on: perceptual enlargement of the more distant image. This was one of the effects which led Bishop Berkeley to write his New Theory of Vision (1709); cf. Wolf (2), pp. 668 ff.

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Worth noting too is the fact that features which we generally associate with depth-perception form a common property of all optical illusions (cf. Gregory, 1). The well-known Ponz figure and the Muller-Lyer line are examples of this. Consider also Baltraudtis (3); Escher (1); Gombrich (1); Campbell (1).

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In the same way we may judge as different the size of two apparent objects which can be proved to give exactly the same-sized retinal image, magnifying too much the thing which we think is the further away. This is the case with the apparent gross enlargement of the sun or moon seen near the horizon—a phenomenon discussed in ancient China (as we have seen in the amusing story of Confucius and Hsiang Tho, Vol. 3, pp. 225 ff.) and recognised already in the Vishnu Purana, by Chang Heng as well as Pacioli. The moon low on the horizon looks larger than when it rides high because it seems to be further away—again the process of distance enlargement by cerebral-mental compensation is at work. On this illusion see: Drucker & Uibe (1); Kaufmann & Rock (1).

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It is now thought that the distance and constancy systems may be two parallel and semi-independent mechanisms of sensory adjustment, capable of giving conflicting information. Of course objects sensed as being very distant look smaller than near objects, but size constancy works over a surprisingly wide range of distance. The changeover zone will vary greatly according to the conditions.
A convenient measure of this tendency is given by what is called the Phenomenal Regression Index

$$\log p - \log r$$

$$\log r - \log s$$

where $p$ stands for a numerical measure of the phenomenal or apparent character (here the dimension of the card chosen), $r$ for a measure of the stimulating character presented (here the 3-in. card), and $s$ for a measure of the 'real' character of the object (here the 6-in. card). On this scale a zero value would indicate no influence of the 'real' character on the perception of perspective, i.e. that the cerebral-mental interpretation of vision was strictly following optical principles; whereas a value of unity would indicate an overriding influence of the 'real' character, i.e. that appreciation of perspective was quite absent. Thouless himself first showed (2) that for European (British) subjects there were wide differences in the index (with an extreme range from 0.2 to nearly unity), but that statistically significant correlations could be made with age, sex, intelligence and artistic training.

He then went on to show (3) a significant difference between representative groups of Indian and British students, the index for the former being 0.76 while that for the latter was 0.61. Subsequently the question attracted much attention in Africa, where it had been found that drawings in approximately optical perspective were not understood by Africans. Beveridge (1) found higher index values for West African draughtsmen than for Scottish students. Bush & Culwick (1) then reported values from East Africa as follows: Haia (Tanganyikan) Africans 0.82, Arabs of partly African descent 0.58, and Europeans 0.54. They could not establish any correlation between the index and the level of education.

Now it is clear that for anyone having a Phenomenal Regression Index higher than zero, a distant object, by comparison with a nearer one, will appear larger than it theoretically should; and the higher the index the greater the effect. The possible implications of this for the understanding of Asian art were immediately appreciated. Toch (3) had two points to add. He regarded Asian artists as strongly 'eidetic,' excelling, that is, in vivid and precise imagination, held 'in the mind's eye' as they wielded their brushes in front of their scrolls. It is true that Chinese painters rarely painted from life, but in quiet recollection. This would have led naturally to a magnification of size as the eidetic image was brought nearer than the 'real' object by a person with a high regressive index. So far could this go, says Thouless, that even the 'divergent perspective' described above could become quite comprehensible. For in fact precisely this effect is produced when we look through a telescope at parallel lines receding from us, as on a railway or in a long corridor. How delighted Ku Khai-Chih would have been with such a demonstration!

(6) Notes on the Historical Development of Building

(i) Words and traditions

As would naturally be expected, the technique of building goes so far back in history that it is worth while to look at what has become embedded in the structure of the ideographic language itself. There are three main radicals which have to do with dwellings, yen \(^1\) (no. 53), which must originally have depicted a lean-to shelter against a cliff; hsieh \(^2\) (no. 116), which was originally a drawing of a cave- or pit-dwelling in rock or loess, and mien \(^3\) (no. 40) which is frankly a roof. From these three origins derive the greater number of characters representing houses or parts of houses, though the technical terms for constructional parts are nearly all obtained, as we have seen, from the wood radical. From yen, the cliff-shelter, come such words as thing \(^4\) (courtyard), hui \(^5\) (a side-house), yu \(^6\) (the space under the caves), mu \(^7\) (gallery or verandah), and k'hu \(^8\) (carriage-shed, treasury, arsenal). These are but a few examples. Hsieh, not so prolific, gave chhuan \(^9\) (window) and tou \(^10\) (drain). Many familiar words, however, arose from mien, such as kung \(^11\) (palace hall, already analysed, p. 72 above, K.106), shih \(^12\) (a private house, K.143), chih \(^13\) (the family), tang \(^14\) (reception-hall), chhin \(^15\) (bedroom).

\(^1\) The Chinese convention of course continues in contemporary Chinese drawing in traditional style, and sophisticated taste can learn to appreciate it just as the Chinese themselves have become accustomed both to their own and to the Western styles. Europeans first came to know of Chinese painting in the +17th century. Joachim von Sandrart seems to have been the first to write of it (\(+1675\) but his account was garbled to a degree (Sullivan, 4)).

\(^2\) For fuller discussion than can be given here see Kelling & Schindler (3).

\(^3\) This derives from the word shang, \(^16\) high and admirable, which has (the lord's) mouth under a roof; one can even see the ridge-pole (K.725 b, c, R).

\(^4\) the ridge-pole (K.725 b, c, R).

\(^5\) the ridge-pole (K.725 b, c, R).

\(^6\) the ridge-pole (K.725 b, c, R).

\(^7\) the ridge-pole (K.725 b, c, R).

\(^8\) the ridge-pole (K.725 b, c, R).

\(^9\) the ridge-pole (K.725 b, c, R).

\(^10\) the ridge-pole (K.725 b, c, R).

\(^11\) the ridge-pole (K.725 b, c, R).

\(^12\) the ridge-pole (K.725 b, c, R).

\(^13\) the ridge-pole (K.725 b, c, R).

\(^14\) the ridge-pole (K.725 b, c, R).

\(^15\) the ridge-pole (K.725 b, c, R).

\(^16\) the ridge-pole (K.725 b, c, R).
2500) Vol.

that all homesteads were originally farms, for the roof has a pig underneath it. The

wider than that of building. For instance, the word family

cold

and

the character for 'early morning' and the court ceremony which took place at that

time, so that the reference may be to early morning worship. Chin,

the sleeping-room, seems to have a brush underneath a roof, probably because at first sleeping-

rooms were also store-rooms* (K 1003).

Ancient tradition among the Chinese as to their earliest dwellings was rather precise.
In a famous passage, the Li Chi says:a

Formerly the ancient kings had no halls or houses (kung shih)*. In winter they lived in
caves (yang hu)* which they had excavated, while in summer they lived in nests (tsanging chhao)*
which they had framed.

There can be no doubt that these winter-dwellings were really holes in the ground, for
shallower circular pits some 3 to 4 ft. deep and 9 to 15 ft. in diameter have been found
by archaeologists investigating the black-pottery Lung-shan culture. Some
of the dugouts (hsitiezh)* are much larger than this,4 and all were covered by thatched roofs.

K 32 K 146 b K 143 b K 1009 K 1003 K 110 b K 661 h

Tsung,* ancestral, a word with such far-reaching import in Chinese culture, represents (K 1003) the symbol for a sign or omen set up within a house; it refers therefore essentially to the ancestral shrine or temple. The usual term for temple however, mio,* comes from the lean-to shelter radical, but we do not yet know the significance of the objects which its earliest forms portray inside it (K 11060). They seem closely related to the character for 'early morning' and the court ceremony which took place at that time, so that the reference may be to early morning worship. Chin,* the sleeping-
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of the dugouts (hsitiezh)* are much larger than this,4 and all were covered by thatched roofs.

a Cf. a derivation of the word 'storey'.
b Ch. 9 (Li Yün), p. 50 b, tr. Legge (7), vol. 1, p. 309.
c See Eberhard (24); Anon. (43), p. 15; Chheng T'Khun (9), vol. 1 and suppl. Cf. Vol. 1, p. 83.
d When conditions permitted, as in the lower country, it was easy to excavate roomy dwellings, such as
those still used in the north-west, some of which I have myself often visited. Cf. Fig. 7 in Vol. 1. Fuller &
Clapp (1) have given a description of these cave-dwellings; see also Creel (a), p. 56; Franck (1); and
especially Lung Fei-Liao (1).
In spite of the supposed seasonal alternation in types of dwelling, it may be that they derive from separate contributions to Chinese cultural evolution, the semi-subterranean caves or pits Tungusic, and the 'nests' Thai. In any case, the 'nests' have of course left no permanent traces of themselves, but it is probable that they were rough shelters or houses built on piles, taking advantage perhaps of jungle trees as supports. If this was so, one can see how they could have given rise to the great tradition of columnar trabeate woodwork in Chinese architecture. It may be, too, that the raised field-watchers' or harvesters' huts (lu 1), which are so common a feature of the western

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Fig. 782. Foundation of a Shang ceremonial building (A4) at Hsiao-thun in the area of the capital of Anyang; c. -1240 (Chéng Te-Khûn (9), vol. 2, fig. 11, after Shih Chang-Jû).  
1 The foundation of tamped earth (terre pisé) with steps still in position on one side, and all the pillar bases in their original positions; length 80 ft., width 26 ft., height of platform 3 ft.  
2 Reconstruction of the skeletal timber structure.  
3 Probable appearance from one end.  
4 Probable general appearance, suggesting a votive temple for ancestors.

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China landscape at the right season of the year, have come down almost unchanged from this remote antiquity. At all events, there can be no doubt that the type of building which was later on to become so universal in China, namely the raising of wooden pillars upon stone plinths above a platform of tamped earth (hang thu'1) foundations, with terre pisé walls afterwards thrown around the structure, had already reached a highly developed state in the Shang period (-2nd millennium). This is proved by the excavations at Anyang. Fig. 783 illustrates the plan and reconstruction of one of these long buildings with thirty column bases, most of which still retained their stones. True to type, the main entrance seems to have been in the middle of one of the 80-ft. long sides, but the chief axis of the building was north-south instead of east–west, as became customary later.

The folk-songs in the Shih Ching (Book of Odes), which may go back at least as far as the 8th century, have several passages of architectural interest, and though not perhaps very informative, they are worth quoting. For example:

Of old, Tan-Fu the duke!
Made kiln-like dwelling-pits with roofs,  
As yet (the people) had no houses.

Of old, Tan-Fu the duke
At coming of day galloped his horses,
Going west along the river bank
Till he came to the foot of Mount Chihi,
Where with the lady Chiang
He came to look for a home.

The plain of Chou was very fertile,
Its celery and sow-thistle sweet as rice-cakes,
Here we will make a start; here take counsel,

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a Besides, one must not forget that many of the tribal peoples formerly on the fringes of Chinese society, such as the Miao, have lived in pile-dwellings until the present day (cf. Liu Tun-Chên (4), pls. 43, 45).  
b See Li Chi (1) and later Academia Sinica publications, summarised and digested by Eberhard (34); Chéng Te-Khûn (9), vol. 2, pp. 20 ff., 27 ff., 41, 44, 50 ff.; Watson (2), pp. 62 ff. Cf. Liu Tun-Chên (4), pls. 6-8. Of course large numbers of the smaller structures at Anyang and other Shang sites were pile-dwellings of the hsiâo type, often oval as well as round or square.  
c Chéng Te-Khûn (9), vol. 4, pl. 54; Creel (2), p. 59.  
d Shang platform foundations as large as 80 ft. × 26 ft., as here, are quite common. The largest so far found measures 280 ft. × 48 ft. approximately. It is interesting that there are no signs of courtyard house plans in the Shang cities.  
e The Mien-mien song (Mao no. 237); Tr. Legge (8), III, i, 3 (p. 437); Karlgren (14), p. 185; Waley (1), p. 248.  
f Tan-Fu was one of the semi-legendary chiefs of the proto-Chou people, dated traditionally in the -14th and -13th centuries.  
g On this see Stein (5). What we now know of the pottery kilns of the neolithic and the Shang periods fully justifies this interpretation of a phrase which has given some trouble to commentators. Cf. Anon. (43), p. 16.  
h Waley (1) remarks that this was not because they were not able to build, but because the ancient shelters were used until the new city could be planned and started. We believe, on the other hand, that the common people continued to live in semi-subterranean dwellings till long after the end of the Shang period, at any rate in some places.
Here notch our tortoise. It says 'Stop', it says, 'Halt, Build houses here'.

So he halted, so he stopped. And left and right
He drew the boundaries of big plots and little,
He opened up the ground, he counted the acres
From west to east;
Everywhere he took the task in hand.

Then he summoned his Master of Works (Ssu Khung)
Then he summoned his Master of Lands (Ssu Thu)
And charged them with the building of houses.

Dead straight was the plumpline,
The planks were lashed to hold (the earth);
They made the Hall of Ancestors, very venerable.

They tilted in the earth with a rattling,
They pounded it with a dull thud,
They beat the walls with a loud clang,
They pared and chiselled them with a faint phing, phing;
Three hundred rod-lengths all rose up,
The drummers could not hold out.

They raised the outer gate;
The outer gate soared high.
They raised the inner gate;
The inner gate was very strong.
They raised the great earth-mound

Whence excursions of war might start.

Here the chief technical interest is the ramming of earth for the foundations and the walls of a temple. Another of these songs describes the erection of a feudal palace.

(The Lord) resembles and succeeds his forebears,
He builds a house of a hundred cubits
To the west and south are its doors,
There will he live and dwell, there laugh and talk.

They bind (the shuttering frames) one over the other,
They pound (the earth in them, it sc. nds) thak, thak;
This will keep out the wind and rain, the birds and the rats,
Here will the Lord be eaves-covered... .

Level is the courtyard, straight are the columns (ying),
Pleasant and cheerful the halls of reception,
Ample the living-rooms, where the Lord can be at peace...

Again we have the moulds for the tamped earth, and a reference to the eaves.

Among other classical references to building and its traditions we may notice one in the I Ching and another in the Mo Tzu book. The Great Appendix in the former (perhaps of Warring States time, certainly Early Han) remarks:

In primitive times people dwelt in caves and lived in forests. Later sages made the change to buildings (kung shih). At the top was a ridge-pole (tung), and sloping down from it there was the roof (yu) to keep off wind and rain.

And it goes on to name the Kua (no. 34) from which the sages might be supposed to have derived their inspiration, in the course of its sketch of social development. Mo Ti, as usual, attacks what he considers undue luxury and elaboration:

Master Mo said: 'Before the art of building halls and houses (kung shih) was known, the people lingered among the hill-sides and lived in caves or pit-dwellings (kueh) where it was damp and injurious to health. Thereafter the sage-kings made halls and houses. The guiding principles for buildings were these, that (the house should be built) high enough to avoid damp and moisture, (that the walls should be) thick enough to keep out the wind and the cold, and (the roof) strong enough to stand snow, frost, rain and dew; lastly, that the partition walls in the palaces should be high enough to observe the proprieties of (separate accommodation for) the sexes. These things are sufficient, and any expense of money or labour which does not bring additional utility should not be permitted.'

On the whole, it will be seen that these references do not give us much of the ancient technicalities. But a glance at the Erh Yz, the most ancient dictionary (already mentioned), in its special section on buildings (Shih Kung), will bring to light at once some twenty or so of the technical terms with which we have now become familiar (e.g. fu and cho); these it duly explains. There are also, of course, others which are rarer or which long ago became obsolete. Nevertheless, it remains clear from this that a substantial part of the technical vocabulary of building construction as we now know it was used by the architects of the Chhin and Early Han (-3rd century).
We may accept, therefore, that the use of tamped earth platforms, halls with many wooden pillars standing on stone bases, and suitable simple roofs, was widespread from at least the 13th century onwards. It must have been towards the end of the Chou period that the invention of the corbel brackets (tau hang) took place, for they are characteristic of all Han buildings. Of course none of these structures have themselves survived, but fortunately the Han people imitated their woodwork in pottery models as well as in the stone of tomb-chambers and funeral steles. The latter were near Pao-ning the stele of Kao I, province on the borders of the Tibetan mountains. Besides these, there are the funeral chambers. Massive tau hang are carved in the stone tomb-shrine of Chu Wei; one of Wang Mang’s generals, who died about +45. So also, in the two-storied hall which appears in the bas-reliefs of the Hsiao-thang Shan 3 tombs (Fig. 783, pl.), the capitals are drawn in such a way as to indicate that the columns were topped by a series of successively longer tau hang (c. +125). We see them sometimes even on, as in the Szechuanese moulded brick of an entrance-gate flanked by towers (chihich kung). And

We can just make them out on what is perhaps our oldest Chinese architectural picture, the bronze bowl from Hsii-she shown already in Vol. 4, pt. 1, Fig. 299 (Liu Tun-Chin, 4, pl. 10, 11). Cf. Fig. 300. This is of the 4th century, but already the story of a two-storied hall, with roofed galleries and side pavilions on the lower level, is clearly visible. Mortuary models of the late Chou period (see Anon. (42), pl. 51) show what seem to be personified tau hang. On late Chou and Han building in general see conveniently Watson (1), pp. 124 ff.; but the best discussion of the Han style in architecture is still no doubt Pao Tung et al. (4). Cf. too Chihen Ming-Ts (1). If.;

We illustrate the columns of the main hall (shih), and by numerous carvings on the shrines themselves in which these carvings are contained, and by numerous tomb-models in pottery. Of these a great number have in recent years been excavated in and near Canton. To illustrate a building of a rather different type from any so far mentioned, we reproduce a remarkable model of a fortified manor-house self-dated at +76 (Fig. 786, pl.). When the pieces are taken apart, animals in their byres, and numerous farming and domestic activities can be seen. Interesting reconstructions of Han palace buildings are now being attempted.

A characteristic Han feature was the use of caryatides as columns. This appears fairly frequently in the Chin Shih So rubbings from Wu Liang Tschu and other sites, but there is little trace of it in later times, save that columns of important buildings were (and still are) sometimes carved in high relief. Dragons, for instance, twine around them, as in the Confucian temple at Chiang-ting (Fukien) and elsewhere. We illustrate the columns of the main hall (Sheng-Mu Tien) at Chin Tzhu in Shansi (Fig. 787, pl.).

During the period between the Han and the Sui, there was a gradual development in complexity, the tau hang becoming more and more elaborate, and the roofs showing a
more and more concave tendency. A By the earlier years of the Thang period this was fully established, for we find it not only in the oldest wooden buildings of China still extant but also in the still older structures conserved in Japan. C The problem of its origin and spread has prompted a question about it different from any of those we have already considered (pp. 91, 97, 102), and some scholars are inclined to regard it as an example of the influence of South-east Asian roof forms. D There is certainly little difficulty in finding examples of all three types of roof curve (the concave slope, the curving ridge and the upfaced eave corners) in the traditional architecture of Indonesia, Indo-China, Siam, Cambodia and the Philippines, but archaeological proof has not yet been provided that they were there before the Liu Chhao and Sui periods. Further research will be required to eliminate the converse possibility that all these forms were inspired by Chinese influence radiating along the trade-routes in medieval times.

The chief new development in the Liu Chhao period was that of pagoda construction. The pagoda (thaï), as it eventually flourished, was a combination of the ancient Han towers of several storeys (known from pottery models, e.g. Fig. 788, pl.9) and the stupa forms from India, which ultimately imposed upon the structure its various plastically curving silhouettes. We shall say more about it presently; here we would rather dwell for a moment on the ancient Chinese inclination to build upwards. A

The process can be followed to some extent in the Tunhuang frescoes. For example, in Northern Wei (late 4th century onwards) cave no. 357 (Anon. (10), pl. a. 5, In Western Wei (5th century) cave no. 53 (Anon. (10), pl. 18 and Yeh Chien-Yu (1), fig. 5). In Sui (+811 to +618) cave no. 229 (Anon. (10), pls. 23-31). At these periods the curvature, though slight, is already perceptible or even quite apparent. Then one finds it fully developed in the architectural paintings of the late 6th-7th century painter Chan Tao-Chhima (cf. Waley (19), pp. 109, 134, 140) preserved in the Imperial Palace Museum at Peking (see Liu Tung-Chhn (4), pl. 52, 43).

The temples of Wu-thai Shan in Shanhi, Nan-Chang Shan (+8th century) and Fo-Kuang Shan (+9th century); we immediately below. The temple hall depicted on the stone lintel of the Ten-Yen Tha pagoda at Sian (+621 to +701) also shows the curving roof slope strikingly; cf. Sickman & Soper (1), fig. 17.

The Golden Hall (Kondô) and the five-storied pagoda (Gojô-no-tô) at the Hâyâji temple near Nara, buildings of c. +712 copied from predecessors of c. +623; as also the portable model Tama-mushî shrine preserved there, which cannot be later than the mid-7th century. Cf. p. 95.

Notably Sullivan (1), pp. 119, 137, 4, p. 228. The great Sung architect Yu Hao (cf. p. 81) has, I think, been wrongly enlisted in this cause. According to the Hou Shan Tham Thanh (Hou-Shan Table Talk) by Chihen Shih-Tsu (Hou-Shan Table Talk) by Chiben Shih-Tsu (c. +900), when Yu Hao came north to Kâiffing from Hangchow he was deeply impressed by the "Tower Gate" of the Huang-Kuo Shan temple, a Thang structure. After closely examining it for a long time, he said, 'They were certainly capable enough (in those days); the only thing is, they didn't understand how to curve up their eaves (toward the corners). The last three words in brackets, inserted by the translator, it seems (cf. Sickman & Soper (1)), are surely right—what Yu Hao brought northwards was the upfacing of the eave corners, not the curving slope of the roof profile, which had long been there. The incident would have occurred about +770.

Naspresso (17); Anon. (27), pl. 5; Anon. (32), pl. 88; Sickman & Soper (1), p. 156; Bulfin (2), figs. 31/2, 22/23, 31/24; Ao Chihung Lung et al. (7), pl. 66-9, examples from a tomb of +182 at Wangtu, with sectional elevation drawings.

This tendency there was, but it does not contradict what was said earlier about the dominance of the horizontal line in Chinese architectural planning, first because great towers were rare, and secondly because they were almost always kept somewhat at a distance from the plan of the layout as a whole. This continued to be true in the Buddhist pagodas.

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The Thang period seems to have been a time of architectural experimentation. It is from the Thang that we possess the oldest existing Chinese wooden building. One of the halls of the Fo-Kuang Ssu Temple at Li-chia-chuang up the Pai-ta-hsing village valley in the foothills of Wu-thai Shan constitutes the oldest; it was discovered and thoroughly studied by Liang Ssu-Chhêng during the Second World War (2, 3, 4). It stands on a high platform adjusted to the slope of the mountain (Fig. 78a, pl.), and its massive columns, beams, and tong hang have withstood all ravages of time since +587. Probably also from before the end of the same century is the main hall of the Confucian temple at Chêng-têng in Hopei. The only wooden work from this century which has remained in China is perhaps that of some of the galleries outside the cave-temples at Tun-huang. Magnificent reconstructions of

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References and footnotes:

1. See Liang Ssu-Chhêng (6).
2. This is the main hall of the Nan-Chhan Sw Temple at Li-chia-chuang up the Pai-ta-hsing village valley in the foothills of Wu-thai Shan. A surviving inscription dates the last restoration at +708. Little has been published about it since its discovery in 1953, but it is illustrated by Liu Chih-Pching (1), figs. 211, 212. Rather small and simple in construction, it demonstrates its antiquity by the use of inverted V-braces or forked-hand struts (cf. p. 100) on each side of the king-posts and as supports of queen-posts, and by the fact that no cantilever rafters clusters. In 1964 Horytlji Ssu (37) p. 128 and Ecke (4) have found a correspondence between Pelliot and the Chinese architectural historians on the subject, published by Liang Ssu-Chhêng (7). Thus the wooden gallery in no. 431 was built and dedicated about +585. Exarch of Tun-huang, Tshao Yen-Lu, in +480, and that of nos. 443 and 444 was the work of his predecessor Tahao Yen-Kung (8) four years before. Photographs of the former before and after restoration are given by Ching-chia Shanshui (2), figs. 12, 13.
3. On the basis of textual and iconographic evidence as well as excavation of the sites; see Kuo I-Fu (1); Liu Chih-Pching & Fu Hai-Nien (1); Hui Ming (1).
4. See Anon. (37), pl. 43. Elaborate description in Liang Ssu-Chhêng (9).
7. At the Fo-Kung Sw Temple (Buddha-Palace Temple). Description in Sickman & Soper (1), p. 274, pl. 176. Soper (1), pp. 150-152; Boerschmann (4); Anon. (37), pis. 54, 55; Anon. (13), pp. 250-252; Bulling (2), p. 25; pp. 25, fig. 82/83; Liu Chih-Pching (1), fig. 197; Soper (1), pp. 373 ff., pl. 177.
8. A useful list of extant (and lost) Sung, JChin and Liao buildings between +700 and +1250 is given by Hung Huan-Chih (1), p. 41. The two latter periods have been the subject of a special study by Sekino & Takeshima (1). A newly studied temple hall dating probably from the early years of the +12th century has recently been described by Chih Ying-Tao (1), and two JChin halls (+12th century) by Tu Hien-Chou (1) and Li Chou-Chun et al. (1). In 1954 I was able to visit and photograph in detail seven temple halls of the Sung, Liao and JChin periods. I particularly recall two T'aoist temples: the Hall of the Holy Mother (Sheng-Mu T'ien) at Ch'in T'ai (9) near Tsuaiyien, built c. +1100, with its alternating true and false cantilever rafters (see Liu Hsi-Yin & Liang Ssu-Chhêng (1)); Sickman & Soper (1), p. 263); and the Temple of the Mystery of Mysteries (Husan-Miao Kuan) (10) at Sachow in Chiangsu, built c. +1179 (see Liu Tun-Chhin, 5).
common. Of course certain sites have a continuous history going back to Han times. At Chihhsung in Szechuan there is a famous hall known as the Ta-Chheng Tien. About +1190 Fei Kun was convinced that the building then standing dated from the end of the Han. In his Liang Chi Man Chi (Bridge Pool Essays) he wrote: a

The Hall of Great Accomplishment in Chihhsung was built in the Chhu-Phing reign-period (+190 to +193). It is indeed great and grand. The month and year of its construction are still recorded in an inscription on the eastern side, written in style by the Han people. So the hall is still standing magnificently after a thousand years. It may be compared with the Ling-Kuang palace in Lu (Shantung). b In the ping-chien year of the Shao-Haing reign-period (+1196) the emperor Kao Taung, at the request of the president of the provincial academy, Fan Chung-Shiu, c wrote with his own hand four characters 'Ta Chheng chi Tien', for this building. Later on, when Hu Shih-Chiang d came as Special Commissioner to Szechuan and Shensi, he visited the hall, and surveyed the beams and pillars. He decided to replace some parts which had rotted, and he added several thousand tiles, but he did not dare to undertake any modification of the ancient structure.

There is nothing impossible in this long survival, as is evident from the oldest building which we now have, but of course we do not know how skilled Fei Kun was at recognising a true Han building when he saw one. The present structure seems to be of much later date, probably not even containing any parts from the time of Fei Kun himself.

We have tended naturally to concentrate attention on the oldest and the most splendid of Chinese buildings, partly because their essential structure and the history of its development can best be brought out in this way, but it would be inexcusable to say nothing of the domestic architecture of the country, fulfilling its homely functions in a thousand beautiful forms over thirty-five degrees of latitude and sixty of longitude. Something indeed of the nature of a debt is owing from one who for years has derived intense pleasure from the buildings of one or another home, farm, inn or temple where he has stayed, in Chinese villages and towns of nearly a score of provinces. One publication is now available, that of Liu Tun-Chen (4), which can convey a measure of this delight to any reader, for it deals solely with the variations of domestic architecture in the different regions of the country. c We are privileged, however, to illustrate some of the styles from another source, so far unpublished, leaves from the sketch-book of a visiting English architect in China in 1954 (Figs. 794, 795, pls.). d Here one can see the flat roofs of mud and wheat-straw used in the north from Kansu to Hopei combined with veranda e and lattice windows, f the stepped and shaped gables of Hunan, Chiampil and Kweichow, horned gables of abrines to the tutelary field-gods in Hopei, and the Cantonese farmhouse with its ridge terminals, central ornament, and recessed bay entrance surmounted by decorative carving. Convex barrel roofs somewhat like

a Liu Tun-Chen (4), pl. 53. A tendency to rounded convexity, softening the sharp edge of the roof ridge, is also found in Ming and Chhing ornamental buildings; brought about by using two uppermost queen-posts of equal height instead of a king-post, it is called the rolled mat-shed style (shen ping). Cf. Liu Chih-Phing (1), figs. 301, 302.

b Personal observations along the Lung-hai Railway in 1958; cf. Liu Chih-Phing (1), fig. 37.

c Cf. Fig. 7 in Vol. 1, and Rudofsky (1), figs. 15, 18. Though we should distinguish between a cave and a house, in China both the caves and the cave-shaped dwellings are called tung, f a fact which leads to some confusion among interpreters and foreign guests visiting the homes of the revolutionary leaders in and around Yanan. An interesting life-story of a peasant builder of both kinds of dwellings has been recorded by Myrdal & Kessel (1), pp. 12 ff. A tung must be defined as a structure with column-beam lattice and roof.

d Cf. Liu Tun-Chen (4), pl. 76.

e For Worcester (14), p. 123.

f Anon. (37), pl. 145; Liu Tun-Chen (4), pls. 112, 113; cf. Dye (4). The example from Nan-chhi is closely similar to that which I knew well at Lichuang near by, the war-time headquarters of the Institute of History and Philology of Academia Sinica. This was where Prof. Wang Ling and I first met, in 1945.

The most extraordinary types of Chinese rural dwellings are those of the Hakka people in Fukien province, known only to few, even among Chinese, until their recent study by Liu Tun-Chen. k The need for security among an originally somewhat hostile indigenous population led to the development of fortified clan community 'apartment houses'. Sometimes these adopt the normal rectangular ground-plan, the place of the highest and most northerly temple hall being taken by a massive block (tang) c of three or four storeys, while long wings (king), of height declining in stages, occupy the east and west.

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and west sides, with an assembly-hall in the centre. But elsewhere the plan is circular (Fig. 798, p.), three or four storeys of inward-facing apartments with balconies for individual families forming the periphery and looking down on a central circular courtyard around which are set guest-rooms, washing-places and yards for pigs and poultry. An assembly-hall and the ancestral chapel are arranged diametrically opposite the main entrance, while lavatories, milling and pounding sheds, also brick-built, occupy lateral positions outside the main perimeter.

It remains to add a few words about other aspects of building in the different periods. The earliest type of roof-material was no doubt the fully grown hollow bamboo stem split in half longitudinally, convenient lengths being then laid in rows with the concavities alternately facing outwards and inwards. This very corrugated arrangement was afterwards carried out in half-burnt grey tile, as we have seen, and the glaze and reduced colours. Most of the Han tomb models suggest this roofing. It reached the climax of its capabilities when the tiles were made in earthenware and covered with a bright ceramic glaze; such are the orange-yellow roofs of Peking’s imperial palaces, the green roofs of temples, and the deep blue roofs of the Temple of Heaven and its ancillary buildings. Slates are used where locally available, and in the north and north-west there are (as we have seen) many houses with flat roofs made of a thatch of branches and reeds surfaced over with beaten mud. The Han stone tomb-shrines were roofed with slabs of stone, but the use of stone in housing for any purpose other than the plinths of columns is now found only in the Tibetan culture-area, and in a narrow zone along the Thai-hang Shan (between Shansi and Hopei).

Anciently, the flooring was nothing but the packed earth of the foundation, and earthen floors continue in use in many parts of rural China to this day. However, lime cement floors are favoured in the south, while floors of brick or stone are commoner in the north; both of these go back many centuries. In large or important buildings, whether public or private, the floors have often for many centuries been made of broad wooden planks. Numerous travel accounts of north China have familiarised Western people with the widespread use of a simple form of central heating in domestic houses there; this is the khang, a raised built-in divan along one side of the room, made of sun-dried bricks or often simply of tamped earth, under which a fire of any available fuel is stoked up for their Drink hot ... The Cooks of the Grandees and Mandarins, as also the Tradesmen that deal in Fire, as Smalls, Bakers, Dyers, and the like, both Summer and Winter make use of this Coal; the Heat and Smoak of which are so violent, that several Persons have been smothered thereby; and sometimes it happens that the Stove takes Fire, and that all that are asleep there are burnt to Death ... Every invention has its inconveniences.

All buildings have to be dulcified with furniture. In the field of cabinet-making China developed along unique and characteristic lines, which had a powerful influence on Europe in the eighteenth century. In the present book we can do no more than mention the carpentry techniques required, referring the reader to a number of useful books and papers which exist on the subject. Archaeological evidence also has been studied. It should not be supposed, however, that the Chinese awaited the activities of the Romans to copy their ideas. The first mention of that appears to be relatively late (+1st century), though Vitruvius describes the essentials of it in connection with the heating of baths. At present there is no way of deciding whether either civilisation influenced the other, or whether the invention was approximately contemporary and independent.

Device was common in Han times, for tomb-model houses show it (Lauffer, 3). This raises the question of its possible relation to the hypocaust so elaborately developed by the Romans. The first mention of that appears to be relatively late (+1st century), though Vitruvius describes the essentials of it in connection with the heating of baths. At present there is no way of deciding whether either civilisation influenced the other, or whether the invention was approximately contemporary and independent.

This Coal is brought from certain Mountains two Leagues distant from the City (Peking), and it is a wonderful thing that the Mine has never fail’d, notwithstanding that for above these four Thousand Years not only this City so large and populous, but also the greatest part of the Province, has consum’d such an incredible quantity, there not being any one Family, tho’ never so poor, which has not a Stove heated with this Coal that lasts and preserves a Heat much more violent than Charcoal. These Stoves are made of Brick like a Bed or Couch three or four Hands Breadth high, and broader or narrower according to the number of the Family; Here they lie and sleep upon Matts or Carpets; and in the day time sit together, without which it would be impossible to endure the great Cold of the Climate. On the side of the Stove there is a little Oven wherein they put the Coal of, which the Flame, the Smoak and Heat spread themselves to all the sides of the Stove, through Pipes made on purpose, and have a passage forth through a little opening, and the Mouth of the Oven, in the which they bake their Victuals, heat their Wine, and prepare their Cha or The; for that they always drink their Drink hot ... The Cooks of the Grandees and Mandarins, as also the Tradesmen that deal in Fire, as Smalls, Bakers, Dyers, and the like, both Summer and Winter make use of this Coal; the Heat and Smoak of which are so violent, that several Persons have been smother’d thereby; and sometimes it happens that the Stove takes Fire, and that all that are asleep there are burnt to Death ...
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of Western scholars before discussing furniture in print; already in about 1000 Huang Po-Seu² wrote of the special tables made in Peking (Ten Chi Thu³), and the line was continued by Ko Shan⁴ with his Thiek Chi Hu⁵ of +1617, and in our own time Chu Chi-Chien (9). These are only a few titles taken at random from a literature which the specialists must explore more fully. As for the various kinds of furniture in ancient times, and their special names, information will be found in Maspero (17) and Kelling & Schindler (1). It is thought that the primary unit of furniture was the low platform or dais (thu, later khang⁶), which, in various shapes and sizes, served for kneeling or sleeping on, or as a table or arm-rest. Possibly the radicals chhia⁷ng (frame, bed) and phien⁸ (lip, strip) were originally pictographs of this piece of furniture. Examples from as early as the +4th century, from princely tombs of the Chhu State, have as many as a dozen storeys (chi), with or without external galleries (wai). The pagoda is a great feature of the Chinese landscape. One chooses the word landscape advisedly, since (as we have already noted) the half-foreign origin of the structure from Indian Buddhism generally prevented it from arising within the city walls to compete with the drum-towers and gate-towers of cosmic-imperial authority. Its ancestor, the stūpa or dagoba, an artificial hemispherical mound, had also had cosmic or microcosmic significance, since it was a model of the whole world or at least the central sacred mountain;⁹ and it contained Buddhist relics at its heart, whence the superimposed parasols of honour from which perhaps the storeys of the pagoda ultimately derive.¹⁰ Its situation in or near Buddhist abbeys at some distance from the town gradually brought about a syncretistic connection with Taoist feng-shui geomancy,¹¹ until the time came when no kien city was complete without a pagoda (that) to harmonise the telluric influences by standing firm near by, on the most suitable isolated hill. Everyone who has lived in China has favourite pagodas of his own, and as in private duty bound, I would like to recall the beautiful towers which overlook the junction of the rivers south of the city of Mienyang in Szechuan,¹² and the eastern gate of Lanchow in Kansu. Sometimes they are found in groups of three (chhinh that), for example the great treasury near Tali in Yunnan, or the smaller group near Chi-hsing (Kashing) on the Grand Canal. These free-standing spires were never campaniles, though bell-casting was so ancient in China—but that does not mean that they were not often ornamented with innumerable small bells (thiek mut, somewhat like Swis cow-bells), which still hang from the eaves and make music when moved by the wind.¹³ Pagodas have as many as a dozen storeys (chi) with or without external galleries (wai).

(7) PAGODAS, TRIUMPHAL GATEWAYS AND IMPERIAL TOMBS

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⁸ See Anon. (42); Anon. (43), psl. 67, 71 b. Dr Lu Gwei-Djen and I had the privilege of examining these before publication when we visited the Honan Provincial Archaeological Institute at Ch’ang’chou in 1935.

¹⁲ Cf. Richter (1) on ancient Western furniture.

¹⁴ (l), p. 245.

² A Han bronze showing this exists, see Stone (1), p. 4. This would have been the development which led to the transfer of the word, which had originally meant the Catalpa tree, to mean chair, as it does today. Cf. Fujita Toyoshichi (2).


* Hence, no doubt, the chairs in the Tunhuang cave-temple frescoes, e.g. no. 285 (dated +338), and nos. 166, 206, 207, all Thang.

¹ We are indebted to Dr C. P. Fitzgerald for reminding us of the interest of this example of cultural diffusion. His own book on the subject (12) appeared too late to guide us in this survey.


¹⁶ This is well seen at Oedigama in Ceylon, where the excavated contents of the relic chamber (garbha) of the Sutíghara stupa (or dagoba) built by Parakkrama Bahu I (+1153 to +1186) are preserved in an adjacent museum. I had the pleasure of visiting this in 1938.

⁷ On the development of the pagoda from the stūpa or dagoba see, e.g., Combaz (3); Bulling (4). It is interesting to recognize here the implicit conflict between Indian and Sinic cosmism.


¹⁰ The sound of these aeolian bells on the fauces of the Tunhuang cave-temples in the night, surrounded by the quiet of the desert, is a memory never to be forgotten by those who have heard it. Cf. Fig. 709 (pl. 11).
Yun,

chapels and were never intended as dwellings, even for monks. A particular type, the Thien-Ning² style, so called from a famous monastery near Peking,² has a more or less unbroken tower from ground level to about a third of its height, the galleries and storeys being repeated only above that level.

Somewhat of this kind is the oldest extant pagoda in China, that at Sung-Yo Sau³ on the sacred mountain of Sung Shan in Honan. It is of brick (tsuan⁴) and was constructed in + 523 (Fig. 800, pl.) under the Northern Wei.⁵ There are fifteen storeys and the structure is twelve-sided. The arrangement exemplifies the statement in Thao Chhien's⁵ biography in the Hou Han Shu, that for pagodas (fou-tsu⁶),¹ one builds below a double (Chinese) tower (chung lan⁷) and above it one pile (Indian) shrines (chin phan⁸). But the beautiful spire on Sung Shan represents already a very sophisticated stage of development, and we must assume that the earlier towers were much simpler. The evidence is that they were square in plan, with successive repetitions of the octagonal one, and the majority of later pagodas are of this design. As it would take us too far to expatiate on their styles and beauties, we shall conclude with a reminder only that the south had also its great tradition of tower-building, as is seen for example by the twin pagodas of Zayton (Chhiian-chou) in Fukien, executed in stone with brick cores (+ 1 150 to + 1 250), elaborate corbel brackets imitative of woodwork in the so-called 'Indian style', and markedly upward-curving eave-corner.s²

Entirely true to its principle of building from repeatable single units or modules (p. 67), Chinese culture contains many small square one-storey buildings which represent, so to say, the pagoda's base or storey in isolation, the single cell apart from the body as a whole.⁴ As we shall shortly see more fully in connection with bridges (p. 167), the arch, in the shape of the barrel vault, was known and used in China probably in the Chou and certainly in the Han. But the true arch with keystone was not generally employed in the building of pagodas; the commoner construction was the corbelled vault. These can be studied particularly well in some of the small one-storey shrine buildings, of which the most famous example is the Sau-Mên Tha in Shantung⁸, dating from + 544. This has a corbelled vault sustained by a central pillar. Many structures of this kind are known, with or without central pillars, but only in use as shrines.⁶ On the desert across from Chhiien-fou-tang one comes upon just such a square one-room chapel, sheltering the image of a Thang abbot, who gazes for ever into the west towards the cliff face with its caves. Somewhat analogous is the small building on a forested hill behind (i.e. to the south of) the great Taoist abbey of Lou-Kuan Tha⁹ near Chhou-chih south-west of Sian.⁶ It is known as the 'Alchemists Tower' (Lien-Tan Lou).¹⁰ and consists of a single brickwork chamber entered by one

¹ Classical works on pagodas are those of Boerschmann (4) and Tokiwa & Sekino (1). Cf. W. C. Milne (1), a paper now a century old, but still interesting. Add Alley (5).

² Thien-Ning style near Peking, with its + 11th- or early + 12th-century pagoda, built under the Liao dynasty (Sickman & Soper (1), pp. 172 ff., pl. 173A; Anon. (37), pl. 61).

³ Sirên (1), pl. 103; Sickman & Soper (1), pl. 158A and p. 230; Anon. (46), p. 449; Anon. (37), pls. 16, 17; Bulling (2), fig. 40/32.

⁴ Such was the old term; according to Chu Chün-Shéng's commentary on the Shao Wên (Shao Wên Thung Hsia Tung Shêng) the word tha is first found in an inscription of + 736. Presumably fou-tsa transliterated buildings.

⁵ Ch. 103, p. 138.

⁶ Anon. (37), pl. 15; Sickman & Soper (1), pl. 157A.

⁷ Lo-yang Chhiieh-Lan Chi, ch. 1 (pp. 19 ff.), tr. Sickman & Soper (1), p. 229; the dates are due to Sirên (5).

⁸ The writer of the Yu Shù Chê in + 1 170 noticed this and remarked on it with admiration (ch. 4, pp. 15, pl. 44).

⁹ Bulling (2), figs. 46/39, 46/40; Sickman & Soper (1), pl. 162A and p. 244. This was built as a memorial to Han-chang. Another tower which shows this well is the Iron-Coloured Pagoda at Kau-fung built of glazed brick in + 1 044; (see Liang Fei-Liao (3); Sickman & Soper (1), pl. 166A; Anon. (37), pl., 52, 53). An example of a different kind is the Wu-Liang Tien temple, with its brick barrel vaults, at Suchow (see Sirên (1), vol. 4, p. 37).

¹⁰ From these early Thang centuries many beautiful monuments remain, such as the Ta-Yen Tha (Great Pagoda of the Wild Geese) at the Tzu-Hun Sau (Loving-Kindness Temple) at Sian. This was Hsüan-Chuang's headquarters, and it was built in + 652 (he had returned from India in + 645), then repaired in + 704. A square, rather squat, brick structure, of seven storeys, it is still to be seen south of the present city of Sian (Fig. 802, pl.); as also is the Hsiao-Yen Tha, slenderer and taller, with thirteen storeys (+ 708).⁵ The most natural development from the square plan was of course the octagonal one, and the majority of later pagodas are of this design. As it would take us too far to expatiate on their styles and beauties, we shall conclude with a reminder only that the south had also its great tradition of tower-building, as is seen for example by the twin pagodas of Zayton (Chhiian-chou) in Fukien, executed in stone with brick cores (+ 1 150 to + 1 250), elaborate corbel brackets imitative of woodwork in the so-called 'Indian style', and markedly upward-curving eave-corner.s²

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door and roofed by a corbelled vault, the layers of bricks rising from the angles to form a series of squinches. An octagon is formed where they meet, then a circular space, and finally a square. The brick was a burnt red brick unlike anything now commonly seen in the neighbourhood, and was arranged in billet mouldings outside

strongly reminiscent of those of the +7th-century Hsing-Chiao Sau pagoda. This little pavilion, so interesting for its proto-scientific associations, may also be of the Thang period, but as its eaves curl up at the corners it should perhaps rather be dated Wu Tai or early Sung. We do not doubt that in those days it was the scene of alchemical experiments.

It is not to be thought that the ancient Indian stūpa was completely absorbed into the Chinese pagoda and wrapped up aloft into the seventh heaven. In a thousand different shapes, it continued on the ground, to be used throughout the length and breadth of China, primarily for tombs and pious aedicules. In this it continued one of its earliest functions. Thus the desert in the neighbourhood of Chhien-fu-tung is strewn with exquisite shapes (Figs. 804, 805, pls.) commemorating monks of the Sung (above and below, front and back, left and right) were mutually linked like the cage of the thorax. Although people might walk on the struts, the six planes grasped and supported each other, so naturally there could be no more motion. Everybody acknowledged the expertise thus shown.

Surely we have to deal here with slanting struts inserted in an otherwise purely rectangular reticulum—diagonal wind bracing.

A remarkable department of pagoda building was that which made them of cast iron, or more often of bronze. These masterpieces have aroused the astonishment and admiration of foreign travellers in China from Ennin in the +9th century to Bernard in the 19th. The oldest existing iron pagoda, at Yu-Chhiian Sau (Jade Springs Temple) at Tanyang in Hupei, which dates from +1061, is of a very considerable size. It is burnt down in +1037 but soon rebuilt, though with only nine storeys, as we know from the enthusiastic description of the Japanese monk Jein, who climbed it in +1072. How long it lasted after that we do not know. Cf. Sickman & Soper (1), pp. 325, 326.

Many details in Boerschmann (4), pp. 336 ff.; cf. Needham (32), pis. 34, 35. They were not of course all of one piece, but were constructed of interlocking plates of metal.

This Japanese monk, so often quoted by us, visited Wu-thai Shan in +890 and mentions eight iron pagodas or rather stūpadhāra on the terraces there, all set up by the empress Wu Ts'e-Thian about +645. Another such monument, seen by him near Leichow in Shantung, had been erected as a votive offering by a naval commander, Wang Hsing-T'ien, in +665; it was 10 ft. high and had seven storeys. See Reichsauer (3), pp. 199, 237, 240, 243, 245, (3), p. 205.


Unless that, is the cast-iron pagoda at Ningpo, dating from +961, is still standing.

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Fig. 803. The 'Alchemy Tower' (Lien-Tan Lou) at the Taoist abbey of Lou-Kuan Thai near Chouchih south-west of Sian, Shensi.

a General view
b Exterior brick billet moulding (in plan)
c Interior corbel vaulting of squinch type supporting an octagon, then a circle and finally a small square.

d Date probably Wu Tai or early Sung.

sion of the techniques of all building to a particular specialised field. It may be guessed, however, that the simple truss forms represented by the sloping struts (bilih ciu, chhat chau, cf. p. 100 above) proved especially useful in high wooden towers. There is a significant story about Yu Hao in this connection. As the reader will remember from p. 81, Yu Hao was the Master-Builder who constructed the Khai-Pao Pagoda in Khai-feng in +989, as well as other famous buildings, and the author of the Mu Ching (Timberwork Manual). In the Mu Ching Pi Than Shen Kua has an entertaining story about the advice he gave to another artisan-architect some ten years later.

When Mr Chhien (Wei-Yen) was Governor of the two Chekiang provinces, he authorised the building of a wooden pagoda at the Fan-Thien Sau (Brahma-Heaven Temple) in Hang-chow with a design of twice three storeys. While it was under construction General Chhien went up to the top and was worried because it swayed a little. But the Master-Builder explained that as the tiles had not yet been put on, the upper part was still rather light, hence the effect. So then they put on all the tiles, but the sway continued as before. Being at a loss what to do, he privately sent his wife to see the wife of Yu Hao with a present of golden hairpins, and enquire about the cause of the motion. (Yu) Hao laughed and said: 'That's easy, just fit in struts (pan) to settle the work, fixed with (iron) nails, and it will not move any more.' The Master-Builder followed his advice, and the tower stood quite firm. This is because the nailed struts filled in and bound together (all the members) up and down so that the six planes (above and below, front and back, left and right) were mutually linked like the cage of the thorax. Although people might walk on the struts, the six planes grasped and supported each other, so naturally there could be no more motion. Everybody acknowledged the expertise thus shown.

As for the technical principles of pagoda building, depending as it did upon frameworks of wood and the bonding of bricks or masonry, they were really only the extension of the techniques of all building to a particular specialised field. It may be guessed, however, that the simple truss forms represented by the sloping struts (bilih ciu, chhat chau, cf. p. 100 above) proved especially useful in high wooden towers. There is a significant story about Yu Hao in this connection. As the reader will remember from p. 81, Yu Hao was the Master-Builder who constructed the Khai-Pao Pagoda in Khai-feng in +989, as well as other famous buildings, and the author of the Mu Ching (Timberwork Manual). In the Mu Ching Pi Than Shen Kua has an entertaining story about the advice he gave to another artisan-architect some ten years later.

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1 Yu Hao
2 Yu Hao
3 Yu Hao
4 Yu Hao
5 Yu Hao
6 Yu Hao
7 Yu Hao
8 Yu Hao
9 Yu Hao
10 Yu Hao
11 Yu Hao
12 Yu Hao
13 Yu Hao
14 Yu Hao
15 Yu Hao
size, being 70 ft. high and having thirteen storeys. Another smaller one (of nine storeys) is at Kan-Lu Su (Sweet Dew Temple) at Chenchang in Chiangtu. Local tradition dates it from the time of Li T’E-Yu, the geographer and minister of State (+787 to +849), who founded the temple, and more probably it was the work of Phei Chhi-tu (+1078 to +1086). In other cases a masonry core may be clothed with cast-iron plates, as at Pei-tu-tshan north-west of Sian, where a Ming (+15th-century) pagoda of this kind rises to a height of 74 ft. in nine storeys.

Another gift from Indian to Chinese architecture was the triumphal gateway, or phai-lou, a free-standing gate of wood or stone, with superimposed beam lintels, erected for commemorative or triumphal purposes on an approach to a tomb, temple or palace, or even across any road or village path. Its name implies that it was to bear aloft a notice, often an epigram. The traveller on the stone pathways of Szechuan comes upon relatively simple ones from time to time, proclaiming the name of a virtuous widow or a popular magistrate. Greater occasions call for three, five or seven arches in a row (Fig. 807, pl.). Lecomte, in the seventeenth century, wrote:

"This temple was founded in the 1st century by Prince Kuang of Ch’in for the celebrated monk Chhi-lu, founder of the Thien Thai school of Buddhism (cf. Vol. 2, p. 407). The remains of 157 monks and 57 novices, spiritual descendants of this divinity, are cast in the metal panels of the pagoda."

They consist in three great Arches abreast, built with long Marble Stones. That in the middle is much higher than the other two. The four Columns which support them are some­where round, but oftener square, made of one only Stone placed on an irregular Basis. In some cases their weight is some 53 tons. A great triumphal arch was the stone gateway (phai-lou) at Pei-lu-tshun, 6th century. In other cases a masonry core may be clothed with cast-iron plates, as at Pei-tu-tshan north-west of Sian, where a Ming (+15th-century) pagoda of this kind rises to a height of 74 ft. in nine storeys.

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Fig. 732. The Great Wall near the Nan-khou pass, north of Peking (photograph of 1962, Chin Shou-Shen, 1). Note one of the slotted access staircases in the right-hand lower corner. Cf. Fig. 13 in Vol. 1. See pp. 46 ff.
Fig. 728. The style of Chinese defensive architecture as seen in a Thang fresco painting (cave no. 468 at Chhien-fo-tung; T 217, P 70). Its general position in the cave can be seen in Vincent (1), pl. 29. One notices the battered, i.e. inward sloping, wall surfaces, and the galleried barracks pavilions surmounting corner towers and gate-towers. The dresses and uniforms of the period (c. +660) are also noteworthy. There has been some doubt about the subject of the picture. Waley (19), p. 124, pl. 17, thought it represented the fight between the armies of Kusinagara and Magadha for the possession of the Buddha's relics; but later, noticing that one side have lances only and the other side only spears, he proposed (in Grey & Vincent (1), pp. 13, 58, col. pl. 44) that it shows the young Sakyas engaging in military exercises outside the city of Kapilavastu, superintended by the Buddha when still the young prince Sakyamuni. Photo: Lo Chi-Mei, 1943.

Fig. 729. Part of the ramparts of the Ming fort at Chia-yü-kuan, guarding the western end of the Great Wall (orig. photo., 1943). Cf. Fig. 14 in Vol. 1.

Fig. 730. The fort at Chia-yü-kuan; an inclined ramp leading to one of the barracks pavilions on the walls (orig. photo., 1943).
Fig. 723. Box bond brickwork in the walls of the old Lo family temple beside the Chungking-Chhengtu road, Szechuan (orig. photo., 1943).

Fig. 725. Hollow stamped and fired brick from a Han tomb-chamber (British Museum, after Davy, i). Two human figures stand, inter alia, underneath porticoes with two-tiered roofs.

Fig. 727. The walls of Sian in 1938 (Bishop, 6). In the foreground, one of the ramps giving access to the ramparts. As in many other cities, shrinkage of population had given place for much agricultural land within the walls.
Fig. 718. A military guard at a post-station in 1793 (from Staunton, 1). See pp. 33 ff.

Fig. 720. Tamped earth (sève pisé) walling under construction; poles used as shuttering, near Sian (orig. photo., 1964).

Fig. 721. Brickwork facing and tamped earth core of a Han watch-tower on the ancient lians; at Thien-shui-ching (Sweetwater Well) beside the desert road between Anhui and Chhien-fo-tung, in the far north-west of Kansu (orig. photo., 1958).

Fig. 722. Contemporary adobe brick walling for a building under construction in the oasis at Chhien-fo-tung (orig. photo., 1958). Upright layer bonding on a foundation of baked brick and stones.
Fig. 714. The old road at Ku-shan near Fuchow in Fukien.

Fig. 715. A typical rural path, at Ko-lo-shan near Chungking in Szechuan (orig. photo., 1943).

Fig. 716. Old road at Pa-ta-chhu near Peking (orig. photo., 1958).

Fig. 717. The way into the hills from the Yangtze at Li-chuang in southern Szechuan (orig. photo., 1943).
a stone tortoise (+ 1420). This building is guarded by four ceremonial columns carrying stylised clouds (Thien Chùi Hua Piao¹). Then, as the procession path through the fields of grain curves slowly to the right, a long range of stone statues on each side is encountered, camels and elephants, horses and mythological animals, civil and military officials (Fig. 820, pl.); this ends in another phái-lou (the Lung-Fêng Mên²). The traveller now crosses two bridges (or rather, he used to do so, for they are today partially washed away³) and begins to be able to make out the majestic roofs of the temples, backed by their tumuli, on each side of the valley reaching back as far as the eye can see. Along a serpentine way paved with great flat stones he reaches at last the tomb of the Yung-Lo emperor (+ 1424), the greatest of the family, with its encircling wall and gatehouses (the Chhâng Ling). To the right, in the first courtyard, as he enters, he passes a pavilion housing the steles which record the duty enjoined upon the local city magistrate by the first Chhing emperor to maintain in perpetuity these monuments of a conquered dynasty (Figs. 811, 812, pls.). Before him he has the main ancestral hall (Ling-En Tien³), today empty, but still sustained by its twenty-four giant cedar columns, each 12 ft. in circumference and 60 ft. high.⁴ Penetrating through this, he gains still further courts, and passing the altar in the sacred grove comes at last to the Spirit Tower (Ling Thai⁵) carrying a great pavilion (Ming Lou⁶) which shelters another stele (Fig. 813, pl.). It will take him a good half-hour to make the round of the walls (Pao Chhêng⁷) which enclose the tumulus. And from the tower itself he will enjoy a magnificent view of the whole valley, and meditate upon the sublime sense of organic plan which conceived the whole pattern of landscape and buildings,⁸ as well as the manifestation of the genius of a people in the skill of its architects and builders.

¹ I leave this description just as I wrote it in 1952, after an unforgettable visit in the company of Mr. Rewi Alley. The great tomb-temples were then in poor repair again after the years of the Second World War, and at the Chhâng Ling we had to push through tangled thickets and long grass among the halls and altars. Though in such conditions there was romantic beauty, the situation completely changed in the ensuing decade, and when I came there again eight years later with Prof. Yeh Chiu-Sun and Dr. Lu Gwei-Djen as well as Mr. Alley, all buildings, courts and gardens were magnificently restored and kept up. One could take tea outside the main gate, and buses brought out the people of Peking to enjoy their possession just as those of Granada are accustomed to enjoy the Alhambra and the Generalife. The Ming Tombs have also changed in two other perhaps more fundamental ways (cf. Needham, 46). Systematic excavation has been begun, and the first tomb to be opened, that of the Wan-Li emperor (the Ting Ling⁹), has yielded a mass of extraordinary treasures; cf. Anon. (122); Hâi Nâi (4). We were privileged to view this before it was opened to the public. In the three large halls built some 60 ft. below the surface of the mound behind the range of temple halls on the surface, one finds the throne of the emperor, his empress and his principal consort, together with the daos on which their coffins rested. Particularly striking are the doors of white jade about 12 ft. high, kept in place by colossal bronze lintels about the thickness of a man's body. Secondly the valley floor, where we had to dig out our vehicle from the mud in 1952, is now covered with many feet of water, for in 1958 a dam was built across its mouth, largely by the voluntary labour of the people of Peking (Fig. 814, pl.). Although this is primarily for power and the irrigation of the dusty North China plain, the reservoir has much increased the beauty of the site as a whole, since it mirrors in its waters ten or twelve of the tomb-temples at the foot of their mountain background. On the epic of its construction see Fig. 877 (pl.) and Yen Yao-Ching et al. (4); Tan Al-Ching (4); Chao Yung-Shen (4).

² Perhaps these were a product of the voyages of the admiral Chhêng Ho (cf. pp. 487ff.).

³ All honour to the geomancers Master Wang Hsien of Shantung, and Master Liao Chhiung-Ching of Chiangsi, who appear to have directed the builders in their auspicious work.

⁴ Perhaps these were a product of the voyages of the admiral Chhêng Ho (cf. pp. 487ff.).

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¹¹ All honour to the geomancers Master Wang Hsien of Shantung, and Master Liao Chhiung-Ching of Chiangsi, who appear to have directed the builders in their auspicious work.
Fig. 739. The Summer Palace (I Ho Yuan) at Peking (Anon. (37), pl. 123). In its present form it dates from 1888, but much of the palace-temple-park complex formed part of the 'Garden of Clear Ripples' (Chhing I Yuan) built by the Chhien-Lung emperor in +1751 and extended in +1760.

Fig. 740. A typical farmhouse; near Shaoshan in Hunan (orig. photo., 1964).
Fig. 733. The Great Wall further west, near Lien-hua-chhih, in north-western Shensi, on the border of the old province of Ninghsia. Range after range the mountains descend to the Ordos desert, and along the ridge of one of them can be seen the wall marked prominently by its 'mile-castles' (photograph of 1909, Geil, 3).

Fig. 734. The Great Wall protecting the Old Silk Road in the Kansu panhandle (cf. Vol. 1, p. 59); now only a ridge of compacted loess with many breaks (orig. photo. 1943).

Fig. 735. Towers of the 'First Frontier Wall' (the Great Wall) along the boundary between northern Shensi and Inner Mongolia, seen from near Chhang-lo-pao village in the neighbourhood of the city of Yulin (photograph of 1920, Clapp, 1). Cf. Fig. 15 (in Vol. 1) and Fig. 721. The Wall has here been almost buried by the sands of the Ordos desert.

Fig. 736. A check-point in the Inner Wall, the Buddhist gate of Chū-yung-kuan in the Nan-khou pass (orig. photo. 1964). See p. 48.
Fig. 742. Entrance to the tomb-temple of the first Chihling emperor at Shenyang (Mukden) in Liaoning (orig. photo., 1952).

It has been suggested that this Taoist symbol derives from the Paschal Lamb of the Nestorians (cf. Vol. 2, p. 160).

Fig. 743. Central octagonal pavilion, sited on the main axis, of the 'Blue Goat Temple' (Chihling Yang Kung) in Chchengtu, Szechuan (orig. photo., 1943). It has been suggested that this Taoist symbol derives from the Paschal Lamb of the Nestorians (cf. Vol. 2, p. 160).

Fig. 746. Corner tower on the wall of the Imperial Palace in Peking (roof-tiles yellow, sides a faded murrey colour, the wall itself grey).
Fig. 748. The skyline of Peking; looking north-west towards the yellow-tiled roofs of the halls of the Imperial Palace (orig. photo., 1952).

Fig. 749. The inner garden of a Taoist temple (Boerschmann (2), pl. I, (3a), pl. 103); the votive temple of Chang Liang (Huang Shih Kung, cf. Vol. 2, p. 155) at Miao-t'ai-tzu, on the road through the Chhin-ling Mountains, in northern Shensi. See p. 72.

Fig. 750. A private garden in Suchow, now open to the public (orig. photo., 1964). The Liu Yuan, founded by Hsi Shih-Thai in +1521; a corner of the artificial lake.
Fig. 751. Air view of the axial plan of the capital city of Peking (from Gutkind (1), pl. 66, photograph of c. 1925). We are looking south from a point just north of the Coal Hill gardens, with the old buildings of Peking University to the left. The Forbidden City (the Imperial Palace) is sharply demarcated by its broad moat; beyond it can be seen on the left the Imperial Ancestral Temple and on the right the Temple of the Land and Grain. Far in the distance, at the top of the picture, one can make out on the left the wooded temenos of the Temple of Heaven, and on the right that of the Temple of Agriculture. The outer and inner city walls, between which these lie, cross the picture almost horizontally. Cf. Fig. 752 on p. 78.

Fig. 753. The five marble bridges across the Stream of Aureate Water (no. 9 in Fig. 752) between the Meridian Gate (no. 8) and the Gate of Supreme Harmony (no. 10).

Fig. 754. The Meridian Gate, or Noon Gate, of the Purple Forbidden City (photo. Vergassor, in Mirams (1), about 1936).
Fig. 755. Air view of the temenos of the Altar and Temple of Heaven, from the south (Anon. (37), pl. 104). Cf. Fig. 752 on p. 78. In the foreground the Orbed Concentric Platforms of the Altar, then the Hall of the Infinite Canopy of Heaven (the smaller round building), and at the northern end of the causeway, surmounting platforms round and square, the Hall of Prayer for the Year. To the right at the top, the complex of buildings for the fasting and preparation of the imperial celebrant.

Fig. 756. Image of Kungshu Phan (Lu Pan), patron saint of artisans and architects (cf. Vol. 4, pt. 2, p. 44 and Fig. 354), one of those in the temple at Mai-chi Shan in southern Kansu (orig. photo., 1958.)

Fig. 758. One of the Buddhist paradises depicted in the frescoes of the Tunhuang (Chhien-fo-tung) cave-temples (cf. the discussion of Waley (19), pp. 126 ff.). A Thang representation, painted about +700, of the Western Heaven of Amida Buddha (cave no. 172; from Anon. (13), pl. 37). Most of these pictures are full of architectural detail worth careful study, and generally contain more than one system of perspective, as in this scene, where one can find axonometric as well as optical drawing, and pick out at least five separate vanishing-points. See the discussion on perspective, pp. 112 ff.
Fig. 761. One of the simplest forms of the corbel bracket system, part of the woodwork at the 8th-century temple of Nan-Chhan Ssu in the foothills of Wu-thai Shan, Shansi (orig. photo., 1964). Cf. p. 95 and Figs. 760, 762, 773, 774.

Fig. 765. Woodwork at Fo-Kuang Ssu, another Buddhist temple in the foothills of Wu-thai Shan, Shansi. Built in 585. Roof detail showing the lever arms or cantilever principal rafters (ang) piercing the corbel bracket clusters (orig. photo., 1964). Cf. pp. 95, 100, and Figs. 766, 767.

Fig. 764. Woodwork at Fo-Kuang Ssu, another Buddhist temple in the foothills of Wu-thai Shan, Shansi. Built in 585. Roof detail showing the lever arms or cantilever principal rafters (ang) piercing the corbel bracket clusters (orig. photo., 1964). Cf. p. 95 and Figs. 760, 762, 773, 774.

Fig. 766. The theatre-temple for New Year and other plays at the Ming fort of Chia-yü-kuan at the western end of the Great Wall (cf. Figs. 729, 730 and Fig. 14 in Vol. I). The hipped gable roof curves gracefully up at all corners (orig. photo., 1943).

Fig. 767. Typical Chinese roof assembly under construction. Cross-beams (liang), posts (cho) and purlins (heng) for a small gate-house, in a glade of the oasis at Chhien-fu-tung (orig. photo., 1958).
Fig. 768. A larger construction, the skeleton framework of a new commune headquarters at Ho-thang near Lo-phing in north-eastern Chiangsi, showing columns, tie-beams, cross-beams, and posts for the purlins (orig. photo., 1964).

Fig. 769. Weight-bearing inverted V-braces (jeen tsu kung, chhua shou) at Fo-Kuang Ssu, a Thang building of + 857 (photo. Liang Ssu-Chheng, 1). See p. 100.

Fig. 770. Workers' houses under construction at Lanchow, Kansu, in 1943. Although at first sight they have a Western look, the walls are not weight-bearing, and the whole timber framework follows the traditional style (orig. photo.).
Fig. 775. An example of mixed perspective principles in an 18th-century scroll-painting of the Madonna, half-European and half-Chinese in character; probably the work of the Jesuits, either Joseph Castiglione (Lang Shih-Ning) or Jean Denis Attiret (Wang Chih-Ch'eng), painters at the court of Ch'ien-Lung; or of a Chinese artist influenced by them (Laufer (28), pl. 9). The colonnade has an obvious vanishing-point, but the interior of the house follows an axonometric projection. Cf. Fig. 642 in Vol. 4, pt. 2. On Castiglione (+1688 to +1766) and Attiret (+1702 to +1768) see Pliester (1), pp. 635 ff., 787 ff. On perspective in general in China and the West see pp. 111 ff.

Fig. 777. One of the oldest Chinese landscape pictures extant; a pair of hollow-tile door-panels from a Han tomb of c. 60 excavated near Chingchow. Continuous depth recession is conveyed to the onlooker by the zigzag lines of a road and a garden wall, so that he seems to be seeing the view from the top of a hill. The scene is constructed by the repeated impression of standard stamps on the clay while still soft. From Bulling (12).
Fig. 771. Miniature buildings as interior decoration; the flying bridge pavilion of the Sūtra Repository at the Lower Hua-Yen Ssu temple at Ta-thung in Shansi (orig. photo., 1964). The great richness of the corbel bracket clusters in this model, made in +1038, is noteworthy, as also the presence of two rows of ang in its roof. See p. 106.

Fig. 772. The map of the city of Suchow carved on stone in +1229 by Lü Yen and two other local cartographers (from Liu Tun-Chiên (5) and Chavannes (8), pl. 9). North at the top. This stele is still preserved in the old College (now a Middle School) attached to the Confucian Temple (Wên Miao) in the lower left, south-west, quarter of the city. The Grand Canal (Yü Hsü) comes in at the top left hand corner as the third stream down, then it flows past the western city wall and out at the bottom just beside the large character Nan (south). Other waterways surround the city, providing canals within it almost as numerous as the streets, and crossed by 372 bridges. Marco Polo, who may well have seen the stele itself, referred to 6000 bridges, but his scribe probably exaggerated by two powers of ten. On the role of canals in East Asian urban planning see p. 309. Part of Lake Thai-hu is visible in the extreme left-hand bottom corner; above it there are the hills which protect the city from the lake, and at the top left hand corner the famous hill of Hu-chih-shan Shan is shown. The Buddhist temple of Pao-En Ssu can be made out in an enclosure at the extreme north of the city, and near the centre, above the inner walled complex of government buildings labelled Phung-chiang Fu (the old name of Suchow), is the great Taihct temple Hsuan-Miao Kuan. See p. 107.
Fig. 780. Excavating a rectangular building, with internal structures and post-holes, storage spaces and ovens, in the large late Neolithic settlement of Pan-pho-tabun near Sian in Shensi (1954). Some of the buildings of this Middle Yang-shao culture, dating from about -2,500 (cf. Vol. I, pp. 81 ff. and Chêng Tê-Khun (9), vol. I, pp. 73 ff.) are impressive in size. Photo. CPCRA and BCFA. See p. 121.

Fig. 781. A Shang royal tomb excavated at Hou-chia-chuang in the area of the capital of Anyang; c. -1,350 (Chêng Tê-Khun (9) vol. 2 pl. 3o). Photo. Academia Sinica. See p. 121.

Fig. 782. A two-storied hall depicted in the Hsiao-thang Shan bas-reliefs (c. +123); the rubbing published by the Fêng brothers in 1822, Chin Shih So, Shih sect. ch. 1. (pp. 90, 91). In the architecture of this Later Han reception hall the clusters of corbel brackets at the top of each column are noteworthy, as also the absence of any curvature of the roof lines. The same features are seen in Fig. 725.
Fig. 784. A country manor-house of the Han period depicted on a Szechuanese moulded brick, probably intended for the decoration of a tomb-shrine (Anon. 22). Entrance gate at lower left, to the right the kitchen with well and stove, behind, a look-out tower with a staircase and in the courtyard a watchdog and a servant with a broom; at the back on the left the master is entertaining a guest while a couple of cranes dance in the garden. The corbel brackets at the top of the tower are to be noted, and the transverse framework of the reception hall. The roofing of all the tamped earth walls is also characteristic.

Fig. 785. One of the tomb gate steles with architectural tops found in Szechuan, the column at the tomb of Feng Huan (+121). The corbel bracketing under the simulated wooden roof is very bold and clear (photo. Sickman & Soper, 4). Cf. the stele of Shen Fu-Chun shown in Fig. 507, Vol. 4, pt. 2. All these are modelled on gate watch-towers (chhiieh).

Fig. 786. Tomb model of a fortified manor-house of the Han period dated +76 found in Kuangtung (Anon. 43). Towers at each corner and two pavilions on the central axis enclose two model buildings of two rooms each; these when taken out reveal figures engaged in various farming and domestic activities.
Fig. 787. Dragon columns of the main hall (Sheng Mu Tien, Hall of the Holy Mother) at the great Taoist temple of Chin Tahu, south of Tshiyuan in Shansi (orig. photo., 1964). This magnificent hall is of great interest in many ways. Built originally about + 1030, its present form dates from the restoration of + 1102. The front porch pillars lean markedly inwards, and the whole front sags in the middle, perhaps intentionally. In the structural woodwork, elaborately painted, true and 'false' beaked 'ang alternate over the columns; three examples of each kind can clearly be distinguished in the picture. This would be one of the earliest appearances of the 'false' or horizontal beaked 'ang (see the discussion on pp. 94 ff. above). Inside the temple there is a remarkable set of some 30 wood and plaster statues, approximately life-size, representing the attendants of the goddess and dating from the Sung period. Many illustrations of these, with other temple buildings and their contents, can be found in Anon. (66, 67).

Fig. 788. Origins of the pagoda; Han pottery model of a tower (Anon. 33). At each storey of the tower (lou) corbel bracket woodwork supporting balconies and roofs can be seen. From a +1st- or +2nd-century tomb at Wang-tu in Hopei. See pp. 128, 137 ff.
Fig. 789. General view of the front of Fo-Kuang Ssu (Buddha’s Aureole Temple), standing among the misty foothills of Wu-thai Shan, the second oldest wooden structure still extant in China, dating from +1477 (orig. photo. 1964). The double and triple ang complexes are conspicuous among the plain tou-hung assemblies. Cf. pp. 95, 100, and Figs. 760, 764, 765.

Fig. 790. Thang woodwork at Tunhuang; the balcony outside cave no. 305 (T 196, P 63), probably of the same date as the frescoes and therefore, according to an inscription, +794 (orig. photo. 1943). Since then it has been preserved and restored.

Fig. 791. Tenth-century woodwork; the Kuan-Yin Hall of the Tu-Lo Ssu (Joy-in-Stolidude Temple) at Chi-hsieh in Hopei, built under the Liao rule in +984 (photo. Anon. 26). More than a dozen different kinds of bracket arms were used to suit the different positions in a lantern hall permitting the sixty-foot image to penetrate all three floor-levels. Several diagonal corbel brackets can be seen in the picture.
Fig. 792. Octagonal wooden pagoda tower, some 200 ft. in height, at the Fo-Kung Ssu (Buddha Palace Temple) at Ying-hsien in Shansi, built in +1056 (photo. Anon. 26). Just under sixty different kinds of bracket arms were used. See pp. 131, 137 ff.

Fig. 793. Wood and brick domestic architecture possibly from the tenth century; the Chhen family mansion at Shantan in Kansu, showing the east end of the main block and a part of the east wing (photo. Alley). Perhaps because of the marked battering of the external columns of the transverse frames, this building has stood through many destructive earthquakes, but in date it may not be earlier than the +13th century.
Fig. 794. Leaves from the sketch-book of an English architect in China; drawings of provincial domestic buildings by Francis Skinner (1955).

a Honan and Hupeh; above left, a dwelling or barn with adobe brick walls and brown-tiled roof, above right, ridge terminals, below left, a shrine to a tutelary deity (thu ti miao), below right, a courtyard farmhouse.

b Hopei; top, adobe brick house with stone quoining, flat thatched roof and brick dentils along the eaves; bottom, house with brick walls and plastered roof with tile eaves, prominent lattice windows appearing at the back of a recessed portico.

c Honan and Hupeh; courtyard farmhouses in a row forming a village façade, below, isolated courtyard houses often, as on the right, with noticeably lop-sided gables on the wings.

Fig. 795. Further leaves from Francis Skinner’s sketch-book. See pp. 132 ff.

a Kiangsu; free-standing farmhouses with light terracotta adobe brick walls, tiled roofs with central and terminal ridge ornaments, and recessed bays in the centre of the entrance side having decorated doors and decorative carving above them.

b Hunan; top and centre, houses with portico on the entrance side and prominent stepped gables, bottom, typical house half-door entrance with lintel supported on shaped brackets.

c Hunan; top, part of a row of houses with alternate blank and recessed bays, the latter with eaves supported on posts, and arched entrances flanked by openwork screens; the main transverse walls ending in shaped gables. Centre, house with recessed bay forming portico. Bottom, stepped and decorated gable outlined with a white band; this is very characteristic of Szechuan and Yunnan also.
Fig. 796. A typical manor-house in Szechuan, with its tiled roof, ornamental finials, half-timbered and white plastered walls, standing on a solid foundation of large stone blocks. The building in this picture was for years during the second world war the home of the Institute of History and Philology of Academia Sinica (orig. photo., 1943). My collaborator in those years, Huang Hsiung-Tsung, is standing in front of it.

Fig. 797. Two Ming sets of tomb-models representing farmstead buildings, probably of the 15th century (photos. ILN).

a Set of seven pieces in baked clay, forming a courtyard. The smaller gate should be placed forward, with the larger one and the spirit-wall outside it. The reception hall is reminiscent of that in Fig. 784 but it has the fully developed roof-curve lacking in the Han picture. Eumorfopoulos Collection, British Museum.

b A more elaborate set, with walls and many models of farm servants and domestic animals, including the master's nag and groom in the foreground. Ontario Museum, Toronto.

Fig. 798. Interior view of a four-storey apartment house of the Hakka people in Fukien, one of the most remarkable types of Chinese rural dwelling. The need for security among an originally somewhat hostile indigenous population is thought to have led to the development of these large circular communal buildings with walls mainly blank on the outside, defensible entrances, and public service facilities in the centre of the ring. Near Yungting. See p. 133.
Fig. 799. A typical mounting for aeolian bells, the nine-storey façade of cave no. 96 at Chhien-fo-tung, Tunhuang (orig. photo. 1958). The Buddha image which it protects is 102 ft. high, set in a cave 130 ft. high, 20 ft. deep and 31 ft. broad.

Fig. 800. The fifteen-storey brick pagoda at Sung-Yo Ssu (Temple of the Sacred Mountain of Sung) in Honan, built in + 433 under the Northern Wei (photo. Anon. 06). Elegantly polygonal with twelve sides, it exemplifies the statement that for a pagoda one must pile Indian shrines on the top of a Chinese tower (p. 138).
Fig. 80r. The six-storey Satmahal-prasadaya at Polonnaruwa in Ceylon, an archaic structure built c. +1185 and now considered a particular type of dagoba (photo. Thomas). The simplest of early Chinese pagodas may have been something like this, and the pattern persisted into later times (see Fig. 802).

Fig. 802. The Ta-Yen Tha (Great Pagoda of the Geese) at the Tzhu-En Ssu (Loving-Kindness Temple) at Sian, built in +652 after the return of the pilgrim-scholar Hsüan-Chuang from India, and repaired in +704 (orig. photo. 1958).

Fig. 804. Crumbling stūpa tombs on the desert across the dry river-bed from the Chhien-fo-tung cave-temples, some of which can be seen in the escarpment of the background hills. On the left the northern end of the oasis can be seen, and the tomb of Wang Tao-Shih, the discoverer of the famous Tunhuang library, is very near by. These stūpa tombs, commemorating monks of the Thang, Sung and Yuan periods, decay extremely slowly because of the dryness of the climate, and their coloured plaster-work is scoured and polished by the sandstorms of many ages. They extend over the desert for miles, up to and within the foothills of the San-wei Shan. Each one has a different design, and every one is beautiful (orig. photo. 1943, taken in the early morning).

Fig. 805. A number of model stūpas or dagobas fallen out from the heart of one of the large stūpa tombs on the desert near Chhien-fo-tung, as it decayed. Such a tomb may contain as many as a hundred, all formed from the bones of the dead monk mixed with a suitable clay and pressed into a mould, then dried in the sun like adobe brick. The thumb-marks of the makers in the +13th or +14th centuries are still visible on the base of the models, and if broken open they may contain a dhāranāi charm (chen yen) or magical prayer. Orig. photo. 1943.
Fig. 806. Stūpa tombs (chhuang) of Ming and Chhing date in the graveyard of a Buddhist abbey in Shantung (photo. Forman & Forman (r), p. 109). The superimposed sections, round, square, octagonal, lotus-petalled, etc., were interpreted as symbolising the five elements.

Fig. 807. A stone triumphal gateway (phai-lou), one of many in the streets of Chhili-fou in Shantung, site of the tomb and Temple of Confucius (photo. Forman & Forman (r), p. 103). In somewhat simpler forms this kind of stone gateway is widely found, imitating woodwork in its roofs and bracket arms. See p. 142.

Fig. 808. A wooden triumphal gateway (phai-lou), that at the main south entrance of the Confucian temple (Wen Miao) at Sian, Shensi, now the Provincial Museum, with its famous 'Forest of Steles' (Pei Lin). The inner side of the city wall can be seen in the background, and in front the marble balustrade of the semi-circular pool (phace-chhiao), canonical in Confucian temples, crossed by its arched bridge (yau chhiao). The phai-lou, supported by struts on each side, blossoms in a wealth of seven rows of corbel brackets one above the other, holding up the massive roofs that cap the whole (orig. photo., 1958).
Fig. 809. The tomb of the Thang empress Wu Te Thien (Wu Hou, r. +684 to +704), the Chhien Ling, at Chhien-hsien, north-west of Sian in Shensi. The tomb, within a steep-sided natural hill, not a tumulus, is approached by a horizontal adit some 200 ft. in length, but has not yet been opened for archaeological study. Below there is the long avenue of ministers, officials and Buddhist monks here seen, as well as about a hundred smaller figures representing envoys and tribute-bearers from various nations to the Thang. Orig. photo., 1964.

Fig. 810. The Ming imperial tombs north of Peking; a pair of camels in the long double row of figures flanking the avenue of approach, in the distance the great pavilion housing an inscribed stele (Pei Thing). Orig. photo., 1952. See pp. 143 ff.

Fig. 811. Ming imperial tombs; the tomb-complex (cf. Arlington & Lewisohn (1), pp. 315 ff.) of the Yung-Lo emperor (r. +1403 to +1424) known as the Chhang Ling. A pavilion on the right-hand side of the courtyard inside the great entrance-gate. Orig. photo., 1952; since that date the temple and gardens have been completely recovered from the wilderness, and now form a public park much visited by the people of Peking.

Fig. 812. Ming imperial tombs; the inscribed stele within the pavilion shown in Fig. 811. This was erected by the first Chhing emperor to record an edict that the tombs of the rulers of the conquered dynasty should be well maintained in perpetuity (orig. photo., 1954).
Fig. 813. Ming imperial tombs; the tomb-temple of the Yung-Lo emperor at Chheng Ling. It stands behind the main Hall of Sacrifice and in front of the broad tumulus containing the burial chambers surrounded by a rampart; it is known as the Brilliant Tower (Ming Lou) and shelters a large stele mounted on a tortoise of stone. The figures on the wall give the size (orig. photo., 1952). The object in the middle foreground is an open-air altar.

Fig. 814. A coloured panorama set up at the Ming Tombs dam site in 1958 (cf. p. 144), showing the thirteen tomb-temples set in the valleys of the Thien-shou Shan range and the artificial lake which now covers the main valley floor (orig. photo.).
BRIDGES

When the architect Frontinus, writing on the aqueducts of Rome in the 1st century, completed his description, he added the following words: 'With such an array of indispensable structures, carrying so many waters, compare, if you will, the idle pyramids, or the useless, though famous, works of the Greeks.'

His Chinese counterparts would have had some conscious sympathy for the attitude of mind which lay behind this remark, but no small part of the genius of their civilisation lay in a subtle combination of the rational with the romantic, and this had its result in structural engineering. No Chinese bridge lacked beauty and many were remarkably beautiful.

In describing the achievements of China in bridge-building it will be necessary to follow a logical classification. Presumably the simplest type of bridge is a beam of wood or any rigid material laid transversely across the stream or other obstacle to be bridged. Here the limiting factors are soon reached, for before any considerable span has been attained, the material will cease to support the weights which its builders will want to send over it. We shall see shortly that the Chinese explored the possibilities of this simple method up to the maximum strength of the strongest natural material available, in a series of remarkable megalithic bridges. Release from the narrow confines of the capacities of single beams or blocks came only with the development of the truss, in which many component members, each taking tension or compression only, are jointed together in reticular geometrical systems. This was fully developed only at the Renaissance in Europe.

As Parsons suggests, it was perhaps originally an

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* De Aquis Urbis Romae, 1, 16. Frontinus (+35 to +104) was a contemporary of Wang Chhung. For a modern treatment of his subject see Ashby (1). Cf. Vol. 4, pt. 2, p. 128.

b Today some of the most important are carefully restored and preserved as national monuments; cf. Mao I-Sheng (2).

c A few words on the literature available may be in order here. Books on bridges tend to be folkloristic (e.g. Robins, 2) or, if artistic, technically misleading (Brangwyn & Sparrow, 1). What is said to be the best history of bridge engineering (Tyrell, 1) has not been accessible for us, but there is much of value in Straub (1) and Uccelli (1). Shirley-Smith (1) is authoritative. As usual, help is also to be obtained from old-fashioned books which have been banished from current shelves, e.g. Jenkins (1) and Fidler (1). Modern popular accounts of bridge-building are not very helpful, e.g. A. Black (1) or Steinman & Watson (1), but one could begin no better than by reading the tour d’horizon articles of Steinman (2), Florange (1) has an interesting analysis of medieval European bridges as depicted on coins—but space precludes mention of further items in the large European specialist literature. Most general books on Chinese architecture, e.g. Anon. (77); Sirén (1); Miramon (1), etc., have something on bridges, but there is a special monograph by Fugl-Meyer (1) which is much more informative than it appears at first sight.

The counterpart to this in China is the larger and very professional work of Lo Ying (1), published more than twenty years later. An excellent album of photographs of Chinese bridges of all periods, with good explanatory text, is due to Thang Huan-Chheng (1). The earlier work of Liu Tun-Chen (2) also covers the field, but with particular attention to beam and cantilever bridges. The Department of Oriental Antiquities at the British Museum possesses the Eagle Collection of photographs of Chinese bridges, catalogued by Mr. William Willetts, but it concerns mainly arched structures and has not yet been made generally available. Lo Ying (1) deals exclusively with this type.

d Especially by Andrea Palladio, c. +1570; cf. Davison (1); Uccelli (1), p. 682. But Leonardo had been familiar with the principle. As we have seen (pp. 101, 141 above), the truss had not been entirely lacking in Chinese constructional technique, for triangular and trapezoidal forms were used for many centuries in the support systems of the heavy overhanging roofs. Instead of giving rise to more complex forms, however, they died out as heavier woodwork came in. Was this, perhaps, yet another consequence of the Chinese lack of deductive geometry? On the triangular roof-trusses of the Greeks, see Hodge (1).

e (2), p. 486.
empirical discovery arising from the study of the timber false work or centering which had been used for centuries (in China also) in the construction of all arches. From geometry the Renaissance engineers knew that the triangle was the only figure which could not be deformed or distorted without changing the length of at least one of its parts; hence the elaborate combinations of triangles in trusses. Drawbridges must come also under the heading of beam bridges, and something must be said too about the different kinds of piers employed when the bridge has more than one opening. These may be of wooden piles, of stone in various designs, or occasionally of wooden tripods, and last but not least, of boats, making those pontoon or floating bridges which appear very early in history.

The next class of bridges is that in which the cantilever beam is employed. Such a beam is one which is rigidly fixed at one end and free at the other, so that it can move slightly according to its flexibility. In cantilever bridges, a series of such beams are thrown out from both sides of the gap and connected by a beam or truss in the centre. The home of these bridges seems to be the Himalayan region, and they were early known and used in China.

Arches have formed perhaps the most frequent and widespread bridge type. They were originally semicircular, and long remained so. In Europe there was a persistent belief that the Roman and Norman semicircular arch was indispensable because it directed the line of thrust vertically downward at the piers or abutments, and this theory was not affected by the use of pointed arches in the Middle Ages, which have the lines of two much larger circles or other curves intersecting at the crown. The great departure from precedent occurred in the 14th century, when the base diameter of the semicircle was allowed to sink, as it were, far below the river, and the bridge itself became segmental, leaping forth from its abutments as if resembling the flying gallop motif in art. In the present section it will appear that this fundamental advance had been anticipated by a Chinese engineer of genius some seven centuries before its appearance in Europe. Other shapes of curves, such as ellipses, could of course be used, and were.

The last important class of bridges is that of suspension bridges. Here the support comes from above, in the shape of a hanging catenary curve embodied in ropes or chains. In all the more primitive forms the passengers and animals follow the curve in crossing, but perhaps as a development from hand-rails connected at short intervals with the deck, there gradually arose the true flat-deck suspension bridge. The suspension bridge is native in many parts of the world, both Old and New, but only in one of them did eotechnic engineers make the transition from the use of ropes to that of iron chains. This occurred at an early date in the very mountainous country of south-west China bordering on Tibet, Assam and Burma, and the later suspension bridges of Europe derive from these remarkable iron-chain bridges.

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<table>
<thead>
<tr>
<th>BRIDGES</th>
<th>Maximum span in ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BEAM</strong></td>
<td>iron: 10</td>
</tr>
<tr>
<td></td>
<td>wood: 20</td>
</tr>
<tr>
<td></td>
<td>stone: 70</td>
</tr>
<tr>
<td><strong>CANTILEVER</strong></td>
<td>wood: 130</td>
</tr>
<tr>
<td><strong>ARCH</strong></td>
<td>stone: semicircular</td>
</tr>
<tr>
<td></td>
<td>pointed or two-centered ('Gothic')</td>
</tr>
<tr>
<td></td>
<td>segmental: 90</td>
</tr>
<tr>
<td><strong>SUSPENSION</strong></td>
<td>catenary: single rope</td>
</tr>
<tr>
<td></td>
<td>V-section rope: 70</td>
</tr>
<tr>
<td></td>
<td>tubular rope network: 200</td>
</tr>
<tr>
<td></td>
<td>decked rope: 450</td>
</tr>
<tr>
<td></td>
<td>bamboo rope: iron chain</td>
</tr>
</tbody>
</table>

It is of interest that the existence of different types of bridges seems to be betrayed in the structure of certain characters. Hopkins (14) considers that the earliest graph for liang, which means a beam or a bridge, was a drawing of a plank crossing a stream (see inset). No early version of the present character itself has been found, but a cognate form contains the components of water and rice, with a third which seems to have been originally a drawing of a man doing something (K 738). Perhaps he was building an irrigation dam across which one could walk. In the Shih Ch'ing the character is generally used to mean a fixed palisade fish-trap, which could very naturally have formed a bridge. The most usual term for bridge, chhiao, adds the radical for wood to a form chhiao which meant high and arched, as evidently appears from the graph of ancient times (K 1138 A, B, F, G). A few words will come later concerning the origin of arches and vaults; although they are not at all prominent in Chou times, their abundant use in Ch'in and Han suggests that the Chinese knew and used them, perhaps only for special purposes, during most of the 1st millennium. Further search among the ancient forms of written characters might unearth references to the cantilever and suspension types (see p. 156).

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*b* It corresponds logically to the corbel in architecture.

*c* Parsons (2), p. 485. In fact, the semicircular arch has the great disadvantage that it needs maximum loading on the haunches and minimum at the centre. Hence the mortuary of Norman towers.

*d* Cf. Vol. 1, pp. 166 ff. For such bridges the abutments had to be made stronger.
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Foreign admirers of Chinese bridges could be adduced from nearly every century of the empire. Between +838 and +847 Ennin never found a bridge out of commission, and marvelled at the effective crossing of one of the branches of the Yellow River by a floating bridge 330 yards long, followed by a bridge of many arches, when on his way from Shantung to Chhang-an. In the last decades of the +13th century Marco Polo reacted in a similar way, and speaks at length of the bridges in China, though he never mentions one in any other part of the world. The 12,000 bridges of Hangchow, famous as an exaggeration of 'Marco Millione', probably arose from the omission of a line of manuscript and a confusion between city-gates and bridges; in fact there were in his time exactly 347. Of these 117 were within the city-walls, no less than 46 having been built during the previous century since +1170. A special edict issued in +1268 called for the increase and repair of the capital's bridges, and under the Governor Chhien Yiieh-Yu more than half were demolished and rebuilt within a year, low ones being raised high to allow canal traffic to pass, and narrow ones broadened. Thus another Rialto awaited the traveller from the Far West.

The first Renaissance visitors to China also conceived great admiration for the bridges which they found there. One of the earlier of them, Galeote Pereira, wrote about +1577 as follows concerning the Fukien megalithic type, which we shall shortly view more closely:

As you come in to either of these cities (near Chinchao in Fukien), there standeth so great and mightie a bridge that the lyke thereof I have never scene in Portugal nor els where. I heard one of my felowe says, that he told me in this bridge, 40 arches. The occasion wherfore these bridges are made so great, is for that the country is toward the sea very plaine and low, and overwhelmed ever as the sea water encreaseth. The breadth of the bridges, although it be well proportioned unto the length thereof, yet they are equally byt, no higher in the middle than at eyther end, in such wyse that you may directly see from the one end to the other; and the sydes are wonderfully well engravt after the maner of Rome workes. But that wee did most marveyle at, was therewithall the hughness of the stones, the lyke of which so as we came in to the citie, we dyd see many set up in places dishabited by the way, to no small charges of thatwy, howbeit to little purpose, whereas noo body seeth them but such as doe come by the. The arches are not made after our fashion, vaulted with sundy stones set togethre, but pavelled, as it were, whole stones reaching out from one piller to another, in such wyse that they lye both for and carriage bridges, when on his way from Chincheo or Changchow; see Boxer (1), p. 313.

If. Imported in the way, the Chinese never passed beyond the use of simple beams to the compound reticular frameworks of wood with which very large truss bridges can be built, could be ascribed, as already suggested, to their lack of theoretical deductive geometry. They used timber centering for arch con-struction just as Europeans did (Fig. 333), and moreover their lattice design and other ornamentation was very geometrical (see Vol. 3, pp. 95, 112). As for other materials, there are a few rare examples of the use of iron bars as bridge beams (Huxton (2)), Fig-Meyer (1), p. 51, but this could not lead far, unless indeed it was what gave the idea of the rod-linked suspension bridges (cf. below, pp. 151, 156). It is not easy from his account to identify which two bridges Pereira had in mind, but very probably the Lo-Yang (Wan-An) Bridge near Chinchao was one of them. An equally colourful description of this written by Domingo de Navarrete, who passed over it in +1659, will be found in Cummins (1), vol. 1, pp. 143 ff. See Table 66.

* Ch. 127 (Moore & Pelliot ed.). Unfortunately Marco Polo did not see or describe them with the eye and pen of an engineer.
* The discrepancies in Marco Polo's accounts, and the bridge-building activities of his Chinese contemporaries, have been discussed by Moore (2), (3), pp. 23, 27; cf. Genet (1), p. 45.
* Chhiuncheh or Changchow; see Boxer (1), p. 313.
* Eden ed. p. 236; Boxer (1), p. 7. It is not easy from his account to identify which two bridges Pereira had in mind, but very probably the Lo-Yang (Wan-An) Bridge near Chinchao was one of them. An equally colourful description of this written by Domingo de Navarrete, who passed over it in +1659, will be found in Cummins (1), vol. 1, pp. 143 ff. See Table 66.
region as the centre of Chinese culture the crossing of the Wei River became particularly important, and a beam structure of many spans, the Hêng C.,* was built by Prince Chao Hsiao† of Chhinb. As soon as his accession — 305. /Linking the capital of Hsien-yang with the lands and passes south of the river, it retained all its importance during the Han, when Chhang-an on the southern side became the capital. c of Hsien-yang with the lands and passes south of the river, it retained all its importance giving a deck width of 55 ft.,e its piers were of stone in its northern section, which was called Shih-Chu C. We can visualise this rude but noble bridge in two ways, first by studying the representations of bridges on Han bricks still in SzechuaneSI museums (Fig. 815, pl.),f as old as the Wu Liang relief, if not somewhat older; and secondly by looking at structures of the same type still existing today. Three rivers fall into the Wei valley near Chang-an, the Pa g and the Chhanh to the east, and the Fêng h to the west, and their old bridges of Han type with up to sixty-seven spans remain still as Ennin saw them when he walked across in + 840 (Figs. 816, 817, pls.). A drawing by Thang Huan-Chhêng explains their simple construction. i All such bridges remain close to water-level and disappear from sight at flood seasons.

Throughout Chinese history, this style persisted. We hear of a trestle structure built by Chang Chung-Yen j in +1158 ten ft in length. In pictures by Sung painters such as Hsia Kuei k we find elegant wooden beam bridges with pavilions crowning their central

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*a Hercufeward we shall abbreviate the word Chhiao (bridge) in this way.
*b This same prince it was who in + 257 effected the first bridge-crossing of the Yellow River, certainly by pontoons (Shih Chung, ch. 5, p. 348; Chavannes (1), vol. 2, p. 94).
*c Two others, however, were then built, both to the east of the Hêng C.; see Adachi Kiroki (1); Lo Ying (1), p. 56. All were described at some length in + 653 by Martinis in his Atlas Sinensis, p. 45, but he gave them high arches.
*d Sun Fa Hwa, Thea, ch. 34, and Sun Fu Chiu, Shih.
*e Thus a nine-tane highway; cf. pp. 5 ff. above. Worthy of a royal, if not yet an imperial, capital. We convert according to Chhin and Chchien Han measure.
*f Liu Chih-Yuan (1), fig. 55; Anon. (24), pl. 34, 157; Thang Huan-Chhêng (1), fig. 6. The scene has been reproduced on a postage-stamp in our time.
*g Thang Huan-Chêng (1), figs. 11, 12, cf. 14; Lo Ying (1), pp. 48 ff., 276 ff.; Gei (1), p. 172. The memoir of Liu T'un-Chên (1) is primarily devoted to these. The Pa bridge was, we know, repaired many times, e.g. in + 22 and again in + 582; I visited it briefly in 1958, when it was as Ennin saw it, but found in 1054 that it had been entirely encased in concrete with a widened deck to take heavy motor traffic. It was still possible, however, to study in detail a smaller bridge of 26 spans, identical in type, just north-west of the, the Fêng C. (Thang Huan-Chêng (1), fig. 13; Lo Ying (1), p. 29; Fugl-Meyer (1), p. 70). Each pier is constructed thus; a foundation of cypress-wood piling supports a transverse row of three discoidal roller-mill base-plates (mien phan); and each of these supports two columns of four superimposed stone cylinders (lu chu) a ft. high and just under 2 ft. in diameter, the lowest cylinders but one in each of the pairs being tied together by a wrought-iron band. Each pier thus has six columns. Measurements made in farmyards of the region showed, as suspected, that the cylinders were standard-size supports, and workmanship is so that they need not have needed any essential alteration since the time of Christ.

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28. BRIDGES

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transport canal at Loyang in +135, was very probably of this kind, though it may have had one or more arches. Among the many which remain in the cities of the eastern provinces there are two veritably of the Sung period at Shao-hsing, one of which, dating from +1256, the Pa Ts'ao C.1, has two approach ramps with balustrades on each side.

All this has relatively little of engineering interest, but during the Sung period there was an astonishing development, the construction of a series of giant beam bridges, especially in Fukien province. Nothing like them is found in other parts of China, or anywhere outside China. These structures were (and are) very long, some of them more than 4,000 ft., and the spans extraordinarily large, up to 70 ft., a duty which necessitated the handling of masses of stone weighing up to 200 tons.2 The art of building these bridges was afterwards forgotten, and no record was kept either of the quarries which had provided the stones or the techniques by which they had been hauled to the site and set in position.3

Much obscurity surrounds the names of the engineers responsible for these megalithic bridges. Inscriptions which some of them bear merely record the provincial officials under whose aegis they were constructed and repaired. One may sense the existence of some master bridge-builder and a school or tradition founded by him. According to local sources, the Wan-An (Lo-Yang) bridge at Chihhsien was built under the superintendence of Ts'ai Hsia2 (+1012 to +1067), a scholar who was prefect in Fukien for some time,4 and who is well known to us for his books on the lichi fruit and on tea.5

a See p. 173 below.
b Description in Chien Taching-Chou (1). Not far from Shao-hsing I found and photographed in 1964 another of this kind over the old Grand Canal extension, the Thal-Phing C., with a double stairway on one side and a series of beam spans on the other (Fig. 820, pl.).
c These are certainly megalithic, but not more so than building components used in other civilizations. The west wall of the main temple at Baalbek in Syria contains three colossal blocks each weighing 950 tons, which must have been put in place about the 3rd century.
d Lo Ying (1), pp. 382 ff., suggests very plausibly that advantage was taken of the differences in tidal level, as also of the manipulation of buoyancy according to the technique of Hsui-Ping (r. +1087, cf. Vol. 4, pt. 1, p. 40).
e The local legend about the origin of his connection with bridge-building has been given in English by Dukes (1), reproduced in Boxer (1), pp. 314 ff. See overleaf.
f His statue ornaments the south-western end of the bridge (photograph in Ecke, 5). The date often given for the construction, +1023, is wrong. Not till +1043 did Li K'uan6 and Ch'en Chhing7 'build dressed stone approaches and a floating bridge'. Then in +1053 Wang Shih,8 Lu Hat9 and the monk Tsung-1 took the building of a megalithic beam bridge in hand but could not finish it, whereupon Ts'ai Hsia2 brought greater resources to bear and the work was successfully accomplished by +1059. We have record of it from his own brush, the Wan-An Chhi-Boo.10 Perhaps it was he, or one of his assistants, Hsi Ch'ang11 and the monks I-Po12 and Tsung-Shan,13 who added an indispensable engineering element of some interest previously missing. By +1078 we learn that a later prefect, Wang Tau,14 obtained an order forbidding people from carrying away stone from the 'ostery-shelba' or 'oyster-clusters' (li jiang),15 cf. R. 212 and Vol. 1, p. 88. These were nothing else than flat foundations of stone in the river-bed considerably larger than the piers which were built on them, and similar in principle to the concrete rafts of the present day. These rafts are not mentioned in the relevant passage of T'AO YU, ch. 99, p. 438, but in the Pa-chu Tseung Chhi and other texts cited by Lo Ying (1), pp. 325 ff.
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There is a famous folk-tale about this which it would be impossible to omit.

Before the Loyang bridge was built, everyone had to cross over by boat. In the reign of the Emperor Shen Tsung (+998 to +1022) of the Sung dynasty, a pregnant woman from Fu-chhing was crossing the river to Chhuan-chow; but just as the ferry was in the middle of the stream the bad tortoise and snake spirits sent suddenly a strong wind and high waves to upset and sink it. All at once a voice cried from the sky: 'Professor Tsai is in the boat. Spirits must behave decently with him.' And scarcely had the word been spoken when the wind and waves died down. All the passengers had heard exactly what was said, but there was no one of that family in the boat except the woman from Fu-chhing. They therefore congratulated her, and she said: 'If I really give birth to a son who becomes a professor, I will charge him to build a bridge over the Loyang river.' Several months later she did bear a son, who was named Tsai Hsiang. Later on (+1035) he did in fact become a professor. His mother related to him her experience on the river, and begged him to fulfil her vow. Being a dutiful son he immediately gave his consent, but at that time there was a law against anyone being appointed an official in his own province, and as Tsai Hsiang was a native of Fu-kien, he could not become Governor of Chhuan-chow, which is in that province. Fortunately a friend of his, the Chief of the Eunuchs in the Imperial Palace, conceived a wonderful plan. One day, when it was announced that the Emperor would walk in the garden, 'he took some sugared water, and wrote on a banana leaf 'Tsai Hsiang must be appointed Governor of Chhuan-chow'. Ants immediately smelt the honey and gathered on the characters in vast numbers, to the stupefaction of the Emperor, who happened to pass the banana tree and saw them drawn up in the form of eight characters. The Chief of the Eunuchs watched him reading them over, and drew up a decree which the Emperor signed.

And so eventually the bridge did get built, with the help of various immortals.

But megalithic bridges, sea-walls, and other public works in this province are connected particularly closely with the names of Buddhist monks, for whom bridge-building was a beatific work (pu-based), and who were probably the real engineers. Fa-Chiao,1 a contemporary of Tsai Hsiang's, built one of the bridges at Chhuan-chow, and another contemporary, the Abbot Kho-Tsun,2 was a great financial encourager of such projects. About +1178 another monk, Shou-Ching,3 built a 1,000-ft. long beam bridge at Nan-an.4 But the most famous of the group was Tao-Hai5 (d. +1278), who built more than 200 bridges of various magnitudes in the province, and who was said to have completed what Tsai Hsiang had begun. His best work was the Phan-Kuang C.6 near Chhuan-chow, but he also built dykes and sea-walls. So did Po-Fu7 in the following century (d. +1350), and it is interesting to read of him that he always used to sleep, doubtless under very rough conditions, with the workers on the job.8 Intensive research in the local histories and topographies of that city, details of which, together with some of the other bridges of the region, are given in the accompanying table.9 Both Marco Polo and John of Monte Corvino must have visited this area, and it is interesting to read of them the accounts of him that he always used to sleep, doubtless under very rough conditions, with the workers on the job.9 Intensive research in the local histories and topographies of the region may well bring to light many more facts about these monastic technologies.10 Some idea of the appearance of these bridges may be gained from Figs. 821 (pl.) and 822, taken from Ecke (3 and 4).11 These illustrate the Chiang-Tung Bridge, on the post-road from Kuangtung to Chhuan-chow, and the Wan-An (Lo-Yang) Bridge north-east of that city, details of which, together with some of the other bridges of the region, are given in the accompanying table.12 Both Marco Polo and John of Monte Corvino must have visited this area, and it is interesting to read of them the accounts of

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Fig. 82a. Megalithic beam bridges; the Wan-An or Lo-Yang bridge across the Lo-Yang R. north-east of Chhuan-chow in Fu-kien. Built +1053 to +1059; length 3,600 ft. A Chinese drawing from the Wu Chiang-ch'ien Thu Shuo (+1900) by Wu Ying, after Ecke (3). Wu Ying was a military and naval commander on the Chhing side in the fighting against the Ming forces under Koxinga (Ching Ch'eng-Kung) and his successors in the sixties and seventies of the +17th century. In these campaigns the bridges had much strategic importance. The mèfie depicted in the foreground is an episode in Wu Ying's exploits against the ablest of the Chheng-Ming generals, Liu Kuo-Hsiian, in +1678. Repairs to the bridge are proceeding in the background, with the aid of a sheer-legs derrick. Metal was used in them, though we do not now know exactly how. Thirty years earlier Fu-Teng had been in the south-east and perhaps learnt some of his art there. We have to thank Dr Else Glahn for advance knowledge of her biography of him.

10 The whole subject of the economic and technological role of Fukienese Buddhism at this time has been studied by Chikusa Mass-aki (1). The bridges are freely ornamented with stūpas, auspicious Tantric Ija syllables (cf. Vol. 4, p. 231), and other signs of religious devotion.

11 Cf. also Sino (1), Vol. 4, p. 204, n. c.

12 Our list is of course far from complete. Many more bridges can be seen in the +17th-century coastal maps of Chhen Lo- Chhing-hsing (see Vol. 3, p. 157). One can count as many as thirty-three in the charts attached to the Fu-chien Yen Sun Chh (Records of the Transportation Bureau of Fukien province), written by Chiang Ta-Kun (+1553). Moreover, there are several discrepancies in the various accounts, which could only be cleared up by thorough field-work in the province itself. Both places and

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Table 66. Some megalithic beam bridges of Fukien

<table>
<thead>
<tr>
<th>Name of bridge</th>
<th>Location</th>
<th>River spanned</th>
<th>Date of construction</th>
<th>Total length (ft.)</th>
<th>Breadth (ft.)</th>
<th>No. of spans</th>
<th>Greatest span length (ft.)</th>
<th>Weight of largest beams (tons)</th>
<th>Builder</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wan-Shou C. or Wenchang C.</td>
<td>Min Chiang</td>
<td>+857 to 1 +812</td>
<td>2,050</td>
<td>148</td>
<td>30</td>
<td>c. 80</td>
<td>-</td>
<td>Wang Fa-Chiu</td>
<td>P3; FM, p. 79; L, 72, 284 ff.; B, pp. 233, 234b</td>
</tr>
<tr>
<td>2</td>
<td>Hsi-Shan C. or Wan-An C.</td>
<td>Min Chiang</td>
<td>+1476</td>
<td>-</td>
<td>-</td>
<td>28</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>P3; mentioned by de Mendozas, 1577</td>
</tr>
<tr>
<td>3</td>
<td>Fu-Chhing C.</td>
<td>Local tidal estuary</td>
<td>Between late Ming and early Qing</td>
<td>800</td>
<td>17</td>
<td>-</td>
<td>c. 45</td>
<td>-</td>
<td>Fa-Chhao</td>
<td>FM, p. 77; P3; E5, pl. 29 fig. 1; THC, p. 18, fig. 17; D, B, pp. 333 ff; L, 74, 249 ff.</td>
</tr>
<tr>
<td>4</td>
<td>Lo-Yang C. or Chiang Kiouen</td>
<td>Lo-yang Chiang</td>
<td>+1053, or more prob.</td>
<td>3,000</td>
<td>15</td>
<td>47</td>
<td>c. 55</td>
<td>-</td>
<td>Tahai Hsiang</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Phan-Tung C. or Wu-Li C.</td>
<td>Lo-yang Chiang</td>
<td>c. +1255</td>
<td>4,000</td>
<td>16</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Tso-Hsii</td>
<td>THC, p. 19, fig. 18</td>
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<td>6</td>
<td>Shun-Chih C.</td>
<td>Chin Chiang</td>
<td>+1900 to +1212 (repaid)</td>
<td>1,500</td>
<td>-</td>
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<td>P3; B, pp. 253, 32; mentioned by de Rada, 1575</td>
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<tr>
<td>7</td>
<td>Fou C.</td>
<td>Chin Chiang</td>
<td>c. +1900 to +1212</td>
<td>800</td>
<td>17</td>
<td>130</td>
<td>c. 57</td>
<td>-</td>
<td>Fa-Chhao</td>
<td>ED, p. 94; THC, p. 19, fig. 19, 20</td>
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<tr>
<td>8</td>
<td>An-Phing C. or Wu-Li C.</td>
<td>Local tidal estuary</td>
<td>+1900 to +1212 (now strengthened to take a main road)</td>
<td>5,000</td>
<td>360</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>E5, p. 272</td>
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<tr>
<td>9</td>
<td>Chung-An C.</td>
<td>Local tidal estuary</td>
<td>+1904, repd.</td>
<td>1,000</td>
<td>18</td>
<td>60</td>
<td>-</td>
<td>-</td>
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| 10             | Changhsin C. or Chih-chou C.    | Chiu-lang Chiang | +1900 to +1212 (repaid) | 1,100         | 18           | 10           | > 70                     | > 200              | Li Shao      | FM, p. 77; P3; E5; E3; ED, pl. 74 b; L, 75, 76, 77 |
| 11             | Thung-Chin C. or Wenchang C.    | Lung Chiang     | +1900 to +1212 (repaid) | 900              | 28           | 40           | -                        | -                | -              | P3; E5, pl. 21, fig. 2; ED, pl. 74 d |
| 12             | Kuang-Chi C. or Hsien-Tau C.    | Han Chiang      | Sung +1900 to +1212   | 1,630             | 20           | 21           | -                        | -                | Ting Chiu-Yuan, Shen Tung-Yu et al. |

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Abbreviations: Boxer (1), Dukes (1), Ecke (1), Ecke (5), Ecke & Demenville (1), FM, Phillips (1), L, Lo Ying (1), THC, Tsang Huan-Chheng (1)

Notes:
- As in private correspondence, I celebrate the Yang builders of this most impressive bridge, the only one of the group that I myself have seen, remembering that sunay May morning of 1934 when Dr Hsiao Hsiang-Tung and I were borne in rickshaws over its granite blocks to see the first of several enjoyable days among the bookshops and hot springs of the city of Puchow. The greater part of our collection of the mathematical classics was purchased there.
- The early Portuguese travelers described a very great bridge north of Hsiang-hu (mod. Phu-thien) between Fu-chhing and the Lo-Yang C. (cf. Boxer (1), p. 333), but it does not seem to exist now.
- Here the characters follow the reading on an 18th-century MS. coastal map described by Mills (5, 6), which is similar to that reproduced as Fig. 210 in Vol. 2; but the more usual modern form is Lo-Yang. (1)
- The name 'Tiger Ferry', Hu-Tu, though sanctioned by Ecke and others, appears to be wrong. The classical numismatic phrase, a 'devout ferrying over into the beyond', was much more proper for a bridge designed by a Buddhist monk (cf. Fung Yu-Lan (3), p. 120).
- Essay in TSCC, Chih fang tien, ch. 1340, s eln 1, p. 8a; cf. ch. 1335, Chihhsien hau hui 5.
have crossed these bridges. The number of spans in relation to the total length of the Fukienese structures is very variable because as the huge stones of the deck failed, later generations were unable to replace them, and had to have recourse to the insertion of new piers between the old ones. In many cases the piers are corbelled or cantilevered out from their bases, to give additional support to the trusses, and the piers themselves are in general markedly boat-shaped. The largest beams (which Pereira so much admired), those exceeding 200 tons in weight, have cross-sections 5 ft. high and 6 ft. broad. With bridges of this type the greatest difficulty was the foundations, which in many cases proved insufficient, so that in different places in Fukien a number of ruined giant beam structures are found. It is clear that whoever was really responsible for them, the main period of their construction was the +11th to the +13th centuries.

An interesting piece of experimental archaeology was done on these megalithic beams by Fugl-Meyer. With the facilities of the Huangpo Conservancy Board's yards at his disposal, he tested the strength of bars of stone similar to those which the Sung builders had used. The maximum tensile stress calculated on the usual theory of bending proved to vary from 437 lb. per sq. in. for the red granite to 1,010 lb. per sq. in. for the grey. Assuming then the weight of the stone to be 160 lb. per cu. ft., and the highest superimposed load to be 80 lb. per sq. ft. of the bridge deck, it was possible to calculate the upper limit of length for a single-span beam, using the best figure (1,010 lb. per sq. in.) obtained above. The resulting figure was 74 ft., exactly corresponding to the maximum lengths of spans met with in the bridges of the Fukien type. The Sung builders had therefore reached the utmost limit of practicability, for baulks of any greater length will break under their own weight. An interesting historical problem remains as to how they found it; whether by bitter experience of failures in practice, or perhaps by the preliminary setting-up of actual empirical strength-of-materials tests at the quarries.

The Fukienese type of bridge-building gives one an impression of uncouth strength and determination, with a prodigious waste of material, as regardless of cost as the most massive Roman masonry. Yet it was a purely provincial style, for, as the sequel will show, the builders of arch bridges in Northern China had already attained six or seven centuries earlier an economy of materials and a grace of design which was not approached in Europe until the dawn of the Renaissance. Nevertheless the giant beam bridge is not to be despised, and holds its own for certain purposes at the present day. The Stone Bridge in Uttar Pradesh, with its twenty-two pre-stressed concrete spans of 150 ft. each, is a true descendant of the granite bridges of medieval China.

Before leaving the realm of the beam, a few moments must be given to drawbridges and pontoon bridges. Drawbridges did not figure prominently in Chning fortification practice, bridges over moats being just made easily dismantlable at need. But in earlier times mechanically movable bridges had been used a good deal. Miguel de Loarca, in his 'Verdadera Relacion' of the overland journey of the Spanish envoys from Amonth to Fuchow in + 1572, described a great bridge of many spans outside Chihianchow, perhaps the Suzh-Chih C., which had a drawbridge at its end, and the Spaniards must have recognized a device of this kind when they saw one. Nearly a thousand years earlier, the Thai Pai Yin Ching, that Taoist military encyclopaedia of + 759, had an entry for the subject in its section on the defence of cities. Li Chihuan wrote:

Turning Portal Bridge (chuan huan chhiao). For this kind of bridge flat planks are used as the deck. At one end of the bridge there is a horizontal bolt (heng thien), and when this is removed the (whole) bridge turns away from the gate, so that soldiers and horses cannot pass over, and all of them fall into the moat. (Formerly, the King of) Chhin used such a bridge as this (in the attempt) to kill Tan, Prince of Yen.

The story about Prince Tan occurs in the ancient fictional biography Yen Tan Tau, written about the end of the +2nd century. The prince, escaping in - 232 from the ruler of Chhin State, where he had been ill-treated as a hostage, had to cross a bridge equipped with some release mechanism (chi fa chhia chi) whereby the king intended to kill him, but he passed over before it could operate (Tan hua chhia chiu fa fefu). Unfortunately the mechanism of these ancient 'drawbridges' is not quite clear from Li Chihuan's description. They were evidently not raised into the air like the drawbridges of medieval Europe, nor were they swing-bridges like Leonardo's, nor elevator-bridges like those of Martin. It seems clear that they either turned over sideways (which might have been rather effective), or else swung on hinges so as to drop into the moat probably at the end nearer the gate and wall. Later on (p. 190) we shall refer to a + 5th-century submersible suspension bridge which acted as a drawbridge.

Floating pontoon bridges are of high antiquity in Europe since the Greek Mandrocles of Samos is credibly reported to have constructed one over the Bosphorus for an expedition of Darius I against the Scythns in + 514. If this date (pace Sarton) may well be anticipated by the first Chinese reference, which takes us back to a - 8th-century text Let us listen to Kao Chheng discussing the matter in the Sung.8

8 See Boxer (1), p. 332.
9 Ch. 36, p. 3b, tr. auct. The passage is also found in Hsi Shih Shih, p. 43b, but somewhat garbled and indeed misleading.
11 P. 1a, tr. Chheng Lin (1); Franke (1).
13 Burton (1), vol. 1, p. 36; Dietz (1); Herodotus, iv, 87, 88. See also Herodotus on Xerxes I and his engineer Hapal. c. - 480, v, 25, 33-46; and for the background of both works Hunt & Delaporte (1), pp. 351 ff., 363 ff.
14 Shih Wu Chi Yuan, ch. 7, p. 114b, tr. auct.
15 梁橋 (bridge) 1 船橋 (pontoon bridge) 4 木橋之類無不具
The Chhun Chhin Hou Chuan 4 says that in the 58th year of the Chou High King Nan 5 (−257), there was invented in the Chhin State the floating bridge (fou chhiaohou chhuan) 6 with which to cross rivers. But the Ta Ming 7 ode in the Shih Ching (Book of Odes) 8 says of King Wen 9 that he ‘joined boats and made of them a bridge’ (tsao chou wei liang) 10 over the River Wei. 11 Sun Yen 12 comments that this shows that the boats were arranged in a row, like the beams (of a house), with boards laid (transversely) across them, which is just the same as the pontoon bridge of today. Tu Yu 13 also thought this... Cheng Kiang-Chhben 14 says that the Chhun people invented it and used it whenever they had occasion to do so, but the Chhin people, to whom they handed it down, were the first to fasten it securely together (for permanent use).

For the Chhin State’s bridge of boats across the Yellow River there is much better authority than Chhen Fu-Liang, for, as we have just seen (p. 150), Sauma Chhien himself recorded its building by King Chhao Hiaing of Chhin at the date here given. 15 With periodical renewals this Phu-Chin C., 16 as it came to be called from its geographical position near the border of Shansi north of the great bend at Thungkuan, lasted for very many centuries, the senior and most famous of the three great floating bridges across the Yellow River. 17 The Chhu Hsiieh Chi encyclopedia of +700 mentions it and just now we found the Japanese monk Einni admiring it in +840. 18 He estimated its length at about 1,000 ft. We have long been familiar with this bridge, for in Vol. 4, part 1, we read about the casting of iron anchor weights in the form of oxen, for fixing the cables, in +724, and how the monk Huai-Ping cleverly retrieved these in +1065 after they had been carried away in a severe flood. 19 From the +8th century also we have much information about the upkeep of these important bridges, notably in the M.S. fragment of the Thang government ordinances of the Department of Waterways (fou chhiao chiao chhuan). 20 Here we learn of the bridgekeepers (tsou chhiao chhiaoh), watermen (chhuou chhioh) and maintenance artisans (chu mu chhiaoh) 21 kept permanently on duty and exempt from military or other service, active in the defence against dangerous floating lumber in flood time and watchful to undo all fastenings when the ice set hard. Replacement

pontoonos (fou chhiao chhiao chhuan) 22 were built in special shipyards and kept available up to half the total number, while provision was made for the manufacture, storage and periodical testing of the necessary bamboo hawseros. 23 The Phu-Chin C. was always an important strategic crossing. In +1049, for example, during one of the campaigns of the Chi-tan Liao against the Hsi-Hia State, it was successfully held as the main line of communication by the Liao general Hsia Phu-Nu 24 and his country’s troops retreated across it. 25 As in all other civilisations, pontoon bridges often figured in military operations because so easily constructed and so readily removed—thus the Yangzte was bridged twice in this way, in +33 and +36.

The mention in the passage quoted above of Tu Yu, 26 the eminent engineer of the Chin period (+222 to +284), is interesting, because he himself constructed the second famous floating, or pontoon, bridge across the Yellow River, the Ho-Yang C. north-east of Loyang in +274. According to the story in the Chin Shu many of the imperial advisers urged that the plan was impossible, since the saints and sages had done nothing like it (li sheng hsien erh pu tuo cheh, pi pu kho), but Tu Yu had the emperor’s confidence, and successfully completed the work. 27 The dynastic history records the modest reply he made when the emperor came to inspect the bridge and drank a toast to him in the presence of all the court.

References to pontoon bridges in the Thang and other periods are not infrequent in the encyclopaedias. 28 For example, there was Chang Chung-Yen’s 29 Jurchen Chhin pontoon bridge of +1158, Thang Chung-Yu’s use of iron chains for securing one in +1180, and another made with inflated skin rafts by the Chhi-tan engineer Shihmo An-Chhe in the Yuan period. Many floating bridges are mentioned in the account of the travels of the Taoist Chhiu Chhang-Chhun about +1221. A famous one over the Amu Darya was constructed in a single month by Chang Jung, 30 the chief engineer of Chagatai, Chingiz Khan’s second son. 31 In the +17th century there was another at Lanchow which greatly impressed an embassy from the Timurid Shih Ruh, 32 and a

8 Vol. 4, pt. 2, p. 64; and p. 191 below.
9 Liao Shih, ch. 87, pp. 49, 50; tr. Wirtzfel & Feng (t), p. 166.
10 ch. 34, p. 98.
11 One event in connection with this bridge illustrates a general principle of action adopted by the bureaucratic administration in many dynasties. About +512 one of the princes of the Northern Wei, Yuan Chhing, 33 acting as governor of Honel, ordered that all empty carts leaving the capital at Loyang should transport stone for the embankments or causeways at each end of the bridge. Commandeering of transport, especially when done so as not to interfere with normal movements, was an important adjunct to the core of itself. The account is in Wei Shu, ch. 14, p. 8a.
12 E.g. TSCC, Chiao heng tien, ch. 31. Ch. 32, p. 25, reproduces a literary-philosophical essay by the Thang scholar Chang Chung-Su 34 (ch. 31) on the bamboo cables for floating bridges—the power of small things individually weak, such as bamboo strips, when plaited together in numbers. For similar ideas in relation to technology, cf. Vol. 4, pt. 2, p. 313, and below, p. 641.
14 Yuri Shih, ch. 151, p. 19b. So close was the connection in the Mongolian mind between inflated animal skins and bridges, Prof. O. Lattimore tells us, that the same word, hur, came to be used for both.
15 Yule (13), vol. 1, p. 298. This was the Chen-Yuank C. 35 composed of 24 pontoons secured by iron chains. A model is a Lanchow Museum.

a By Chhen Fu-Liang 4 of the Sung.
b III (1), 21; Mao no. 236; Legge (8), vol. 2, p. 435; Karlsgren (14), p. 188; Waley (1), p. 26a.
c The +3rd-century philologist.
d Eminent engineer connected with water-mills (cf. Vol. 4, pt. 2, pp. 379, 393 above), astronomer, historical geographer, etc.
e Cheng Hiaian, the +4th-century commentator.
f Shih Chi, ch. 5, p. 34a (cf. Chavannes (1), vol. 2, p. 94). Chhu Hsiieh Chi, ch. 7, p. 236, gives the name of the actual builder as Chhen Fuh-Chhun, 4 a son of the reigning prince of Chhin.
g The others were the Ta-Yang C. at Shenchow 5 built by Chhun Hsiieh Chi, 6 in +637 at a Northern Chou check-point, and the Ho-Yang C. near Meng-hsien 7 built in +274. Together with the Hsiao-I C. 8 across the Lo River below Loyang they formed the four celebrated bridges of boats enumerated in Thang sources such as the Thang Tien summarised in Yeh Chhu Li (+1673), ch. 6, p. 19. See Lo Ying (1), pp. 468 ff., 501 ff.

1 See Reischauer (2), p. 80; and p. 148 above. 1
1 Studied and translated by Twitchett (2). The articles on bridges are 20, 24, 26, 30, 31, 32, 33.
28. BRIDGES

28. CIVIL ENGINEERING
28. CIVIL ENGINEERING

28. BRIDGES

In all southern and western parts of China, and especially near the Himalayas and Tibet, the people responded to the challenge of gorges and turbulent streams up to 150 ft. wide by the construction of cantilever bridges (kung mu chhiao). The two cantilever arms were built out with superimposed timbers from the sides in various ways (see Fig. 823), and then connected in the middle of the span by long wooden beams. Additional struts (strainer-beams) may or may not be present. The abutments were, and often are, of timber filled and weighted with stones, but heavy masonry works in which the cantilever arms are embedded also occur. The principle is applied, moreover, to long bridges with many piers, the cantilever arms then springing from the abutments.

While travelling in China during the Second World War, I came across several floating bridges, mostly in Chiangsi and Kuangtung. A special type occurs on the western border of Szechuan, near Yachow, where at certain times of the year a raft of bamboo is moored abreast from shore to shore, and across it a gangway, good at least for pedestrians, is laid. Bridge pontoons are shown in Ming technical books. Bamboo is moored afloat from shore to shore, and across it a gangway, good at least for pedestrians, is laid. Bridge pontoons are shown in Ming technical books.

All this, however, has thrown no light on the oldest use of the device. Although the ode in the Shih Ching certainly refers to the founder of the Chou dynasty Wen Wang in the 11th century, to insist on dating it at that time would be most unwise, and the —8th or —7th centuries would be quite enough to do it justice. Its phrase about the bridge echoes down through the Han period, as in the Capital), written by Pan Ku about +87, and much later (see, e.g., Thang Huan-Cheng (I), figs. 21, 23, 24). Another, on the Kansu-Chinghai road, is figured by Liu Tun-Chen (I), pl. 56. A very fine example of a bridge of this kind with several spans is the covered bridge at Hang-ning in Hunan (Anon. (37), fig. 140; Thang Huan-Chheng (1), fig. 41), and an even more magnificent one (Fig. 815, pl.) is the Chheng-Yang C. at the place of that name north of San-chiang in northern Kiangsi (see overleaf). This bridge, though little known, was rightly included in the postage-stamp series issued by the Chinese government in 1962.

A very fine example of a bridge of this kind with several spans is the covered bridge at Hang-ning in Hunan (Anon. (37), fig. 140; Thang Huan-Chheng (1), fig. 41), and an even more magnificent one (Fig. 815, pl.) is the Chheng-Yang C. at the place of that name north of San-chiang in northern Kiangsi (see overleaf). This bridge, though little known, was rightly included in the postage-stamp series issued by the Chinese government in 1962.

Combination of horizontal cantilever and strainer-beam supports, often found in the many-spanned bridges of Hunan, e.g. at Li-liang over the Lo-shui (Fig. 814, pl. 5), south-east of Changsha (Borschmann (34), fig. 108; Parsons (1), p. 271; Thang Huan-Chheng (1), fig. 27). See also Figs. 24, 35; but also over the Mo-chiang and elsewhere in Yunnan to the south-west (Thang Huan-Chheng (1), fig. 25; Mock (1), p. 53; Fugl-Meyer (1), fig. 13); and in Chiangsi to the south-east, as at Gansien (Bosten (1), p. 164), a bridge well known to me.

Soaring cantilever, used across gorges or routes of water-traffic, e.g. the famous covered bridge in the city of Lanchow, Kansu (Cieel (2), p. 319; Thang Huan-Chheng (1), figs. 26 and 27, and the ‘Extended Arm’ bridge (Shen-Pei C.) in the Mul District of south-west Szechuan (Thang Huan-Chheng (2), fig. 23; Fugl-Meyer (1), fig. 54). This form occurs also in Tibet, e.g. the Lhasa bridge built on toll log-crib piers (Thang Huan-Chheng (1), fig. 21).

Multi-angular soaring cantilever, in which the main beams spring forth at two or more angles with the abutments, known mainly from the painting by Chang Te-Tsun (+ 1126) of a great bridge at the Sung capital Haliang (Chheng Chen-To (3); Anon. (37), fig. 58; Thang Huan-Chheng (1), figs. 28, 29). See Fig. 816 (pl.)

Fig. 823. Types of cantilever bridges.
(a) Simplest type of strainer-beam support (pa tsu chhing chhiao), used in small bridges, e.g. at Lungyen in Fukien (Thang Huan-Chheng (1), fig. 39).
(b) Horizontal cantilever, used over gorges, crossing e.g. the Brahmaputra at Phomi in Tibet (Thang Huan-Chheng (1), fig. 24). Another, on the Kansu-Chinghai road, is figured by Liu Tun-Chen (1), pl. 56. A very fine example of a bridge of this kind with several spans is the covered bridge at Hang-ning in Hunan (Anon. (37), fig. 140; Thang Huan-Chheng (1), fig. 41), and an even more magnificent one (Fig. 815, pl.) is the Chheng-Yang C. at the place of that name north of San-chiang in northern Kiangsi (see overleaf). This bridge, though little known, was rightly included in the postage-stamp series issued by the Chinese government in 1962.

(c) Combination of horizontal cantilever and strainer-beam supports, often found in the many-spanned bridges of Hunan, e.g. at Li-liang over the Lo-shui (Fig. 814, pl. 5), south-east of Changsha (Borschmann (34), fig. 108; Parsons (1), p. 271; Thang Huan-Chheng (1), fig. 27). See also Figs. 24, 35; but also over the Mo-chiang and elsewhere in Yunnan to the south-west (Thang Huan-Chheng (1), fig. 25; Mock (1), p. 53; Fugl-Meyer (1), fig. 13); and in Chiangsi to the south-east, as at Gansien (Bosten (1), p. 164), a bridge well known to me.

(d) Soaring cantilever, used across gorges or routes of water-traffic, e.g. the famous covered bridge in the city of Lanchow, Kansu (Cieel (2), p. 319; Thang Huan-Chheng (1), figs. 26 and 27, and the ‘Extended Arm’ bridge (Shen-Pei C.) in the Mul District of south-west Szechuan (Thang Huan-Chheng (2), fig. 23; Fugl-Meyer (1), fig. 54). This form occurs also in Tibet, e.g. the Lhasa bridge built on toll log-crib piers (Thang Huan-Chheng (1), fig. 21).

(e) Multi-angular soaring cantilever, in which the main beams spring forth at two or more angles with the abutments, known mainly from the painting by Chang Te-Tsun (+ 1126) of a great bridge at the Sung capital Haliang (Chheng Chen-To (3); Anon. (37), fig. 58; Thang Huan-Chheng (1), figs. 28, 29). See Fig. 816 (pl.)
heads of each pier (Fig. 824, pl.). Bold single-span structures occur commonly all over western China from Kansu to Yunnan as well as in Tibet, the arms sometimes horizontal but often ‘soaring’ upwards from the abutments at an angle of about 25° to join the level connecting deck beams. Horizontal-arm cantilever bridges of many spans occur particularly in Hunan. These are impressive enough in themselves, but when combined with covered housings and pavilions over each pier, as in the south-west of the province and over the border in Kuangsi, they produce some of the most superb structures of traditional Chinese bridge-building (Fig. 825, pl.).

In spite of the fact that boarding is usually placed in position to protect the cantilever arms from the weather, there is bound to be decay in the woodwork, and for this reason none of these bridges is very old. However, in the late 11th-century Sheng Shui Yen Than Lu1 (Fleetling Gossip by the River Sheng) due to Wang Phi-Chih, there is a clear reference to the building of a cantilever bridge.

In the south-west of the city of Chingchow4—acting as the land is very hilly, and for long the town was cut through by the Yang River (Yang Shui) into two parts. Originally wooden piers were set up in the stream, and a bridge supported upon them, but when the wave rose in its autumn floods, these piers were frequently damaged, and the bridge became unsafe. The magistrates were always worried about this. In the Ming-Tao reign-period (+1025 to +1033) the governor of Chingchow, Hia Ying-Kung,1 was greatly destrous of overcoming the difficulty (and gave encouragement to) a certain retired guard, who was known for his ingenuity. He piled up large stones to make firm abutments, and then by connecting several dozen great beams together, he threw across the river a kind of ‘flying bridge’ (fei chhiao)2 with no central pier. Though now more than fifty years in use, this bridge has never suffered injury. Then in the Chhing-Li reign-period (+1041 to +1048), when Chhen Hsi-Liang was governor of Su (-chou),3 he noted that the bridges on the Pien6 Canal often fell into disrepair, so that they damaged or destroyed official shipping, hurting and even killing travellers. He therefore ordered that (they should be rebuilt) following the pattern of the Flying Bridge of Chingchow. Now all the bridges between the Fén10 River and the Pien Canal are of this type, which is a great benefit to communications. The common people call them ‘rainbow bridges’ (hung chhiao)4.

The cantilever principle was thus most welcome since it obviated the necessity for central piers, obstacles particularly liable to flood damage and prone to get in the way of navigation. Forming a veritable illustration to this passage is the depiction of a great bridge outside the city of Khaifeng, the capital of the Northern Sung, painted in a scroll by Chang Tse-Tuan about +1120 on the very eve of its capture by the Ch’in Tartars. With its wonderful detail of daily life, this Chhing-Ming Shang Ho Thu1 (Going up the River at the Spring Festival) has helped us before and will do so again.8 The bridge which it shows (Fig. 826, pl.) is of the multi-angular soaring cantilever type borne not only upon ten great beams rising out of the abutments at some 40° and supporting a series of central horizontal members, but also upon another set interdigitating with them and rising at some 55° to sustain corresponding pairs of sloping members which meet at the crown of the structure; the whole being trussed together with bars and collars similar to those used with the more ordinary bundles of parallel cantilever beams.9 The deck of the bridge is thronged with busy life, and large river ships are being worked to and fro underneath.6

The further historical elucidation of these beautiful forms of bridge-building is not a very easy matter. A clear description of a timber cantilever bridge with stone abutments is given in the Sha-Chou Chi5 written by Tuan Kuo1 in the +4th or +5th century; it refers to one then built by the Thu-yü-hun + people (a Hsien-pi tribe) across the river of the Tunhuang oasis. This seems to be the oldest textual record. According to local tradition at Lanchow, however, the cantilever bridge in the western suburbs (Hsi-Chin C.) dated from the Tang period.4 By the time of the Ming (+16th century) the technique which had produced the Khaifeng bridge seems to have been lost (or was at any rate unknown to metropolitan scholars), for the Ming copies of Chang Tse-Tuan’s painting replace the cantilever structure by a single great arch.6 But possibly in the meantime its simple lattice-like geometry had travelled to Europe, for an almost identical design was proposed by Leonardo da Vinci (c. +1480) for a military bridge.6 Searching back in the Chinese literature, much will depend on the extent to which the term ‘rainbow bridge’, mentioned at the end of the quotation from Wang Phi-Chih, is to be taken as a technical rather than a popular descriptive term. For example, in the late +3rd century Chou Chhus wrote in his Fén Thu Chi7 (Record of People and Places): ‘In front of Yang-hsien there is a great bridge 720 ft. long from north to south, and very high in the middle so that it looks like a rainbow. It was built there by the Lord Yuan.8 It is not difficult to imagine this as a series of...’

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1 Sheng Yen Shui, +1025.
2 Chhiao (or chhiao) denotes a wooden bridge. For a modern model, see Anon. (37), fig. 172.
3 Hsi-Chin means ‘exterior’.
4 In Shensi province, running past Tsaiyuan. Thus was Wang Phi-Chih saying that is from Shansi through Honan and Anhui to Chiangsu everybody began to build large-span timber bridges.
6 An interesting modern model is figured by Thang Huan-Chhing (1), fig. 29.
7 The painting of the bridge is now often reproduced, e.g. in Anon. (37), fig. 48. Lo Ying (1), pp. 44 ff., 67 ff., treats this type of bridge as a wooden arch, and says that some smaller examples still exist in Fukien and Chekiang. It would join with his hemi-decagonal stone cantilever arches as precursor of the ‘Gothic’ arch. See p. 151 below.
8 Yang Chhun-Ho (2), quoted by Lo Ying (1), p. 59. I knew and admired this covered bridge (cf. Thang Huan-Chhing (1), figs. 26, 37) in 1945, but afterwards it was taken down. A model is in the Provincial Museum, Mao I-Shing(1) mentions another cantilever bridge in Kansu, but gives no reference.
9 As is seen, for example, in the Ming set reproduced in full by Priest (1).
11 Modern I-hsing, a town up-country behind the Thai Hu Lake in Chiangsu.
12 Cit. Chu Hsin Chi, ch. 7, p. 25 a, tr. synt.
short spans of parallel cantilever pattern like those of the Hunan type, with a single soaring, perhaps multi-angular, cantilever span in the centre to allow the passage of traffic under sail. But it may equally well have been a series of arches with a tall central arch.

One fact possibly relevant to the origin of the cantilever bridge in China is that in Han times pavilions were sometimes built out over lakes on corbelled brackets resembling cantilevers. Such structures were called **thi chhihao** (ladder bridges). Chavannes reproduced a relief showing this many years ago, and in 1958 I photographed an extraordinarily similar one which is preserved at the Temple of Confucius at Chhûfu in Shantung (Fig. 827, pl. 1). A pavilion somewhat of this kind still exists at the Yan-Yu Temple at Hanoi in Vietnam and has been described by Yû Ming-Chhîen (f). Dating from +1049 (repaired in +1105), it is borne on a cylindrical stone column rising out of a pool, and upheld by wooden cantilever corbels and strainer-beams. But the roof-supporting system of corbel brackets in Chinese architecture as a whole (cf. pp. 92 ff. above), and not only such corbels as these, presents itself as the background of the Chinese cantilever bridge.

The comparative approach does not get us very far either, at least in the analytical sense. The area of this type of bridge extends well outside China throughout the Himalayan region, as we have already seen. Robin's illustrates a good example from Srinagar in Kashmir, and Uccelli gives one from Bhutan. Besides Leonardo, Villard de Honnecourt drew several types of cantilever bridge, and if the structure which Trajan threw across the Danube in +104, and which is depicted on his famous Column of +113, was (as it seems to have been) a cantilever bridge of many spans on stone piers, the computed distance of 170 ft. for each span may not have been impossible. It would thus have been similar to the Hunan type, but it seems to have been an isolated effort in occidental antiquity. The enormous wooden bridges erected in Germany by the Grubenmann brothers between +1755 and +1758 were a combination of the cantilever and arch reticulate truss principles; the longest span is said to have attained 390 ft. But simple cantilever bridges had been built throughout the Middle Ages in the Savoy Alps. It would be interesting to know the original home of the basic design, and the stages of its spread, but the invention seems to have taken place so early that it is difficult now to trace its course through history. Perhaps if the Himalayan massif was the zone of origin of both cantilever and suspension bridges we might expect them to occur combined, and this does in fact occasionally happen. It is also possible, though in China unusual, to build a cantilever bridge in stone. This brings us to the arch.

### (3) Arch Bridges

The generally accepted view used to be that the arch was an Etruscan invention of perhaps the -5th century, and that its Italian origin accounted for the fact that the Romans made such great use of it while the Greeks used it hardly at all. It is true that Greek architects did not employ it before about -500 and never much even then. Argument has also centred round the use of the arch in India, for some, such as Ferguson, believed that it was very rare in pre-Muslim times, being associated only with Buddhism, while later writers (e.g. Havell) held this to be an over-statement. All such discussions have now entered a different phase with the establishment of the fact that the arch, the vault, and the dome were alike familiar to Sumerian Mesopotamia. This makes it easier to understand the appearance of the arch and the barrel-vault in full flower in Chhin and Han tombs, and to suppose that the use of the arch for city-gates and bridges was well understood by the Chou people, if not indeed by the Shang.

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*a* For a picture of a vertiginous unruled packhorse bridge with at least one point of suspension at the end of a cantilever arm, see Bonate & Leonhardt (4), p. 9; it crosses the Yarkhun in Chirgil.  
*b* A Chaking example is given by Thang Huan-Chhîng (f), fig. 47; Lai Tun-Chhîn (f), pl. 78. See further Lo Ying (f), pp. 38 ff.  
*c* Cf. Robertson (1).  
*d* The question is in fact complicated. The earliest surviving specimens of structural vaults in brick or masonry date from between the +4th and the +6th centuries (Ter, Chezzaka, Bhargapani, Bodh Gaya). But there are many representations of timber 'arches' in rock-cut caves (Karle, Bhaja, Barabar) going back to the +3rd century, and in reliefs (Bharath, Mathura, Anuradavati), which go back to the +1st. This is the 'caitya-arch'. Perhaps the most satisfactory recent reference is Coomaraswamy (6), p. 73. We are indebted to the kindness of Dr. F. R. Alchin for advice on this subject.  
*e* Till recently the true arch was not suspected in the Amerindian cultures, which avoided it by the extensive use of corbel vaulting. But Beth & Ekholm have now reported a true barrel-vault in a Maya structure of the late classic period at Campeche described by Ruppert & Denison.  
*f* Cf. Woolley (3).  
*g* A Chekiang example is given by Thang Huan-Chhîng (f), fig. 48; Li Tun-Chhîn (f), pl. 78. Cf. Robertson (1).  
*h* A Chekiang example is given by Thang Huan-Chhîng (f), fig. 48; Li Tun-Chhîn (f), pl. 78. Cf. Robertson (1).  
*i* Cf. Robertson (1).
In antiquity, both West and East, arches were invariably semicircular. This type will not conveniently bridge gaps of more than about 150 ft. at the most, and the average spans of Roman semicircular bridges (such as the Pons Milvius of - 109 and the Pons Fabricius of - 62) range between 60 and 80 ft., while aqueduct arches are generally much less, about 20 ft. The longest surviving Roman arch is that of the Pont St Martin near Aosta which spans 117 ft.

The essentials of the arch itself, with its ring of shaped voussoir stones culminating in the key-stone at the crown, were naturally identical in Roman and Chinese work. But Fugl-Meyer, himself a bridge engineer, found when he examined Chinese methods that the whole construction was so unlike in the two kinds of structure that there had never been, he was convinced, any contact between Roman and Chinese bridge-builders. The Roman bridge arch, he said, is of very massive masonry, so bulky that in some cases the chalk in the middle of the structure has remained plastic to the present day and will still harden when exposed to air. It was also over-dimensional, unnecessarily wasteful of material. On the other hand the characteristic Chinese bridge arch is a thin stone shell loaded with loose filling, and this is kept in place by side-walls of stone, and topped with stone slabs to form the deck and approaches.

While such a method was most economical of materials it was also much more liable to deformation caused by rise or fall of the foundations, and the Chinese were therefore driven to invent a number of subsidiary devices, bonding-stones to hold the casing together, and built-in shear-walls running through the structure to counteract deforming forces. Since the Chinese bridge was constructed of a minimum of material, wrote Fugl-Meyer, it was an ideal engineering product, fulfilling both technical and engineering requirements.

It will be worth while to look more closely at these structural details before considering a few of the great arch bridges (hung chihao) of China.

For the arches themselves several different types of bonding (chhsiian) were used as the stones were laid down upon the wooden centering (Fig. 828). In the transverse method (ping lieh, 'abreast') a number of essentially separate arches were built up side by side in a series till the required width of the bridge was reached (I). The stones were often elongated like arcs of the circle, and the adjacent arches always bonded by alternate jointing. This was the method used for the great segmental arch bridges (cf. p. 90 above); except, of course, for tombs, and major gates in the walls of cities, palaces and temples. We may find a reflection of this in the remote of a modern Chinese engineer, Tan Pei-Ying (I), p. 124, that the semicircular arch was never used in domestic architecture, because it was not considered lucky.

With a qualification concerning arches not free-standing (see p. 179 below).

b Except with the use of modern theories and methods. One of the largest masonry spans in the world, the Cabin John Aqueduct Bridge at Washington, D.C., stretches 218 ft. Structures of reinforced concrete are also here excluded.

c See Robertson (1); Jenkin (1); Neuburger (1); Gauthy (1). The oldest surviving Roman bridge, on an old Etruscan road, the Via Amerina, antedates the Pons Milvius by about twenty years, but its span is very small (Perkins, 1).

d So Robertson (1); later authorities prefer the Ponte d'Augusto at Narni with an arch of 105 ft. span (Goodchild & Forbes), or 144 ft. (Tyrell). It depends what one counts as extent. However, the range is clear.

We have seen a very similar contrast with regard to roads, cf. pp. 2, 7 above.

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walls between the arches, square ends of stone can often be seen; these are the through­ binders (chhang shih liang), or long stone ties running from wall to wall to prevent the walls from bulging outwards. Since in many parts of China, such as the Yangtze delta, the subsoil was so bad that it was impossible for the Chinese engineers to make the foundations unyieldingly firm, the built-in shear-wall (chin p'i) was devised—namely a vertical stone wall running buried through the fill at right angles to the bridge axis and on each side of each arch. This can be well seen in Fig. 829 (pl.), a bridge at Khunshan in Shansi, taken from Mirams. The shear-walls consist of long stone slabs, placed vertically side by side, mortised into the foundation and gathered at the top into a long horizontal stone which ties once again with the side-walls. They are therefore genetically identical with the simple rows of vertical slabs which, as we saw above (p. 152), constitute one of the forms of piers for the smaller kinds of stone beam bridges; but their combination with the arch was a brilliant idea. For while the arch itself is a loose chain which cannot resist any bending moment, the forces tending to deform the arch are transferred through the fill of clay and chips to the two shear-walls. Occasionally the side-walls and the fill of the arch section finish at the shear-walls, so that only the centre part of the bridge is built, connection being made with the banks by means of two beam spans. Fig. 830 (pl.), from Siren, shows another bridge at Suchow, to illustrate the degree of deformation which these structures can stand without collapsing. The arch has become almost elliptical, but it continues to do duty. The rings of these arches, Fugl-Meyer found, are almost daringly thin; in an ordinary small bridge 1/50 of the span, but on the larger ones as little as 1/100. The bond of the stones used in the retaining side-walls varies somewhat, but usually rows of horizontal and upward­ ended slabs alternate, and in any case a number of the stones are placed with their long axes inwards, like so many spikes pointing into the fill, so as to act as additional ties between fill and wall.

Another remarkable invention of Chinese bridge engineers was that of the complete circle structure, the arch of the bridge above being mirrored by a corresponding inverted arch (fan jang) springing from the same abutments deep under the water. Great stability, especially valuable when rock or clay foundations are not to be had, can be obtained by such rings of masonry. The first bridge of this kind in China was built somewhere in Chiangsu, taken from Mirams. The shear-walls consist of long stone slabs, placed in rows. In Chiangsu, the road-bridge where Fen Causeway crosses the Cam.

Other examples, from Hopei, Shensi and Yunnan, will be found in Thang Huan-Chhêng (1), figs. 77, 78 and 85, 86. Cf. Uecri (1), p. 251 ff.
Li C. outside the south gate of Chhengtu is claimed as one of them. a The Yang-Chhii Waterways Classic b the former interpretation seems the more likely. Chinese bridge entirely of stone, but one cannot be sure whether it had beams or arches from the inscription recorded in the Shui Ching Chu (Commentary on the Waterways Classic) c the latter year induced the judicial commissioner of the province, Wu Lin-Jui, 14 to undertake the building of a long bridge of stone arches, and this was completed in +1647. Floods severely damaged it in +1744 but it was repaired by the then prefect, Li Chhao-Chu. 15 Finally in 1887 three arches were again swept away and others damaged, and this was the occasion on which Hsieh Kan-Thang took in hand the repairs which gave rise to his book. Of its great sociological interest this is not the place to speak, how Hsieh and some friends worked as supervisors without pay, how everything was financed by subscription without help from the local or provincial government, how Buddhist piety motivated many of those who volunteered their work, how believers in feng-shuh 16 objected to the quarrying of stone and felling of trees, etc. For us the interest lies in the fact that although Hsieh's book was written at such a late date, everything seems to have been done by traditional esoteric methods showing little or no textual evidence for arched bridges earlier than this, but if the one here described had a span of some 80 ft. like the Pons Fabricius, as would seem to follow from what is said of the river traffic, it cannot possibly have been the first of its kind, and we could reasonably conclude that small arched bridges must have been constructed first in the Later Han period if not before.

As for the many bridges of Loyang they are all made of (dressed) stones piled up into high and gallant structures. Although with the passage of time there is some decay, they never fail to do their office. When Chu Chhao-Shih 5 was travelling (in his military campaigns) he wrote to his elder brother saying, 'Outside the palaces of Loyang some six or seven li away there is a bridge built all of great blocks of stone, and underneath it is rounded so that not only does the water pass, but large ships can go through (hsia yu an tiang shui, huo shou ta fang kuoyeh). An inscription on it says that it was built in the 3rd year of the Thal-Khang reign-period (+282). In the construction 75,000 men were employed each day, and after five months it was finished. In the course of years this bridge fell disrepair and was then completely restored, but the inscription is no longer to be seen.

Such was the Lü-Jen C.7 Bridge of Wayfaring Men). Chinese historians of engineering have found no textual evidence for arched bridges earlier than this, but if the one here described had a span of some 80 ft. like the Pons Fabricius, as would seem to follow from what is said of the river traffic, it cannot possibly have been the first of its kind, and we could reasonably conclude that small arched bridges must have been constructed first in the Later Han period if not before.

The Thien-Chin C.8 at Loyang was reconstructed with streamlined piers towards the end of the +7th century by Li Chao-Tsje, 9 a renowned engineer who built many other bridges at the same capital. This century is indeed something of a turning-point, for while hardly any extant structures can reliably be considered earlier in date, some of the noblest and most interesting that China possesses derive indubitably from its initial decades. 10 We can therefore entertain no doubt that between Ma Hsien and Li

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a Not perhaps very convincingly. During the Second World War I often passed over this bridge, and dined in the well-known restaurant beside it, but I failed to realise its interest and never carefully examined it. It is referred to in a famous poem by Tu Fu (tr. Alley (6) p. 99).
b By Li Tao-Yuan, ch. 560; ch. 16, p. 178. Cf. TSYF, ch. 48, p. 45a.
c 'A flying bridge', says the Hou Han Shu (ch. 84, p. 139), 'with stone steps (or piers) bestriding a gap across a watercourse (fei liang shih ting kuan hua tso il). Cantilever construction might be thought of here, but surely it was a beam bridge at some height above the water.

d Ch. 16, pp. 203, 214, tr. suer. Chiu Chhao-Shih was a general who served the first ruler of the Liu Sung dynasty and was killed by Hsien Pho-Pho (cf. 43 above) about +434. His letter is also to be found in CSHK (Chin sent.), ch. 141, p. 8a.

e See immediately below, p. 175.

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Chhun there was a powerful and vigorous tradition of arched bridge-building though few or no identifiable examples have happened to survive. Different parts of the country have had their traditionally famous bridge-builders, e.g. Phêng Jung, 11 Mao Feng-Tsai 2 and the monk Tai-Yin 3 in Szechuan, or Ko Ching 4 and Huang Phan-Lung 5 in Kweichow—but most of the names which have come down to us are of the Sung or later.

The major works of arched bridge-building in China are of course those in which many spans had to be built. Beautiful bridges of three or four arches occur in almost every city, 6 but pre-eminent among those with long arcades is the Wan-Nien C.6 at Nan-chêng 7 in Chiangsi, 8 partly because it has had a special book devoted to it. 9 The Wan-Nien Chiao Chih 10 (Record of the Bridge of Ten Thousand Years), written by Hsieh Kan-Thang 8 in 1896, is a full story of this bridge, as detailed as any of the local histories and topographies (cf. Vol. 3, p. 517 above). 11 It is a work of twenty-four arches, 1,803 ft. in length, which crosses the Ju Shui 12 River, six & east of the city where Hsieh Kan-Thang lived. It was always an important communications link between Chiangsi and Fukien, and from literary references we know that between +1271 and +1653 the crossing was made by a pontoon bridge. But the drowning of some thirty persons in this latter year induced the judicial commissioner of the province, Wu Lin-Jui, 14 to undertake the building of a long bridge of stone arches, and this was completed in +1647. Floods severely damaged it in +1744 but it was repaired by the then prefect, Li Chhao-Chu. 15 Finally in 1887 three arches were again swept away and others damaged, and this was the occasion on which Hsieh Kan-Thang took in hand the repairs which gave rise to his book. Of its great sociological interest this is not the place to speak, how Hsieh and some friends worked as supervisors without pay, how everything was financed by subscription without help from the local or provincial government, how Buddhist piety motivated many of those who volunteered their work, how believers in feng-shui 16 objected to the quarrying of stone and felling of trees, etc. For us the interest lies in the fact that although Hsieh's book was written at such a late date, everything seems to have been done by traditional esoteric methods showing little or no textual evidence for arched bridges earlier than this, but if the one here described had a span of some 80 ft. like the Pons Fabricius, as would seem to follow from what is said of the river traffic, it cannot possibly have been the first of its kind, and we could reasonably conclude that small arched bridges must have been constructed first in the Later Han period if not before.

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no trace of modern influences. The techniques used have been discussed in a special paper by Liu Tun-Chen, which reproduces many of the engineering diagrams of the book itself. Thus for example, Fig. 833 shows the picture of the dredger (pha sha③), Fig. 833b the gravel-filled bamboo gabions (tha nang④), Fig. 833c the cofferdam for working on the foundations (sha huat⑤), Fig. 833d the dowelling and cramping of the stones of the piers (chhi tun⑥). Finally, Fig. 833e the piers themselves (chhi tun⑥) with their trussal seat-waterend (fen sha⑧) and their upper parts forming the arch spandrels (sha haat tun⑧); finally Fig. 833f the wooden half-centering (phien veeng⑨). This may be the place for a word about the use of metal dowels and cramps in Chinese stonework. ‘Mutual inlaying’ was common practice from the Thang and Sung onwards, as for instance in the stone causeway which impressed the Korean traveller, Chhoe Pu, in +1487; and in the Thien-Chin C. in Honan, which was strengthened in this manner during the +10th-century repairs made by Hsiang Kung. As we shall see in a moment, iron cramps were used in an arch bridge of particular interest erected early in the +7th century, but before that point it is more difficult to trace the technique back. One would hardly expect to find it in the stone tomb-shrines of the Han, which were not subject to any great stresses, and no stone bridges of that period have survived.

Another bridge, of sixty-eight arches and 1,000 ft. long, crossed the Wei River near Chiang-an (Sian), but it was destroyed before the Sui. Barrow, on his way south in +1793, was very impressed by a bridge of ninety-one semicircular arches which seemed to run parallel with the Grand Canal on which his party was travelling, and crossed an arm of the Thai Hu Lake south of Suchow at a point where it was about half a mile broad. This was probably the Pao-Tai C. originally built in +806, which has central arches higher than the rest just as Barrow described (Fig. 834, pl.). And indeed Chiangsu is rich in such many-spanned structures, for not far away, at Wuchiang, there is another of the kind, the Chhui-Hung C.④ also crossing an arm of the lake. This, we know,⑤ was at first a wooden bridge from +1047 onwards, rebuilt afterwards in stone by Chang Hsien-Tsu⑥ under the Mongols about +1344. It then had sixty-two arches on pile foundations, each secured by a steel tie-bar 13 ft. long.⑦ The greatest invention in arch bridge-building, both for engineering merit in economy of materials and for aesthetic quality, came when builders dared to abandon the idea that security demanded semicircular arches in which the ring approached the pier-line tangentially and so ‘conducted the weight vertically downwards’. When it was realised that the curve of the arch could be made much flatter if it was a segment of a much larger semi-circle, and that the bridge could thus be made to fly forth from the abutments as if tending to the horizontal, the segmental bridge was born.⑧ This discovery, which in Europe may have had something to do with the parallel development of the flying buttress, seems to have been made by Westerners late in the +13th century, for there are several structures of that period, such as the long Pont St Esprit across the Rhône and the small Abbot’s Bridge at Bury St Edmunds in East Anglia, which show it. But it was not applied daringly and widely until the early part of the +14th century, and its growth, which can be followed in the illustrated pages of Uccelli, was then rapid. The Ponte Vecchio of Florence (+1345) was quickly followed by the covered bridge at Pavia (+1351), the Castelvecchio bridge at Verona (+1354), and the largest though most short-lived of all, the bridge at Trezzo (+1375). This reached the maximum span of the group, 243 ft. Sixteenth-century bridges such as the Rialto at Venice, and the Santa Trinità at Florence, simply carried on the tradition, adding elegancies. The height above the chord-line was reduced from a full radius to less than one half (see Table 69).

Since all these bridges are rightly regarded as great achievements it must remain an extraordinary fact that a comparable bridge of even more advanced character, together with a number of smaller ones, was built about +610 by a Chinese engineer of outstanding quality, Li Chih.⑨ His activity, and that of his pupils—for it is clear that he founded a school and style which lasted for centuries—left its mark mostly in the

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① For river-bank control; see p. 339 below. ② Each cofferdam was drained by eight square-pallet chain-pumps (cf. Vol. 4, pt. 2, p. 339 above). For other uses of the term sha huat, cf. p. 315 below. ③ It is noteworthy that this is all made of right-angle joints, like the posts and beams of a Chinese house-roof, and does not involve slanting joints. ④ On this general subject see Briggs (a), pp. 78 ff. Dowels and cramps were much used in the temple building of classical antiquity, and I remember being struck by the strange effects produced in the walls of the temples at Palmyra due to the ‘quarrying’ of later metal-thirsty generations. Cf. p. 178.

⑤ Meskill tr. p. 91. Perhaps he was counting in other bridges as well.

⑥ For another essay from the same title written in the Yuan period by Yuan Chio④ we know that the name of the engineer really responsible was Yao Hsing-Man.① Perhaps he was counting in other bridges as well.

⑦ The beautiful Charles Bridge at Prague, begun in +1357 and finished about +1370, is sometimes classed among these segmental arch structures, but in fact its appearance is somewhat illusory for the haunches of the almost semicircular arches are hidden by the sheer-water ends of the protruding piers. See Gauthey (1), vol. 1, p. 32 and p. 107; cf. Macartney (I), p. 366. ⑧ The special monograph by Novotny, Pocci & Ehri is concerned with the artistic rather than the engineering aspects of the bridge.
The dredger (pha sha). 'The winch mounting should be set up in conformity with the current. The hemp cable more than 90 ft. long, should be heat-dried every night to avoid damp rot.'

The gabions (sha nang). 'Bamboo strips are woven into loose nets 5 ft. long and 5 ft. across.'

The cofferdam (shui kuei). 'This is a divergence from old methods; we did not use bamboo matting (alone), because it is extremely difficult to stop leakage in that way—that is a point not to be forgotten. First the main framework is set up, and then the bamboo matting nailed on; in this state it is light and convenient to handle, and a boat takes it out to its position. Later (after draining) wooden boards of unequal length are inserted within the framework; it is only when it is in position that the lengths of the boards can be fixed (to fit the inequalities of the river-bed).'

Dowelling and cramping the stones of the piers (hsiang shih). 'The pier stones are inlaid with metal alternately, like dog teeth, and iron anchor pieces (dowels) hook the seams together. At the pointed (upstream) ends, the stones are fastened with hooks (cramps).''

The piers (chhi tun). See text.

The half-centering (phien weng). 'Each side has eight "rafters". The curvature changes in eight steps.' Notable here is the use of pillars, cross-beams, tie-beams and king- and queen-posts, exactly as in the transverse framework of a Chinese building, but with the cross-section of the array of purlins arranged to be convex rather than concave.

The two last illustrations are full double-page openings like a, but reduced to half-scale.
provinces of Hopei and Shansi, centring on his finest work, the Great Stone Bridge (Ta-Shih C.i) named An-Chi C.2 near Chao-hsien.3 The country here is the edge of the provinces of Hopei and Shansi, centring on his finest work, the Great Stone Bridge.

Li Chhun threw a bridge just mentioned, for its spandrels are perforated by two arches on each side.5 This construction not only reduced the resistance to the flow of water in floods, but also lessened the burden on the arch and economised in materials.

Li Chhun’s bridge still carries inscriptions written by Thang officials and later visitors praising the “system of four holes near the two banks” (liang yai chhuan su hriteh).6 Chang Chia-Chen’s7 (ft. + 675), for example, says:8

And in the Ming the author of the Piao I Lu said that the bridge looked like a new moon rising above the clouds, or a long rainbow hanging on a mountain waterfall.9 Ambassadors and other important travellers used to go out of their way in order to see it.10 Indeed they still do. After the time of Li Chhun spandrelled arches were used in many +12th-century Chinese bridges,11 but they did not appear in Europe until the +14th century, when we find them in the Pont de Ceret over the Tech near Perpignan.12 This is a large semicircular arch of 148 ft. span having one small semicircular arch in each spandrel, and three other semicircular arches in the approaches, two on one side and one on the other.13 Li Chhun’s spandrel-arch construction was thus the ancestor of those many modern bridges of reinforced concrete which dispense with all filling between the arch ring and the deck, connecting them only by vertical pillars or a reticulate construction of concrete members. In our own time it has undergone a thorough restoration fitting it to stand for centuries more.14 One cannot help comparing Li Chhun with Anthemius of Tralles, whose 100 ft. diameter dome of the Cathedral of the Holy Wisdom at Constantinople had been finished rather less than a century earlier, in + 537. Great though his achievement was,15 it had been a natural development from the older domed basilica, and what Li Chhun did was really much more original.

In order to appreciate the full originality of the work of Li Chhun we must take a closer look at the statement just made that the invention of segmental arches appeared in Europe no earlier than the +14th century. This is true only if we refer to marked segmentality in free-standing bridges, for segmental arches embodied in buildings go back to the Hellenistic period. At the temple of Deir al-Medineh in Egypt, built in Ptolemaic times (early — 2nd century), stone segmental arches with brick walls above are used in the roofing of chambers, probably chapels;16 but they are almost certainly Coptic, for the temple afterwards became a Christian church, and therefore not older than the +4th or +5th centuries.17 However, at the Roman port of Ostia segmental arches made of large thin bricks appear to occur in a number of buildings dating from the —1st and — 2nd centuries, notably the ancient trapezoi known as the Theron-pool, though some at least of them may be true semicircular arches the haunches of which are hidden in the brickwork piers from which they seem to spring.18 In any case, many real segmental arches are to be seen at Ostia embedded in brickwork or serving as the lintels of doors, and all this is characteristic of Roman architecture in other places also. Surprisingly, it may turn out to be characteristic of ancient Chinese brickwork too, for traces of two built-in segmental arches or vaults have come to light in the

and further note that the larger outer arch in each case is itself segmental.

and its convexity (yeng) is so smooth, and the voussoir-stones (chen) fit together so perfectly... How lofty is the flying arch! How large is the opening, yet without piers!... Precise indeed are the cross-bondings and joints between the stones, masonry blocks delicately interlocking like mill wheels, or like the walls of wells; a hundred forms (organised into) one. And besides the mortar in the crevices there are slender-waisted iron cramps (yao theek shun tishu) to bind the stones together. The four small arches inserted, on the other side, break the angle of the roaring floods, and protect the bridge mightily. Such a master-work could never have been achieved if this man had not applied his genius to the building of a work which would last for centuries to come,...

This stone bridge over the Chiao River is the result of the work of the Siu engineer Li Chhun. Its construction is indeed unusual, and no one knows on what principle he made it. But let us observe the marvellous use of stone-work. Its convexity (yeng) is so smooth, and the voussoir-stones (chen) fit together so perfectly... How lofty is the flying arch! How large is the opening, yet without piers!... Precise indeed are the cross-bondings and joints between the stones, masonry blocks delicately interlocking like mill wheels, or like the walls of wells; a hundred forms (organised into) one. And besides the mortar in the crevices there are slender-waisted iron cramps (yao theek shun tishu) to bind the stones together. The four small arches inserted, on the other side, break the angle of the roaring floods, and protect the bridge mightily. Such a master-work could never have been achieved if this man had not applied his genius to the building of a work which would last for centuries to come,...

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tomb of Liu Yen, the Chien Prince of Chungshan (d. +88 or +90), as well as in the larger vaulted tomb of similar or earlier date at Ying-chheng-tzu. But what could be done in buildings was not so easy to apply to bridges which had to launch forth into the void.

The attempt has sometimes been made to show that many medieval European bridge arches were segmental and that the departure of the +14th century was not so very revolutionary. Fortunately, this question is susceptible of quantitative answer. A simple measure of the 'flatness' of an arch form can be obtained by calculating the ratio of the rise to the half-span, \( r/s \), where \( s \) is the sagitta (or, in the limit case of the semicircular arch, the radius), and \( l \) the chord (in the limit case, the diameter). A further property is given by what is called Spangenberg's 'Audacity Factor', i.e. the square of the chord or span length \( l \) divided by the sagitta \( s \), i.e. the rise from the chord-line to the crown, as the sofit or under-surface of the key-stone is termed. This is a measure of the horizontal thrust on the abutments and in the arch ring for a given load per unit length. Data and derived characteristics for a number of bridges of known dimensions in East and West at different periods are assembled in Table 67 and Fig. 838.

It thus appears that in the West very slight approaches to segmentality occurred from Roman times onward, though often only to be seen by close inspection and measurement. The rising base-line in Fig. 838 shows the increase of the factor for semicircular arches of increasing size, and the degree of segmentality can be gauged from the height of the point above this line. There was thus only one important bridge with any substantial segmentality in Europe before the +14th century, no. 4; and its flatness ratio was only 0.51, contrasting with the Florentine bridges of after +1340 with their ratios of 0.38 and 0.36. Meanwhile all had been outdone long before not only by the Sui bridges of the +7th century, including the masterpiece of Li Chhun (no. 13) with its flatness ratio of 0.38, but also by the later Sung bridges of the +12th century, one of which (no. 14) gives the lowest ratio of any in the table. It is thus demonstrated that the segmental bridges of +17th-century China can be placed without hesitation among the best constructions of the kind in +14th-century Europe; indeed when we allow for the subsidiary segmental spandrel arches Li Chhun's school has a priority of more than a millennium, for not until the railway age (the seventies of the nineteenth century) did comparable, if larger, Western bridges arise in the work of No. 4.

Table 67. Segmental arch bridges in East and West

<table>
<thead>
<tr>
<th>No.</th>
<th>Date of construction</th>
<th>Flatness ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>+17th century</td>
<td>0.38</td>
</tr>
<tr>
<td>13</td>
<td>+17th century</td>
<td>0.38</td>
</tr>
<tr>
<td>12</td>
<td>+16th century</td>
<td>0.36</td>
</tr>
<tr>
<td>11</td>
<td>+15th century</td>
<td>0.36</td>
</tr>
<tr>
<td>10</td>
<td>+14th century</td>
<td>0.38</td>
</tr>
<tr>
<td>9</td>
<td>+14th century</td>
<td>0.38</td>
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<tr>
<td>8</td>
<td>+14th century</td>
<td>0.38</td>
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<td>7</td>
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<td>6</td>
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<tr>
<td>5</td>
<td>+14th century</td>
<td>0.38</td>
</tr>
<tr>
<td>4</td>
<td>+14th century</td>
<td>0.51</td>
</tr>
<tr>
<td>3</td>
<td>+14th century</td>
<td>0.51</td>
</tr>
<tr>
<td>2</td>
<td>+14th century</td>
<td>0.51</td>
</tr>
<tr>
<td>1</td>
<td>+14th century</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Notes:
1. Tomb of Liu Yen, the Chien Prince of Chungshan (d. +88 or +90), as well as in the larger vaulted tomb of similar or earlier date at Ying-chheng-tzu.
2. Data and derived characteristics for a number of bridges of known dimensions in East and West at different periods are assembled in Table 67 and Fig. 838.
engineers such as Paul Séjourné and Robert Maillart. It is not often that we are able to make a graph of achievement with a chronological coordinate, but the segmental arch begs for illustration in these terms, and Fig. 839 portrays the results of plotting the flatness ratio of bridges against their dates of construction. The brilliance of the segmental arch style spread to Kweichow and Kuangsi (cf. no. 15) without spandrel arches and of uncertain date. At some time seemingly during the Ming or Chhing the Chinese anticipation is here made plainly manifest.

Li Chhun’s great bridge was not at all an isolated phenomenon, for nearly twenty others exist in various parts of China, mostly in the northern provinces but not exclusively. Those included in Table 67 vary widely, some, such as no. 21, being almost semicircular, but others (e.g. nos. 14 and 17), the Yung-Thung C. (Ever Communicating; Fig. 840, pl.) and the Ling-Khun C. (Soaring across the Void), exceedingly segmental. Both of these date from the +12th century and both were

\[ \text{flatness ratio} = \frac{\text{span} - \text{height}}{\text{span}} \]

built under the Jurchen Chin dynasty, the former by an engineer whose name has come down to us, Phou Chhien-Erh. Some are large, with spans of up to 70 ft. or so, others hardly larger than culverts, but all in the same segmental style. Particularly beautiful is no. 15, the Chi-Mei C., a low bridge of four spans, two very flat and two semicircular, the central pier being perforated by an arch of its own. This brings us to the longest many-spanned bridge of segmental arches in China. The celebrated Lu-Kou C. which crosses the Yungting R. and gives its name to a small town near Peking, dates from +1189, and must have been standing by about +1280 in exactly its present form since Marco Polo describes it in detail. In modern times foreigners have given its own name to it. Always strategically placed, it added to its renown by being the scene of incidents which started the Sino-Japanese war in 1937. It was thought by Marco Polo to be probably unequalled by any other bridge in the world (Fig. 841, pl.). Some 700 ft. long, it has eleven segmental arches averaging 66 ft. span each, abutting on piers pointed both up and down stream; and the Venetian visitor was greatly

\[ \text{Spangenberg factor} = \frac{\text{span}}{\text{height}} \]

\[ \text{degree of flatness} = \frac{\text{flatness ratio}}{\text{Spangenberg factor}} \]
impressed by the fact that it was possible for ten mounted men to ride abreast upon the deck without inconvenience. The parapets of carved marble with their 283 stone lions, all different, were also a delight to him. The name of the original builder has not been handed down, and we know only the name of Yang Chhi (the time of the magnetic compass and the stern-post rudder) so that perhaps the engineer who repaired the bridge.

On several occasions elsewhere in this book we have instanced the segmental arch bridge as one among the inventions transmitted from China to Europe. Though almost nothing can be said about the details of the transmission we are not disposed to doubt the reality of the influence. The technical upsurge of the European 14th century in this particular respect points very clearly to travellers of Marco Polo’s own time, though possibly the only message they brought was that the flying arch had been made by Asian men, and that it stood up. Beyond this, what emerges from the analysis here outlined is that conceivably a similar message had come through in the +12th century (the time of the magnetic compass and the stern-post rudder) so that perhaps the Pont St Esprit as well as the Ponte Vecchio was really fathored at Chao-haien. We must hope that future researches will enable us to ascertain exactly to which cluster of transmissions the segmental arch bridge belongs.

Could Galeote Pereira have seen the segmental arch bridges of Hopei as well as the megalithic beam bridges of Fukien, he would have been doubly confirmed in his opinion: ‘This causeth us to think, that in all the world there be no better workmen for buildings, than the inhabitants of China.” One wonders what he would have thought of the iron suspension bridges of the western provinces, logically in a way the converse of the eastern arch bridges. It is to these, passing from the domain of compression to that of tension, that we must now turn.

(4) Suspension Bridges

The idea of spanning a mountain river-gorge by a suspended rope instead of a solid bridge must be very old in the history of human techniques; certainly it has been widely implemented. It was put into practice in the New World by many Amerindian peoples inhabiting the southern part of the continent (e.g. the Peruvians) where cables of

* Elsewhere Marco Polo drew attention to the roofed bridges common in Szechuan and other parts of Western China.

• I had the pleasure of visiting this fine structure with Mr Rewi Alley, Miss Ma Hsiao-Mi and other friends in the summer of 1932. Photographs in Thang Huan-Chih (1), fig. 93; Mao I-Shing (2), pl. 3, (1); Sinha (3), vol. 1. pl. 92a.


As an accompaniment to the ensuing sub-section the reader may like to make use of an introduction to the theory of suspension bridges such as the recent treatment by a master of the subject (Pugsley, 1). The only contribution specifically devoted to the history of the suspension bridge in China is that of Goodrich (16); it appeared long after the present sub-section had been written, but we were glad to find that little change was necessary.

• Cf. Mason (4); Robins (2); and especially von Hagen (3), pp. 106 ff., 113 ff., 131, 141 ff., 157 ff. The oldest Inca suspension bridge site he studied was of +1200. The classical description is that of Garcia de la Vega el Inca, written about +1610, (1), pp. 572 ff.
The next step in the development of the suspension bridge was the fixing of the rope to points at more or less equal height on each side of the river, and the adding of arrangements which would permit travellers to cross without hanging in a cradle or acquiring the skill of a tightrope walker. One of the simplest ways in which this was done was to suspend additional ropes as hand-rails so that the set of three formed a V-section, the rails being attached to the tread-rope at short intervals; this type is attested for China as well as India, Burma, Gilgit, the Celebes, Borneo and Sumatra. An improvement consisted in adding to the hand-rails an overhead rope and plaiting the whole together so as to form a continuous tubular structure, 3 to 5 ft. in diameter. Such bridges are made by the Abor tribespeople on the Assam-Tibet border some hundred miles up from Dibrugarh, and reliable descriptions speak of spans of as much as 800 ft. with a swing of 50 ft. from side to side. The Nagas also construct impressive bridges with various combinations of ropes.

When we consider the techniques which could have led to the establishment of such bridges, that which immediately comes to mind is the use of arrows with cords attached to them, so that the arrow could be recovered with the prey. Hopkins (5, 25) has suggested that the character 'yi' which came to mean a south-western barbarian, was originally a picture of an arrow with a string attached to it (K551). This method of shooting birds with arrows to which long strings and weights are attached so that the arrows used, 

...
very name of the Hindu Kush (Hsien-tu = Hsüan-tu) means 'suspended crossings or passages', a testimony to the antiquity of the invention. The passage just quoted is not, however, the earliest that we can find, for a few pages later on the same chapter of the Chhien Han Shu quotes the speech of Tu Chhin² made in +25 and directed against the sending of Chinese diplomatic missions to Chi-Pin (Gandhāra, mod. Afghanistan),³ on account of the extreme difficulties of the trans-Himalayan journey. The reader may remember, perhaps because of its description of mountain-sickness, the translation of this speech given in Vol. I, p. 194, but we shall repeat a small portion of it here in an alternative and almost certainly better form.

Then comes the road through the San-chhih-phan gorge, 30 li long, where the path is only 16 or 17 inches wide, on the edge of unfathomable precipices. Travellers go step by step here, clapping each other (for safety), and rope suspension (bridges) are stretched across (the chasms) from side to side (sheng to hsiang yin). After 20 li one reaches the Hsien-tu (mountain pass). . . . Verily the difficulties and dangers of the road are indescribable.⁴

Most geographers agree that this road (if road is precluded by the 'ninefold interpreters (necessary)' (i.e. by the enormous difficulty and dangers of the road) is precluded by the 'ninefold interpreters (necessary)' (i.e. by the enormous difficulty and dangers of the road).⁵

Keeping on through the (valleys and passes of the) Tsungling⁶ mountain range (the Pamirs, the eastern parts of the Hindu Kush), we travelled south-westwards for 15 days. The road is difficult and broken, with steep crags and precipices in the way. The mountain-sides are simply stone walls standing straight up 8,000 ft. high. To look down makes one dizzy, and when one wants to move forward one is not sure of one's foothold. Below flows the Hsien-thou Ho⁷ (the Sindhu, the Indus). Men of former times bored through the rocks here to make a way, and fixed ladders at the sides of the cliffs, seven hundred of which one has to negotiate.⁸ Then one passes fearfully across (a bridge of) suspended cables to cross the river (nieh hsiian kung huo ho), the sides of which are here rather less than 80 paces (c. 480 ft.) apart. (Access to this place) is precluded by the 'ninefold interpreters (necessary)' (i.e. by the enormous distance), which is why neither Chang Chhien nor Kan Ying in the Han period ever reached this spot.

Further information was collected by Kuo I-Kung⁹ early in the +4th century in his Kuang Chih¹⁰ (Extensive Records of Remarkable Things),¹¹ and all the foregoing sources were made use of by Li Tao-Yuan about +500 in the opening chapter of his Shu Ching Chu.¹² Within twenty years thereafter more intrepid monks were daring the suspension bridges of the Himalayas, but for a reason which will presently appear we shall reserve their statements for a few pages.¹³ Two and a half centuries later such bridges figured prominently in the campaigns of the great Korean general of the Tang, Kao Hsien-Chhi¹⁴, in western Sinkiang and the neighbouring regions.¹⁵

Well has it been said that the suspension bridge was almost a condition sine qua non for intercourse in historical times between the people of China and those of Tibet, Afghanistan, Kashmir, Nepal, India, Assam, Burma and Thailand.¹⁶

A seventeenth-century description occurs in the Chin Chhuan So Chi (Fragmentary Notes on the Chin-chhuan Valley) by Li Hsin-Hêng,¹⁷ who says:

In this region (Chang-ku, now Tan-pa,¹⁸ on the Szechuan-Sikang border) there are three suspension bridges. Hundreds upon hundreds of stakes and piles are driven in on the two banks of the river, and stones heaped over them. Long bamboo cables are suspended between them, with wooden boards laid down, and large ropes at the sides to help the traveller to support himself. Passengers walking over these bridges feel their feet declining and sinking as if they were on soft mud. But such bridges can be built where no stone structure is possible. About the same time Athanasius Kircher, the Jesuit scientist, spoke in his Chines Monumenta Illustrata (+1667) of a 'flying bridge in Shensi having but one span 400 cubits long',¹⁹ but he illustrated it by a copper-plate of a gigantic semicircular arch. His source was his colleague Martin Martini, who in the Noctus Atlas Sinensis of +1655 had told of a bridge across the Yellow River '40 Chinese perches from end to end (400 ft.) in the neighbourhood of Ninghsia.²⁰ And indeed there is the site of a cable suspension bridge (so chhiiao²¹) marked just at the point where the line of the Great Wall crosses the Yellow River south-west of Ninghsia and turns north-west to cross the Gobi and protect the Old Silk Road (cf. p. 49 above). Bamboo cable suspension bridges are still extremely common in the mountainous parts of Yunnan, Szechuan, Sikang, Sikkim, Tibet²² and Nepal.²³ But their distribution covers also Burma and Indonesia.²⁴

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¹ P. 125.
² Chi-Pin included Kashmir only later on; see the interesting excursus of Petech (1), pp. 61 ff., on this region and its name.
³ CVI. auct.; we diverge here from Wieger's interpretation of roped mountaineers (TH, p. 550), which we followed before, but also from Petech (1), p. 16, who did not notice the phrase used on p. 94. The passage is also found in TCKM, ch. 6, p. 113b, and (in condensed form) in Shu Ching Chu, ch. 1, p. 48.
⁵ Lefty chart iee (pp. 20 ff.), called owing in the Pamirs (cf. Polovtsov (1), pp. 133 ff.).
⁶ On these two famous travellers see Vol I, pp. 173, 176.
⁷ See YHSF, ch. 74, p. 350 a. 8. He agrees that the mountains got their Chinese name from the bridges.
⁸ 智顗
⁹ 斯優
¹⁰ 智顗
¹¹ 智顗
¹² 智顗
¹³ 智顗
¹⁴ 智顗
¹⁵ 智顗
¹⁶ 智顗
¹⁷ 智顗
¹⁸ 智顗
¹⁹ 智顗
²⁰ 智顗
²¹ 智顗
²² 智顗
²³ 智顗
²⁴ 智顗
Most remarkable is the fact that identical developments took place, as we have seen, in South America, and Robins (2) reproduces a photograph of an Inca suspension bridge in the Huancayo Valley, Peru, made with cables of maguey fibre and hide, and spanning 150 ft., which, with its porches and abutments on each side of the river, resembles quite closely the type of Chinese bridge seen in Fig. 852 (pl.)

Already at this stage we have to note the distinction between what we are calling the ‘catenary’ bridge and the suspension bridge as we know it, with its flat deck hanging level from the ropes or chains. In the first case the passengers travel along the curve, however tightened the longitudinal lines may be; in the second they move horizontally. It seems probable that the second form arose out of the first by a hypertrophy of the hand-rails. Even in the bamboo-cable bridges we begin to see a tendency for the hand-rails to take their origins from points higher up the banks in relation to the dipping deck than that which they occupy at midstream. This can be seen in a photograph of a bridge over the Dhauli River in Nepal on the Tibetan border, or in another of a bridge built by the Nung tribespeople of Upper Burma.

Cable suspension bridges were sometimes put to military uses in China, quite apart from the strategic importance which always tended to make them centres of combat operations. The Wei Shu contains an account of an ingenious submersible suspension bridge which could also be used as a boom. It was constructed by a Wei general, Tshui Yen-Po, who was one of the commanders fighting Hsiao Yen (later Liang Wu Ti) about + 494. Tshui was guarding certain places on the Huai River, his object being to deny the use of its waters and its banks to the enemy. So he took the wheels of some carts, removed their rims, and cut short the spokes (to make cog-wheels) so that they would engage with one another. Strips of bamboo were twisted together to make ropes, and more than ten of these cables were strung together in parallel so as to form a bridge (with cross-planks). At both ends large windlasses were set up so that the bridge was submersible at will. It could therefore neither be burnt nor cut. In this way the line of retreat of Hsiao Yen’s generals, Tsu Yueh (1) and the rest, was blocked, and moreover ships and boats could not get past. Thus the forces of (Hsiao) Yen could not go to the rescue, and finally Tsu Yueh’s brigade was all captured.

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The majority of West China suspension bridges consist of a single span. At each end of the bridge a substantial bridge house is built on a stone foundation (cf. Fig. 846, pl.), its roof being supported either by wooden poles or stone walls. Inside this house or porch are placed two rows of stout vertical wooden columns, one for each of the side-cables of the bridge (Fig. 847, pl.), and these columns act as rotating capstans for the tightening of the bridge ropes. The columns are socketed into the foundations below and into beams of wood above, the whole structure being kept in place by the

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1. Cf. Brigham (1) for Guatemala, and Shippee (1) for the Colca Valley in Peru. The relation between this kind of suspension bridge and that characteristically Amerindian device, the hammock, should not be overlooked.

2. Smythe (1).

3. Anon. (7).

4. For example, the cable bridge built across the Imjin River by the Korean and Chinese allies in the campaign of + 1593 against the Japanese invaders; cf. Hubbert (1), vol. ii, pp. 8, 9. This was not quite, as Hubert thought, 'the first suspension bridge that history records'. Cf. pp. 188, 199.

5. Ch. 73, p. 118. We are indebted to Dr Arthur Waley for directing our attention to this passage.

6. This region was quite outside the usual area of distribution of suspension bridges. But one does occasionally come across mentions of them in East China—for instance the south gate of Kao-yu on the Grand Canal (cf. p. 214) had a hanging-bridge lock (tsao chiao cha) outside it in + 1563 (cf. Gandz's (1), p. 39).

7. Weighting could of course have been used, but there are some Chinese hardwoods, such as the Yunnanese chestnut, which sink like a stone, as the bridge engineers of the Burma Road found out during enemy bombings in the Second World War (Tan Pei-Ying (1), p. 114).

8. Tr. auct.

9. Cf. Brigham (1) for Guatemala, and Shippee (1) for the Colca Valley in Peru. The relation between this kind of suspension bridge and that characteristically Amerindian device, the hammock, should not be overlooked.

10. For this Tshui Yen-Po received a well-deserved title. Later on, in connection with iron chains, there will be something more to say about the military aspects of suspension bridges and booms.

11. The most careful study of the catenary suspension bridges of West China is that of Fugl-Meyer, and we cannot do better than follow it here. On the remarkable properties of plaited bamboo strips, something has already been said (Vol. 4, pt. 2, p. 64), and the subject will necessarily recur in connection with marine cordage (pp. 597, 664 below). The bamboo cables of the bridges are made in the same way as those used for towing ships against the current of rivers, but of larger dimensions. Bamboo strips taken from the inner part of the culm form a core in the centre of the rope, and round them is woven a thick plaiting of bamboo strips taken from the outer silica-containing layers. The plaiting is so done that the outer portion grips the core more tightly the higher the tension. Such ropes (to) are generally about 2 in. thick, and three or more twisted together form one of the bridge cables (too). When placed in a testing machine, the straight inner strands break first, while the plaited material shows very great strength, not rupturing until a stress of 26,000 lb. per sq. in. is reached, though an ordinary 2-in. hemp rope can carry a stress of only about 8,000 lb. per sq. in. Moreover, the silica-containing outer surface is very resistant to wear, e.g. against rock surfaces, which is naturally important both in towing and bridge cables.

The majority of West China suspension bridges consist of a single span. At each end of the bridge a substantial bridge house is built on a stone foundation (cf. Fig. 846, pl.), its roof being supported either by wooden poles or stone walls. Inside this house or porch are placed two rows of stout vertical wooden columns, one for each of the side-cables of the bridge (Fig. 847, pl.), and these columns act as rotating capstans for the tightening of the bridge ropes. The columns are socketed into the foundations below and into beams of wood above, the whole structure being kept in place by the
weight of a formidable crib of stones fitted underneath the roof.\(^a\) Tightening is done by hand-spike, and the whole process resembles the adjustment of a violin string by the turning of the key. The main cables under the deck are fastened to the capstan-columns nearest the span, or to horizontal winch-columns under the floor-boards, and in front of the bridge-house they pass through hardwood leads to keep them in their proper positions. When the deck cables begin to deteriorate, they are replaced by turning of the key. The main cables under the deck are fastened to the (or a single piece of metal is used in the whole structure. Further details are available in the papers of Liu Tun-Chen, and which will be described in the following Section. The An-Lan S.C.\(^b\) consists of no less than eight major spans, the greatest of which is 200 ft., and its total length is somewhat over 1,050 ft. Good photographs of it are not plentiful owing perhaps to the mists and clouds of the region, but Figs. 848–851 (plls.) give a fairly good idea of this splendid bridge.\(^c\) The bridge is 9 ft. wide, and supported on ten bamboo cables each 64 in. in diameter. The hand-rails are unusually elaborate, consisting of five of the same ropes each. One of the piers is built of granite masonry and crowned by a decorative gate and wooden roof, but the others are all hardwood trestles, roofed, and surrounded by additional piles to prevent scouring. Fortunately there are human figures visible in Fig. 850 to give some scale, and in fact the height of the bridge at the piers is about 50 ft. above the level of water or dry gravel bank of the Min River. One should remember, as Fugl-Meyer says, that not a single piece of metal is used in the whole structure. Further details are available in the papers of Liu Tun-Chen (1), Liang Su-Chhêng (2) and others;\(^d\) all of whom show an admiration for the Kuanhsien bridge that may easily be understood.\(^e\)

A document of +1177 records the crossing of this bridge by the great scholar and traveller Fan Chhêng-Ta. In the diary of his journey from Szechuan to the south-east, he wrote:\(^f\)

Here I passed over the great suspension bridge (shêng chhiao). This has five spans each 120 ft. long and 12 ft. wide. All the planks of the passage-way are held together by ropes. Bamboo fences are arranged at each side, and the bridge is borne upon several tens of huge wooden posts erected in the river and strengthened by piles of rocks. The bridge thus hangs between them in mid-air. When there is a strong wind, it sways up and down. It is like the nets strung out by fishermen for drying, or the loops of coloured silk suspended by the dyers.

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\(^{a}\) Cf. Fugl-Meyer (1), fig. 56, location unfortunately not given.

\(^{b}\) In the Sung, yet another name, Phhng-Siih S.C.\(^c\)

\(^{c}\) E.g. Lo Ying (1), pp. 273 ff.; Lane (1); Stevenson (1); Thang Huan-Chhêng (1), pp. 75 ff.; Mock (1), p. 32. Accounts differ as to the lengths of spans because in recent years additional trestle piers have been introduced, and if two small approach sections at each end are counted, the number of spans is now 10.


\(^{e}\) I had to give up my litter, and walked across swiftly in a manner which might have seemed unnatural that some more durable material should have been sought. The decisive step in the perfecting of suspension bridges was undoubtedly the use of wrought-iron chains, and as we shall shortly see, it looks as if this invention was made in south-west China not later than the end of the +6th century and quite probably in the +7st. The essential pre-conditions were there—traditional catenary cable bridges and an advanced metallurgy of iron.\(^f\) To accompany the ensuing discussion we add one more provisional table which gives data on some of the more interesting iron-chain suspension bridges in the provinces of China (Table 68).\(^g\) We call it provisional because the material is hard to assemble from literary sources alone; extensive travels would be required to do justice to the facts, though further detailed study of documents would undoubtedly bring more information to light. Here no attempt has been made, for instance, to work through the relevant chapters of the encyclopaedias, in which so much has been collected; this must be left to others.\(^h\) To introduce the subject visually, and to suggest something of the great beauty of these iron-chain suspension bridges, we show in Fig. 852 (pl.) the Chi-Hung T.C. across the Mekong River on the old road to Burma, seeming to match with its tension the lowering weight of the surrounding mountains. Of similar nobility is the ancient bridge across the Huâ Chhâng which carries the road from the north in Kweichow to join the modern Kweiyang-Kunming highway at Phan-hsien. And to show this type of bridge in a calmer rural setting Fig. 853 (pl.) depicts the 'Fishermen's Bridge' at Pin-chhuan in Yunnan between Tali and the Yellow River.

The iron-chain suspension bridges generally have no tightening arrangements,\(^i\) the

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\(^{i}\) Cf. Fugl-Meyer (1), fig. 56, location unfortunately not given.

\(^{g}\) The special guilds of builders and repairers of suspension bridges in West China (private communication from Mr. M. C. Gillen).

\(^{h}\) See Sect. 307 below, and meanwhile Needham (31, 32).

\(^{f}\) Henceforward we abbreviate Thêh Chhiao ("iron bridge") as T.C.

\(^{h}\) For example, the Phêl Wên, Yen Fu and the Thu Sta Chi Chhêng (Khoùng Hsü hing). Lo Ying (1), pp. 113 ff., mentions over 30, and Mr Tsang Chi-Mou (private communication, April 1949) has details of 46 iron-chain suspension bridges. Goodrich (16) counts 118 suspension bridges of all kinds. No list approaching completeness has ever been attempted.\(^i\)

\(^{j}\) Cf. Kingdon Ward (14), opp. p. 66; Farrer (1), opp. p. 140.

\(^{k}\) But the chains may be hauled into position by powerful windlasses, as we read in the account of the building of the Ta-chhiao bridge (no. 10 in Table 68), given by the Sue-tieh Fu Chhâng (Thang Huan-Chhêng (1), p. 78).

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### Table 68. Some iron-chain suspension bridges

<table>
<thead>
<tr>
<th>No.</th>
<th>Province</th>
<th>Location</th>
<th>Name of bridge</th>
<th>River</th>
<th>Width (ft.)</th>
<th>Longest span (ft.)</th>
<th>No. of chains</th>
<th>Date</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yunnan</td>
<td>100 K.S.W. of Chang-tung*</td>
<td>Lan-Chin T.C.</td>
<td>Lan-ti-chuang ch.</td>
<td>—</td>
<td>320</td>
<td>20</td>
<td>Traditionally +53, perhaps Sui, rep.</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>2</td>
<td>Yunnan</td>
<td>100 K.S.W. of Chang-tung*</td>
<td>Yu-an-chiang T.C.</td>
<td>Tsai-chiang ch.</td>
<td>—</td>
<td>200</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>3</td>
<td>Yunnan</td>
<td>100 K.S.W. of Chang-tung*</td>
<td>Ts'ai-ch'ung Kuan T.C.</td>
<td>Chin-sha ch.</td>
<td>—</td>
<td>235</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>4</td>
<td>Yunnan</td>
<td>82 K.W. of Lichiang*</td>
<td>Shu-mo Kuan T.C.</td>
<td>Chin-sha ch.</td>
<td>—</td>
<td>235</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>5</td>
<td>Yunnan</td>
<td>E. of Lichiang*</td>
<td>Ching-ti T.C.</td>
<td>Ching-sha ch.</td>
<td>—</td>
<td>288</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>6</td>
<td>Yunnan</td>
<td>N. of Tung-chhuan†</td>
<td>Chiu-Min T.C.</td>
<td>Sui-lan ch.</td>
<td>—</td>
<td>288</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>7</td>
<td>Yunnan</td>
<td>Between Pao-san* and Tshing-yi†</td>
<td>Chiu-Chiang T.C.</td>
<td>Chiu-Kuo ch.</td>
<td>—</td>
<td>288</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>8</td>
<td>Yunnan</td>
<td>Between Pao-san* and Tshing-yi†</td>
<td>Hui-ting T.C.</td>
<td>Na-ch. (Salween)</td>
<td>—</td>
<td>213 (+15)</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>9</td>
<td>Yunnan</td>
<td>Near Hsun-san*</td>
<td>Tsai T.C.</td>
<td>Yung-chi ch.</td>
<td>—</td>
<td>212</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>10</td>
<td>Szechuan</td>
<td>Near Shu-ting*</td>
<td>Tseng T.C.</td>
<td>—</td>
<td>180</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>11</td>
<td>Szechuan</td>
<td>Around Onei shan* (N. of Chang-tung*)</td>
<td>Sun-Hia T.C.</td>
<td>Min ch.</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>12</td>
<td>Szechuan</td>
<td>Jung-ching* (S. of T. Wang-kung)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>13</td>
<td>Szechuan</td>
<td>Lu-shan* (N. of T. Wang-kung)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>14</td>
<td>Szechuan</td>
<td>Hsiao-ho-chiang*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>15</td>
<td>Szechuan</td>
<td>K'iu-tsun-chang*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>16</td>
<td>Szechuan</td>
<td>Hsiao-yuan-chih* (S. Chang-kung?)</td>
<td>Ku T.C.</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>17</td>
<td>Szechuan</td>
<td>Li-tung*</td>
<td>Lu-tung T.C.</td>
<td>Tu-chi ho</td>
<td>—</td>
<td>288 (formerly 364)</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>18</td>
<td>Szechuan</td>
<td>Between Ya-no* and Tse-chien-li† (K'ang-tung?)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>19</td>
<td>Da</td>
<td>Between Analun* and Ama*</td>
<td>Tiao T.C.</td>
<td>Chi-chih ho</td>
<td>180</td>
<td>133</td>
<td>10</td>
<td>107</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>20</td>
<td>Da</td>
<td>Between Shui-hsi* and Phan-bai*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>21</td>
<td>Kweichow</td>
<td>Between Analun* and Ama*</td>
<td>Kuan-tung T.C.</td>
<td>Hua ch.</td>
<td>—</td>
<td>200</td>
<td>30</td>
<td>107</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>22</td>
<td>Kweichow</td>
<td>Between Shui-hsi* and Phan-bai*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>23</td>
<td>Kweichow</td>
<td>Between Yung-yi and K'iu-yi</td>
<td>Chung-an T.C.</td>
<td>Chung-an ch.</td>
<td>—</td>
<td>200</td>
<td>30</td>
<td>107</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>24</td>
<td>Kweichow</td>
<td>Between Yung-yi and K'iu-yi</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>25</td>
<td>Shensi</td>
<td>Ma-tung* (N. of Pu-chuang)</td>
<td>Me-tao T.C.</td>
<td>Pu ho</td>
<td>—</td>
<td>50</td>
<td>6</td>
<td>107</td>
<td>THC, Ss. 203; Go; L. 42</td>
</tr>
<tr>
<td>26</td>
<td>Shensi</td>
<td>Shi-chia-hi (m. Tung-yo)</td>
<td>Pho-chi T.C.</td>
<td>—</td>
<td>—</td>
<td>8</td>
<td>107</td>
<td>THC, Ss. 203; Go; L. 42</td>
<td></td>
</tr>
</tbody>
</table>

**ABBREVIATIONS**

- Bo = Bourne (1)
- FM = Fugl-Meyer (1)
- Gu = Grootaers (1)
- Gs = Goodrich (1)
- Gs = Grootaers (1)
- Gr = Grubert (1)
- Ha = Hackmann (1)
- Hor = Horwitz (1)
- Ho = Hommel (17)
- Ke = Kemp (1)
- KT = Kii (1)
- LG = Leach (1)
- PEL = Phel (1)
- Pho = Pho-shen (1)
- THO = Thi (1)
- Up = Ureft (1)
- Wi = Wiers (1)

* Figures above pages, proceeded in the case of von Richthofen (2) by a volume number; and figure-numbers are indicated as such.

* This is abbreviated to ch.

* This may have been only a bamboo cable bridge.

* The name Kuo-Kuo T.C. on modern maps may refer only to the modern suspension bridge on this road. Older maps have a Fei-Lung (T.C.) further up river, probably too far for it to be a synonym of the Chi-Hung T.C.; if so, this was probably a bamboo-cable bridge.

* This is the traditional association with Chango Liang.

* The name Chiang-Kuo T.C. on modern maps refers to the bridge described by Thang Hoan-Chi (1), pages 75, 77, and 78, where the deck plates were made to interlock by means of male and female joints secured with iron bolts, and also the provision of solid wooden guards. It also mentions the wicket gates used for bringing the chains to the right tension, and their fastening in position with "stone columns." This bridge was removed, and used, for vehicular traffic.

* Place-name unidentifiable. Thang Hoan-Chi (1), fig. 107, has Lo-chen ch., perhaps another bridge of this region.

* The bridges in this region were regarded by the Sai-tung Fu Chih as the oldest of the kind.

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* Four spans.

* Characters uncertain; there is a place of this name in Kuangsi. Goodrich (16) gave only the Romanized form of the Szechuanese place-name.

* This former southern province of the Tibetan marches has become Chhangtu Territory (Chhangtu T.C.), with loss of its eastern third to Szechuan.

* Another iron-chain suspension bridge in this region is described by Edgar (1).

* This bridge is said to have been preceded by a floating bridge made by a Taoist at Lo-fou Shen. See p. 203.
problem involved being one of anchorage only. For this purpose massive stone abutments are built to contain the chain ends, as for example in the photographs of bridges across the Mekong and the Yangtze (Figs. 852 and 854, pls.). In the Lu-tung bridge, the chains are embedded 40 ft. into the pillars on both sides. This problem still remains in the most modern suspension bridges (cf. Steinman). No Chinese examples of chains covering more than one span are known, and when a pier occurs, as at one of the Mekong crossings, it is built on a natural island, and the two iron-chain bridges do not form a continuous way right across. The chains are always hand-forged, with welded links made of bar iron 2–3 in. in diameter. Owing to the constant lateral movement caused by the winds of the gorges, the links close to the abutments tend to wear out, and in the old days replacement was not easy, since the country is such that communication links made of bar iron 2–3 in. in diameter.

Types of catenary used—at least three bridges are known (and there were probably many more, some still existing) which are constructed of linked iron bars. Deep in the mountains of the Szechuan-Sikang border, such a bridge 300 ft. in length, described by Fugl-Meyer, has round bars 2½ in. in diameter in lengths of 18 ft. joined by pin connections. It crosses one of the tributaries which enter the Min Chiang before it issues from the mountains at Kuanhsien, and in this case three intermediate stone piers have been built, the bars passing smoothly in channels over their rounded convex tops, so that the bridge presents a gently undulating line.

Of these bridges, perhaps the most famous, if not the most interesting technically, is the Lan-Chin T.C. near Ching-tung in Yunnan. As the local history and topography says:

On the west bank of the (Lan-)tshang river there are perpendicular cloud-piercing cliffs reflecting the waters, and near by a waterfall plunges down over beautiful but dangerous precipices. The prospect is wonderful. Here iron chains are fixed north and south to form a bridge. Local tradition says that this was built in the time of the emperor Ming of the Han (c. +65). It was repaired in the Yung-Lo reign-period (c. +1410).

This raises the important question of the age of the earliest iron-chain bridges. Later generations certainly believed that this one dated from the Han, for example Chang Chia-Yin, who wrote a poem about the songs of the Han soldiers resounding in the gorge (c. +1545). Modern historians, however, have shown disinclination to believe in the possibility of so early a date. They have pointed out that pre-Thang texts mention only the crossing of the Mekong River at this point and do not distinctly describe any bridge. Some have even suggested that the attribution to Ming Ti sounds like a story emanating from the local Buddhist abbey. For this was the emperor who traditionally patronised the first beginnings of Buddhism in China, and since the building of bridges was a religious duty, his name might well have become associated with an important one. In any case there is no ground whatever for doubting its repair in the early +15th century, and that event alone antedates any iron-chain suspension bridge in Europe. Moreover, as we shall see in a moment, there is some evidence for the building of other famous iron-chain bridges in the Sui, and that might possibly be the date of the Ching-tung bridge also. But the best claim to renown which this bridge has is that it was described by several of the early travellers in China, and knowledge of it reaching the West through Jesuit channels, it became the accepted precursor of all successful eighteenth- and nineteenth-century iron-chain suspension bridges. The story of this, however, will come better at the end of our account.

Perhaps we have been too sceptical about the ability of the Han engineers to throw an iron-chain suspension bridge across the Mekong River. Since the criticism of the traditional attribution much new knowledge has come to light about the iron and steel technology of Han times, and if it was possible then to make cast iron more than a millennium before Europe could do so, it was surely not impossible to manufacture 250-ft. lengths of chain formed of substantial wrought-iron links. Since China was the focus of advanced siderurgical skill, not Tibet or Gandhara, we must view in a new light the indubitable existence of long-established iron-chain suspension bridges on the route to India by the beginning of the +6th century. Fa-Hsien had not found them, but Sung Yün and Hui-Seng, who travelled that way in +519, did. The narrative of their journey says:

From the country of Po-Lu-Lo (Bolor, modern Gilgit) to the kingdom of Wu-Chiang (Udyåna, modern Swat, Chitral, etc.), they use iron chains for bridges. These are suspended in the void, in order that one may cross (over the mountain chasms). If one looks downward no bottom can be seen, and there is nothing to grasp at in case of a slip, so that in an instant a man may be hurled down ten thousand fathoms. On this account travellers will not cross over if a wind is blowing.

a (1), p. 122; cf. Huson (3). We cannot identify the exact place, as Fugl-Meyer gives its name only in aberrant romanised form, another example of the lamentable practice of omitting characters for Chinese place-names. It may or may not be identical with the Lan-chün-chhi of Thang Huan-Chhib (2), p. 81.

b Cf. Thang Huan-Chhib (1), fig. 107.

c TSSC, Chih fung tien, ch. 1490, p. 34, tr. auct. From Nan Chao Yeh Shih (+1550), ch. 26, tr. Sainson (1), p. 208.

d TSSC, Kiao hung tien, ch. 33, i sob, p. 6, which writes Yin.

1 建江 '建洋' '建洋镜' '张传熙' '老君瑶' '引
After this it is natural to find that these bridges were still in use in Hsüan-Chuang’s time. In his account of Udyana, written about +646, he says: 18

Reascending the Hain-tu River (Sindhu, the Indus) the roads are craggy and steep; the mountains and valleys dark and gloomy. Sometimes one has to cross the gorges by (bridges of) cables, sometimes on chains of iron stretched (side to side). There are galleries (chao tao) along the edges of abysses, vertiginous flying bridges, and wooden ladders or stone steps up which one has to climb. . . .

It seems most reasonable to suppose that the making of iron-chain suspension bridges radiated from the regions of most advanced iron technology, and it may well be therefore that the Ching-tung bridge was actually the predecessor of these bridges on the upper Indus between Gandhara and Sinkiang. 19

Concrete, indeed decisive, evidence for the early building of iron-chain suspension bridges comes from a time intermediate between Sung Yun and Hsüan-Chuang. It concerns an interesting cluster of these bridges in north-western Yunnan in the region of Lichiang, a city which stands at the base of a tongue of mountainous country some sixty miles long formed by a northern detour of the Yangtze (here the River of Golden Sand, the Chin-sha Chiang) as far as the Szechuanese border. 20 Above the sharp bend where the detour begins, the river was crossed by two famous iron-chain suspension bridges. The first of these was between Chhi-taung 21 and Chu-tien 22 near the Tha-chhing Kuan bridge, formerly the border between the Nakhie tribesfolk of the Nan Chao kingdom and the Tibetans; here there was a Thieh-chihao Chheng (Iron-bride Town), the present village of Tha-chhing. 23 This was without doubt on an important line of communications through Chung-tien 24 to Tibet, and apparently a special official, the Iron Bridge Commissioner (Thieh Chhiao Chheng-Tu) 25 , was at one time in charge of it. Now encyclopedias preserve a statement by Mu Kung 26 , the Honourable Mr Mu, of the Yunnan, himself a Nakhie from this part of the country, which reads as follows. 27

Hua-Ma Kuo. 28 This (tribal region) was formerly called Chi-chin-chau. 29 The Yuan emperor, Shih Tse (Khubilai Khan), came here on a tour of inspection, and (afterwards) enfeoffed (Tuan Hsing-Chih) in 1253. Continuing his tour to the west he visited Hua-Ma Kuo and (passed) over the iron bridge south to Stonegate (Shih-mh Min Kuan). This bridge, which spans the River of Golden Sand, was built, according to the Sui Shih 30 by (Shih) Wan-Sui 31 and Su Jung. Going north (from the river) one comes to the Hei Shui (Black River) which connects with Pa and Shu (Szechuan) flowing out to the east, and eventually to the San Wei (Shan) Mountains (Mountains of the Three Dangers, near Tunhuang)—in all, ten thousand 6 of mountains.

Khubilai Khan was really in these parts, but it was not exactly on a serene tour of inspection, it was as a military commander of the Yunnan expedition of the Mongols under his reigning elder brother Mangu Khan in +1252, and he was leading one of three columns in the attack on Tali. 32 This was probably the occasion when the bridge was captured by A-Tuang A-Liang, 33 a Nakhie chieftain who was fighting on the Mongol side. 34 But by the time of Khubilai it was already old, and must have been long since repaired, for we know that it had been destroyed in +794 by the Nan Chao king I-Mou-Hsin 35 during the course of a campaign which he undertook in alliance with the Thang dynasty against the Tibetans. 36 In this way he cut off the retreat of their forces, and gained a considerable victory. As for the original builders of the bridge, there seems no reason for doubting the attribution to a general and a military engineer of the Sui dynasty. Other sources date the construction in the Khai-Huang reign-period (+581 to +600) under Sui Wen T'i. 37 And we know that from +594 to +597 Shih Wan-Sui was in command of an expeditionary force in the south-west to conquer the Man tribes of Yunnan, so that there was every reason for him to improve communications, like General Wade in another mountainous country. 38 Indeed the dynastic histories specifically mention his river crossings in the campaign. Su Jung was probably his military engineer, and the bridge would have been built in the last years of the century. Holes in the rocks for securing the chains can still be seen, but the bridge itself has long since disappeared.

Further down river between Chu-tien and the sudden northward bend at Shih-khu there was another great iron-chain suspension bridge across the Chin-sha Chiang near


20. We note from this that bamboo-cable bridges persisted along with the stronger iron-chain ones, probably for shorter spans.


22. Besides the exhaustive account of this region by Rock (vol. 1) with its magnificent Illustrations, there is a very living description by Gaullart (1) who was Depot Master of the Chinese Industrial Cooperatives at Lichiang during the Second World War.


24. TSCC, Chih Fian T’ien, ch. 1505, 1506, 2, p. 224 a, tr. auct.
201. BRIDGES

Lacking, there is nothing at all impossible in this tradition. About +1540 the Chi-Hung T.C. inspired a poem by Yang Shen:

Feartul of step, on the flying ladder one advances.
Woven of iron, a lonely thread running straight through the sky.
In malicious mists above one the cloud-dragons wander,
In the abyss below the peacocks drink of the river’s spray.

South from the Lan-Chin Bridge went the road to the Al-Alo Country.
West from the borders of Phu ran the chain of camps of Chuko Liang—
Far, far, a myriad li from here, is China’s heartland,
Thinking of ancient deeds, how could one’s own heart not be full?

The name of the engineer who effected the conversion to iron chains has fortunately been preserved. In his account of this bridge, Ku Tau-Yü says: ‘Wang Huaü it was who began to link iron chains together (here), adding cross-planks over which people could walk as if on level ground.’ Presumably during the alterations a cable-bound pontoon bridge was provided, for he goes on to say,

According to the Ch’i (the local history), the Chi-Hung bridge over the Lan-tah River was formerly of bamboo cables, but afterwards at the beginning of the Ming, when (Yunnan was) pacified, Hua Yo cast iron (mooring-) posts and set them up on each bank so that boats could be connected together (to form a bridge). A

This period was one which saw many such conversions, for we know of yet another engineer, Chao Chhing, who replaced at least one of the cable bridges over the Lung-
chuan River in northern Yunnan by an iron-chain bridge just about the same time as Wang Huai. It would be tedious to descend much further on the iron-chain suspension bridges of China, and a few more words must suffice. The Ku T.C., also in Szechuan, must be at least 202

Those in Shensi and Shansi are interesting (Table 66) because they show the extreme geographical limits of the suspension bridge zone. The Lu-t'ing T.C. across the Ta-tu Ho in the mountains of western Szechuan is known to have been put into its definitive form by Haung Thai and the monk I-Fan in +1700, but it is likely that there were the usual earlier versions at that place. After various +18th-century references, this bridge acquired great fame in modern times as the scene of a heroic military exploit. In 1935 on the circuitous route of the Long March the Red Army was swinging north up this valley towards Yenan in northern Shensi, and succeeded in storming the bridge after the plastering had been largely removed and in the face of heavy enemy fire. The way to the north was thus opened.

Accounts of military operations reveal a close connection between suspension bridges, pontoon bridge cables and defensive harbour booms; all form a single technological complex. Interesting examples of the use of iron chains may now be added to the case of the submersible bamboo-cable-bridge of the late +5th century already described (p. 190). There were many ways of using catenaries besides capturing existing bridges or denying their use to hostile forces. The following account, from the Wu Tai Shih Chi, tells of a battle in +928 when the second king of the Nan Han State, Liu Yen, gained a victory over his enemies.

In the 4th year of the Pai-Lung reign-period the army of Chhu attacked Fengchow (on the West River near the western border of modern Kiangtung) with numerous ships, and

\[ \text{Defeated the defending forces on the Ho River.} \]

(Liu) Yen was alarmed. Making phalaboristic divination about it with the aid of the Book of Changes he encountered the Hua Ta Yu ('Greater Abundance') so he proclaimed an amnesty throughout his realm and changed the reign-period name to Ta-Yu. Then he sent his general Su Chang with a 'Magic Crossbow Division' (shen au chiu) of 3000 men to the relief of Fengchow. Su Chang took a pair of iron chains and sank them deeply in the Ho River, with very large winches (or capstans, lit. wheels, lun) on each bank (to tighten them), and tamped earth redoubts to conceal the winches and their crews.

Then he invited battle with light boats which, pretending defeat, fled, hotly pursued by the men of Chhu. At the right moment (Su) Chang set in motion the great wheels, which hauled up the booms and cut off the Chhu ships, exposing them to the cross-fire of powerful arcubalistae set up on each bank, so that hardly a man of the Chhu forces escaped to tell the tale.

Chinese military engineers must have had recourse many times through the centuries to these techniques. For again in +1771, when the armies of the Ming were invading the west to re-establish imperial authority over Szechuan, the technicians of Shu flung boldly across one of the greatest of the Yangtze gorges three cable suspension bridges commanding as many iron-chain booms, and equipped with bomb-throwing trebuchets and all kinds of firearms. Later on we shall tell this fully in another context (p. 687). Just as the arch bridge found its Boswell in Hsieh Kan-Thang so the iron-chain suspension bridge also rose, in one case, to the dignity of a book. This concerned the bridge at Kuan-ling over the Northern Phan Chiang, in south-western Kweichow, and Hummel (17) has given us an account of it. The Thieh Chhiao Chih Shu (Record of the Iron Suspension Bridge) was written by Chu Hsieh-Yuan and printed in +1665, though he is concerned the erection of the bridge which had taken place already in +1629. Chu Hsieh-Yuan's father, Chu Chia-Min, had been the prefect under whose auspices the bridge had been built, so that he himself had access to all the official documents. His book was illustrated by a panoramic drawing of the structure and its approaches, part of which is shown in Fig. 855. This may be compared with the description given by the famous explorer and traveller, Hail Hsa-Kho (cf. above, Vol. 3, p. 544), who visited the bridge in +1638, not long after it was finished. His diary has the following:

The Phan Chiang bridge is held up by iron chains which connect the cliffs on the eastern and western sides of the river, a distance of 150 (Chinese) feet. The warp so made has a web of planks. The cliffs themselves are about 300 ft. high and between them a swift raging stream
Hsieh-Yuan. It depicts the Kuan-Ling bridge in the gorge of the Northern Phan Chiang, between An-shun and An-nan in south-western Kweichow. Thirty to thirty-six chains bridged the span of some broader but easier place about half a mile downstream. Chu's drawing has many interesting features. Left there is a masonry embankment against which break the hundred-foot waves. In the foreground on ground there are a number of temples, including a Kuan-Yin pagoda and a library for the perished in the crossing before the bridge was built.

Under the bridge we read: 'The water is so deep here that it has no bottom.' To the right in the back of the bridge is a Buddhist statue, and on the left the 'stone of weeping', a monument to those who perished in the crossing before the bridge was built.

Then in the 4th year of the reign-period the present Governor, then a judge, Hsi Hsia-Kho took a great interest in bridges, and what he says about them would be worth careful study. Like us, he worried about the dates of suspension bridges and their conversions from bamboo to iron; see, for instance, his remarks on the Lung-chhuan River bridges in northern Yunnan, ch. 16, pp. 326-332.

Though Martini (Wei Khuang-Kuo) may not have seen this himself in the course of his travels in China, the information would easily have reached him through the intelligence service of his Jesuit colleagues. In a moment we must take up the influence of such accounts had on the engineers of Europe.

Fig. 855 is by no means the oldest Chinese representation of an iron-chain suspension bridge is protected by a high iron railing woven with smaller chains. On each bank there crouch two stone lions, three or four feet high, which clench these railing-chains tightly in their mouths.

Hsi noted a point of technical interest here, namely that the railings were also made of chains, thereby taking a portion of the weight and inviting a transition to a flat deck suspended entirely on the catenary. From other sources we know that Li Fang-Hsien's bridge was partly destroyed in the turn of the old in +1644, but repaired in +1660 and many times later. In 1939 a modern steel structure replaced the old one, but this was destroyed by the Japanese a year later. In 1943 a steel suspension bridge, 390 ft. long, was erected about a mile downstream, but when I passed back and forth over it in the following years I had no idea how interesting the spot was, and did not try to find the old abutments.

It is possible that the work of the Kweichow bridge-builders was brought to the notice of Europeans only a few decades after the description of Hsi Hsia-Kho. For in the map of this province in the sixth volume of Blain's great Atlas (entitled Novus Atlas Sinensis) Martin Martini in +1655 marked an iron-chain bridge over a River 'Puon' to the west of a place, so far unidentified but probably somewhere near Kuan-ling, called 'Picie'. Then in his description of the monuments of Kweichow, he wrote:

Ad Picie occidentalem partem supra profundissimam vallem, per quam torrenti ingenti aquarum in praeceps ruentium lapsu, atque impetu volvitur, ut viam sternerent, ut superimpositis asseribus pontem efformarent.²

Though Martini (Wei Khuang-Kuo) may not have seen this himself in the course of his travels in China, the information would easily have reached him through the intelligence service of his Jesuit colleagues. In a moment we must take up the influence which such accounts had on the engineers of Europe.

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¹ The local people must have taken a pride in telling people this, for the legend in the picture says the same thing.

²Though Martini (Wei Khuang-Kuo) may not have seen this himself in the course of his travels in China, the information would easily have reached him through the intelligence service of his Jesuit colleagues. In a moment we must take up the influence which such accounts had on the engineers of Europe.
bridge. Wang Chen-Phêng\textsuperscript{1} depicts one in a painting which gives his imaginative reconstruction of a Thang palace called the Ta-Ming Kung, done between +1312 and +1320. Here an iron-chain bridge is slung across the mouth of a huge cavern, over which a dragon head spouts a great waterfall. Access to it is gained by a chur tao (cf. pp. 20 ff.), and together with an imposing fountain pavilion, it affords cool promenades for the court in summer.\textsuperscript{8}

The question of the approach of these traditional catenary suspension bridges to the flat-deck type needs further investigation. Gill found a bridge of this kind in northern Szechuan at Hsiao-ho-chang\textsuperscript{2} above Phing-wu\textsuperscript{3} on the upper waters of the Fou Chiang.\textsuperscript{b} Fugl-Meyer maintained that in the Tibetan and Himalayan bridges the load was generally carried by two slack main cables with a flat deck slung below,\textsuperscript{2} but he was not personally acquainted with the region and gave no illustrations. His only reference was to the travels of Sarat Chandra Das (ed. Rockhill), but while this book mentions several bamboo-cable bridges,\textsuperscript{4} and at least three iron-chain ones,\textsuperscript{5} nothing is said about the flat-deck type. However, one such bridge has been described by Waddell.\textsuperscript{f} It crosses the Brahmaputra with a span of 450 ft. at Chak-sam-ch'ô-ri, and is known from a sketch to have had a flat deck in 1878, though this had been removed by 1903. The bridge had a tower at each end, but the deck was only wide enough for pedestrians. The date of construction is given as in the close neighbourhood of +1420, and the engineer is supposed to have been Than-ston-rgyal-po, who lived (according to tradition) from +1361 to +1485. He was associated with the Tantric and ascetic forms of Lamaism, and his pontifical importance (in the constructive sense) is shown by his Tibetan title Lcags Zam Pa, the Builder of Iron Bridges.\textsuperscript{8} Numerous other Tibetan and Bhutanese iron-chain suspension bridges have been reported by travellers,\textsuperscript{1} but unfortunately as yet there has been no systematic study of them. Such a work would be well worth undertaking by a Tibetanist, even if only on account of the social interest of so advanced a technique in so theocratic a culture. It would enlighten us too on the first origin of the iron-chain bridge in Bod-Yul. At present we have nothing except the mention in the Tibetan chronicle found at Tunhuang which relates to the year +762. It runs as follows:

\textsuperscript{a} This painting, in the Crawford Collection, was exhibited in London in 1965; see Sickman et al. (1), p. 36, no. 44. On fountains, see Vol. 4, pt. 2, pp. 129 ff.;\textsuperscript{1} (1), p. 136;\textsuperscript{b} (1), pp. 7, 8, 115;\textsuperscript{c} (1), p. 318.\textsuperscript{f}
\textsuperscript{d} E.g. one at Rungit reminiscent of the Kuanhsien bridge.
\textsuperscript{e} Pp. 144, 204, 228.
\textsuperscript{f} (1), p. 318, See Fig. 856 (pl.)
\textsuperscript{g} For these dates we are indebted to Dr Li An-Che. A more probable range is given by Tucci (3), pp. 143, 204, 228.
\textsuperscript{h} As the Chinese government had collapsed, it was not the right time for presenting tax-silk and maps of the country. (On the contrary) Zaô-rgyal-zigs and Zan-ston-rtsah, having crossed the iron bridge at Bun-liê, invested with their forces many Chinese cities ... which fell into their hands.\textsuperscript{8} This is but a gleam of light in the darkness, however, for we do not know how old the bridge was at this time,\textsuperscript{b} nor whether it had been built by Tibetans or Chinese, nor even its exact location. From the context it was probably somewhere on the upper Yellow River south of Sining in the Thang-hsiang\textsuperscript{1} or Tangut country, and doubtless commanded the approaches to Kansu.

We come at last to the history of suspension bridges in Europe. Not the +6th century, but the +16th, brought the first Western specification for a suspension bridge. Faustus Verantius in +1595 proposed two towers (cf. Fig. 857), a flat deck and a system of linked rods or inverted brackets, formed of eye-bar chains.\textsuperscript{5} The fact that

\textsuperscript{b} From the text it does not sound a new thing; cf. the estimate in Vol. 1, p. 124.
\textsuperscript{c} His pl. xxi; cf. Beck (1), p. 524; Parsons (3), p. 506, fig. 172; Davison (11). Also a cable one in Verantius' pl. xxi.
\textsuperscript{d} 九華山
Fig. 859. Map to illustrate the civil engineering works of ancient and medieval China—the distribution of bridge types; reservoirs, dams, weirs and diversion projects irrigation and transport canals. See detailed key opposite. Scale 1 : 5,000,000.
The image shows a map detailing engineering works of ancient and medieval China—the distribution of bridge types, reservoirs, dams, and sea-walls. It also includes灌溉 and transport canals. See detailed key opposite. Scale 1:5,000,000.
bridges of rods had already been used in south-west China is rather remarkable in this connection. But we have no proof that Verantius gathered anything from the cargo of tales, experiences and wonders which the Portuguese travellers of the early part of the century brought back with them. Any suspicion we may entertain on this score must for the present arise only from the contiguity of dates. In any case, Verantius did not actually construct such a bridge. Meanwhile Martin Martini, in the sixth part of the Blaeu Atlas already mentioned, published at Amsterdam in + 1655, marked also the Ching-tung iron-chain suspension bridge, and described it, giving the Han date—

\[ \text{'hunc pontem Mingus Hanse familiae Imperator condidit, circa annum a Christo nato quintum supra sexagesimum'} \]. The wonder of the work was greatly emphasised by Athanasius Kircher in his China Illustrata of + 1667. In the + 18th century it was illustrated several times, notably by J. B. Fischer v. Erlach in his Historia Architectur (+ 1725), here reproduced in Fig. 858 (pl); and more fantastically by Schramm (+ 1735). According to Robert Stevenson, the earliest iron-chain suspension bridge in Europe was the Winch bridge over the Tees (+ 1741), and perhaps, significantly, this was of the catenary, not of the flat-deck, type. About the same time the Saxon army built temporary military ones (+ 1734). But it is astonishing that the first suspension bridge capable of carrying vehicles was not built until 1809, crossing the Merrimac River in Massachusetts by a span of 244 ft. Next there was Telford's Menai Straits bridge (580 ft.), of 1819-26, and after that they became common. One feels driven to the conclusion that there must have been, in this whole succession of events, a real series of stimuli from the Chinese iron-chain suspension bridges to the engineers of Renaissance and later Europe, even though we cannot as yet elucidate all the stages of the process. Indeed it was almost acknowledged in the generous, though pleasantly realistic, words of Athanasius Kircher, who, after speaking of the structure and dimensions of the Ching-tung bridge, goes on:

\[ \text{Quem cum plures simul transeunt, pons titubat ac hinc inde movetur, non absque trans- euntium metu ruinae perculsorum, horrore et vertigine; ut proinde satis mirari non possim} \]

\[ \text{Darmstadter says that the first suspension bridge was constructed by Andrea Palladio in + 1550} \]

\[ \text{over the River Cismone, but this is a mistake; it was a compound truss bridge (Uccelli (1), p. 68).} \]

\[ \text{Catena ejusmodi viginti sunt, duodecim perticarum longitudine singulae} \] (there are twenty of the same chains, each twelve perches (c. 200 ft.) long).  

\[ \text{P. 59, fig. 15. In his 'Dissertation on Oriental Gardening' of + 1773 Sir Wm. Chambers gave it an ecstatic description. Later, Thomas Telford studied the Chinese bridges (Hague, 1).} \]

\[ \text{Cf. Uccelli (1), p. 709, fig. 139; Pugsley (1), p. 2. Roy (1) reports similar catenary bridges about the same time in the Appalacian Mountains of North America. A few are still in use in Europe, e.g. at Carrick-a-rede in Ulster (photo. in Deane, 1). Stevenson, writing in 1821, knew that there had long been iron-chain bridges in China, but had no details of them. The Winch bridge collapsed in 1802.} \]

\[ \text{Feldhaus (1), col. 152.} \]

\[ \text{The builder was James Finley, and his work still stands, in reconstructed form.} \]

\[ \text{Cf. Pugsley (1); Scoub (1), pp. 170, 191.} \]

\[ \text{It has been suggested that suspension bridges were known in that strange Turkic-Jewish kingdom of the Khazars which, until the middle of the + 10th century, occupied the lands north of the Caucasus between the Don and the Volga (cf. Vol. 3, p. 684). Arabic sources seem to say that the royal tombs of the Khazars were hung upon chains across flowing water (pers. comm. from Dr A. N. Poliak) but it is more likely that they were dug out under it (Dunlop (1), pp. 111, 115).} \]
Key to Fig. 859

**Reservoirs and Dams**
- Shao Pei; Peony Dam (Sunshu Ao)
- Shih Kung Pei (Shen Chu-Liang)
- Chhien-Lu Pei (Shao Hsin-Chhen)
- Chhien-thang Sea-Wall (Hua Hsin, Chhien Liu and Chang Hsia)
- Hsin-f~ng Hu (Chang Khai)
- Lien Hu (Chhen Min)
- Mu-lan Pei (Chhien Ssu-Niang)
- Chhien-Iiuh Sea-Wall (Hua Hsin, Chhien Liu and Chang Hsia)

**Weirs and Diversion Projects**
- Chang River Irrigation System (Hsimen Pao and Shih Chih)
- Fen River Irrigation System (Phan Hsi)
- Shouhsien System (Chhen Teng) [remains still extant]
- Meihsien System (Khung Thien-Chien)
- Ninghsia System (Meng Thien)
- Chengkuo Canal and Wei-Pei Irrigation System (Chheng Kuo)
- Kuanshsien System (Li Ping & Li Erh-Lang)
- Kunming System (Shan-Ssu-Ting)

**Canals**
- Hung Kou = Pien (= Pan) [Chou to end of Nan Pei Chhao]
- Hsin-chu = Ching Chi Tu (Hsin Hsien) [incorp. in Gd Canal]
- Chhien Chih = Shih Lu
- Chhian Chih
- Chhien Hsin Ho (Yuu-wen Khai)
- Chhien Hsin Ho (Yuu-wen Khai)
- Thung Hui Ho (Kuo Shou-Ching) [pt of Gd Canal]
- Pai Ho [pt of Yung Chi Chih, then of Gd Canal]
- Yuh Ho [pt of Yung Chi Chih, then of Gd Canal]
- Pai Ho [pt of Yung Chi Chih, then of Gd Canal]
- Hu-Tho R. and Fen R. canals [unsuccessful, replaced by cart-road portages]
- Yung Chi Chih (Yuu-wen Khai)
- Yung Chi Chih (Yuu-wen Khai)
- Chuang Hui Ho (Kuo Shou-Ching) [pt of Gd Canal]
- Chi Chou Ho (Kuo Shou-ching & Oqquq) [summit section of Gd Canal]
- Hua Chhao Kou (Hua Wte) [incorp. in Gd Canal with extensions]
- Yung Yen Ho [a network]

**Courses of the Yellow River**
(for full details see Table 69, p. 242 below)
- antiquity to -602
- -602 to +11
- +11 to +1048
- +1048 to +1099
- +1099 to +1148
- +1148 to +1234
- +1234 to +1324
- +1324 to 1887 (entirely after +1495)
- 1887 to 1889 and 1938 to 1947
- 1853 to present date

N.B. Numbers indicating towns and cities are the same as those in Table 60 above, and reference there will identify them.
Kircher admired, and Kircher was writing three quarters of a century before Europeans had constructed even the smallest viable suspension bridge, with its modest span of 70–80 ft. With all his optimism as a man of the scientific renaissance he could hardly have dreamed that the application of scientific principles in years to come would permit of the 4,200 ft. span of the Golden Gate Bridge. But if he had been able to do so, he would not have been averse, as a Jesuit, from saluting its first origins in the kingdom of Nan Chao.

(5) Geographical Distribution of Types

If we glance at the map (Fig. 89) on which the locations of many of the bridges here discussed have been marked, we can see that Fugl-Meyer was broadly right in dividing China into three regions from the point of view of bridge engineering. In the northern zone, extending down to the northern parts of Chekiang, Chiangai and Hunan, arch building was predominant, beam bridges being reserved for minor or decorative structures. This was the zone of the segmental arches and the long multiple-span arch bridges. In the western zone, on the other hand, which includes besides Yunnan, Szechuan and Kweichow, the two former provinces of the Tibetan marches (Sikang and Chinghai), and also Kansu and part of Shensi, all bridges of importance were cantilever structures or suspension bridges. Beam bridges are rarely found there. In the southern zone, centring on Fukien but including the two Kuangs, beam bridges are the commonest type, culminating in the megalithic giants of the Fukienese coast. Here arch bridges are only for minor or decorative purposes, and cantilevers and suspension bridges never seen. While obvious reasons of a topographical nature may be adduced to account for this distribution, it does not seem impossible that it might have some genetic connection with those local cultures to the fusion of which Chinese society owes its existence (cf. Vol. I, p. 89 above). But the nature of the terrain and the materials available must have played a part at least equal to invention and its subsequent stylisation within particular ethnic or social groups.

a 'When several people cross the bridge at one time it moves and sways and oscillates up and down in such a way as to evoke in them no small diminution and fear of the danger of falling off; yet I find it impossible sufficiently to admire the skill of the Chinese engineers, who have executed so many and such arduous works for the greater convenience of wayfaring men.'

b In: +1688 Ch'oe Pu had remarked in his Physiologiae Rur (cf. p. 366) on a distribution of bridge-types (Metcalf tr., p. 153). He associated stone bridges with the regions south of the Huai River, and floating or cantilever wooden bridges with the north. But he did not diverge much from his route home to Korea through arch bridges. Besides these Casways they have the convenience of a great many Bridges for the Communication of the opposite Shores; some are of three, some five, and some seven. Arches, the middlenest being always extraordinary high, that the Boats may go through without putting down their Masts. These Arches are built with large pieces of Stone or Marble, and very well framed, the Supporters well fitted, and the Piles so small that one would think them at a distance to hang in the Air. These are frequently met with, not being far under, and the Canal being strait, as they usually are, it makes a Prospective at once stately and agreeable.

This great Canal runs out into smaller ones on either side, which are again subdivided into small Rivulets, that end at some great Town or Village. Sometimes they discharge themselves into some Lake or great Pond, out of which all the adjacent Country is watered. So that there are clear and plentiful Streams, embellished by so many fine Bridges, bounded by such neat and convenient Banks, equally distributed into such vast Plains, covered with a numberless multitude of Boats and Barges, and crowned (if I may use the expression) with a prodigious number of Towns and Cities, whose Ditches it fills, and whose Streets it forms, does at once make that Country the most Fruitful and the most Beautiful in the World. Surprised and as it were astonished at so Noble a Sight, I have sometimes bore a secret envy to China in Europe's behalf; which must own that it can boast nothing in that kind to be compared to the former. What would it be, then, if that Art which in the wildest and most unlikely Places has raised magnificent Palaces, Gardens, and Groves, had been employed in that rich Land, to which Nat. 2 has been lavish of her most precious Gifts. Lecomte was thus full of admiration for the hydraulic engineers of China. He realised that their work went back even into the legends, for he went on:

The Chinese say their Country was formerly totally overflowed, and that by main Labour they drained the Water by cutting a Way through these useful Canals. If this be true I cannot enough admire at once the Boldness and Industry of their Workmen who have thus made great Artificial Rivers, and a kind of Sea, and as it were created the most Fertile Plains in the World.

a I.e. the Manchu conquest half a century previously.
Lecomte was also quite clear about the dual function of the waterways, for transport and for irrigation. Thus he says that the 'Great Canal' was necessary for the Transportation of Grain and Stuff, which they fetch from the Southern Provinces to Pekin. There are, if we may give credit to the Chinese, a Thousand Barks, from Eighty to a Hundred Tun, that make the Voyage once a year, all of them Freighted for the Emperor, without counting those of particular Persons, whose number is infinite. When these prodigious Fleets set out, one would think they carry the Tribute of all the Kingdoms of the East, and that one of these Voyages alone was capable of supplying all Tartary wherewithal to subsist for several years; yet for all that Pekin alone hath the benefit of it; and it would be as good as nothing, did not the Province contribute besides to the Maintenance of the Inhabitants of that vast City.

The Chinese are not only content to make Channels for the Convenience of Travellers, but they do also dig many others to catch the Rain-Water, wherewith they water the Fields in time of Drought, more especially in the Northern Provinces. During the whole Summer, you may see your Country People busy in raising this Water into abundance of small Ditches, which they contrive across the Fields. In other places they contrive great Reservoirs of Turf, whose Bottom is raised above the Level of the Ground about it, to serve them in case of Necessity. Besides that, they have everywhere in Chensi and Chansi, for want of Rain, certain Pits from Twenty to an Hundred feet deep, from which they draw Water by an incredible Toil. Now if by chance they meet with a Spring of Water, it is worth observing how cunningly they husband it; they Sustain it by Banks in the highest places; they turn it here and there an Hundred different ways, that all the Country may reap the benefit of it; they divide it, by drawing it by degrees, according as every one hath occasion for it, insomuch that a small Rivulet, well managed, does sometimes produce the Fertility of a whole Province.

Even allowing for a little enthusiasm, Lecomte was perfectly right that the Chinese people have been outstanding among the nations of the world in their control and use of water. The purpose of this Section will be to examine more closely the nature of their achievements and the engineering techniques which they developed in the process. To begin with we must sketch a broad view of the problems they had to face and the solutions they adopted. There was the climate, with its special features of rainfall. There was the topography, and the peculiarities of the great river-systems which formed the given framework for human enterprise, involving the first of the great requirements, protection from floods. The second great requirement, that of irrigation-systems, was dictated partly by the nature of the loess soil of the upper Yellow River basin, and partly by the widespread adoption of wet rice agriculture (Fig. 86b). The Chinese may constitute a fifth of the world's population, but their irrigated land is a third of the world total, approximately 100 million acres out of 300 million acres.

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*b* As modern general accounts of what they did the well-illustrated articles of Anderson (1) or King (1) may serve as introduction, and there is a short historical paper by Hsieh Pei-Yuan (1). Boerschmann (10) made a survey in terms of human geography. We shall discuss the literature further presently (p. 216).


*d* This 100 million acres accounts for 20% of China's arable land and some 50% of her gross agricultural output. 62 million acres lie south of the 32nd parallel of latitude, 12 million in the north, north-west and north-east, and 24 million in the west. Rice cultivation occupies 64 million acres, and cotton-growing 1·5 million. About 5·5 million acres consist of irrigation-systems covering individually

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Fig. 86b. A late Ching representation of Yu the Great exhorting irrigation workers, from SCTS, ch. 5, I Chi. The caption quotes the words: 'I caused the channels and canals to be dug and deepened...' (cf. Medhurst (1), p. 66; Karlgren (12), p. 9).
28. HYDRAULICS

28. CIVIL ENGINEERING

Thirdly, the more centralised the feudal-bureaucratic State became, the more essential was the construction of waterways along which tax-grain could be transported, and this led naturally to the fourth factor, namely the military aspects of defence. Centralised granaries and arsenals could furnish army supplies at need, and canals were themselves an important obstacle to the penetration of the Chinese agrarian civilisation area by nomad tribes. All this is comprehended in the classical Chinese term for hydraulic engineering, still used today, shi li, 'benefit of water'. While its general and social aspects have been much enlarged upon, historians have been too content to leave the technological principles and practices to relatively restricted professional engineering circles—canal planning and river training, silting and scouring, dredging and dykes, gabions, stanchions and sluices. All this of course is our legitimate material for the history of science and technology, but as in other fields, economic and political history itself must remain in a measure superficial without some real understanding of it. Indeed, if there had been less subjective speculation about the 'hydraulic foundations of oriental despotism', and more objective study of the development of hydraulic engineering itself, we might now be better informed than we are about the real origins of feudal-bureaucratic society.

To complete this introduction a few words may be added in clarification of what hydraulic engineers could hope to do with water throughout the centuries. The fundamental physiographic unit is of course the river-valley, whether it descends slowly or rapidly, shooting in cascades or broadening out into miles of lake and marsh. The harnessing of a river can take place in one or more of the following ways:

(a) Construction of a dam across a valley, forming a reservoir or tank, with one or more spillways to take care of any excess, and derivative irrigation canals to lead the water away for more than 2000 acres each. Since the institution of the People's Republic of China in 1949 further acres have been irrigated, and it is planned to increase the total to 250 million acres. Already about 1 million acres are electrically pumped. These figures are derived from Koevada (5), writing in 1959.

(b) Thus from the point of view of origins, irrigation canals were a contribution of the northern States (Chin, Ch'ing and Chhin), while canals for water-transport were rather a southern contribution (Wu and Chhin). This is discussed by Hsu Chung-Shu (5).

(c) See, for example, the literary treatments of Brittan (1) and Payne (1), easy reading but no help in depth.

(d) Those who have not previously given much attention to the subject-matter of this Section may like to know of a few books which might be consulted by way of background to the reading of it. A history of hydraulic engineering, which concentrates on the basic principles of hydrodynamics, has been written by Rouse and Incce (2), but it does not devalue the useful articles of Skempton (3), Pilkington (1) and Hadfield (1). On particular areas such as Lombardy or Ceylon there are a number of monographs which we shall refer to in their place. On the most ancient works see the review of Biweas (4).

In the technical literature old textbooks such as that of Vermon-Harcourt (1) are almost more relevant to the earlier history of hydraulic civil engineering than more up-to-date books such as those of Barrows (2) or Linsley, Kohler & Paulhus (1). But the writings of Letavsky (1, 2) furnish an ideal contemporary scientific orientation on the works here to be described.

Of books on the great dams there is no need. That of de Boos (2) may be mentioned in any case, serving to describe the most spectacular developments of what started so long ago in the Middle East, China, India and Ceylon. On the history of dams see Schnitter (1); on that of arch dams Globot (2).

A glimpse of the present state of play in this fundamental sociological field may be gained from Anderson (3), a stimulating critical study of Leach (1) on hydraulic engineering in Ceylon and its relation to the sociological history of that culture. We shall make a few comparisons between the Chinese and Sinhalese achievements later on (pp. 368 ff.).

*  

1. The older form is probably the stop-log gate (cf. p. 347 below) in which a number of horizontal submerged embankments, often aslant to the river's main axis; these facilitate the retention basins whereby the upper waters of an inundatory river in the valley of a perennial river, which then descends more gradually than the main stream, following higher contours and branching northerly, can be captured for the canal. The flow of water in it, and the distribution of water by branch canals from it, is controlled by suitably adjustable gates (sluices). A similar system was employed in the canal in the valley of the river at the site of the People's Republic of China. The Chine Canal was cut, high up the valley of a perennial river, which then descends more gradually than the main stream, following higher contours and branching northerly, can be captured for the canal. The flow of water in it, and the distribution of water by branch canals from it, is controlled by suitably adjustable gates (sluices). This method is also very ancient in Asia, where it was carried out on a grand scale. In medieval times, both East and West, the same principle was used to feed the races of water to the city. The oldest form is probably the stop-log gate (cf. p. 347 below) in which a number of horizontal sluices are let down into, or drawn up from, two vertical grooves made in the embankment. This system was combined with the principle of the swinging gate, as by de Bélidor in the 18th century.

2. Flash = flash = scour. Boats going upstream were hauled through against the current by winches, while those coming down shot the rapids with the 'flash' of the water.

3. So called because water is impounded between the gates in the short basins or the long reaches. See pp. 356 ff., below.

4. This is perhaps the largest class of transport canals; cf. Skempton (4), fids. 280, 286, 288, 289; Pilkington (1), p. 351; Hadfield (1), fig. 209. Many of them were built in Europe from the 14th to the 18th centuries, as they had been in China during the previous dozen centuries. Significantly, one thinks of the Duke of Bridgewater's Canal, parallelled and finished by James Brindley in 1776 (see Smiles (5), vol. III, pp. 170 ss) as the type specimen of the kind of England—but in China it was the Chiang-an Canal (cf. p. 273 below), paralleling the Wei and finished by Hsi Po in —130.
water-mills, and today it appears with great effect in the layout of some kinds of hydro-electric
generating stations.
If a lateral canal has its terminus in a water-course other than that from which it
came it is termed a contour canal. Deriving from the upper waters of a river, it can wind gently
round high contours and over a saddle among the hills into a second river-valley, effecting a
junction there. If both rivers are, or have been rendered, navigable, such a canal will give
traffic communication between two whole river-systems. This was first accomplished in China
before the beginning of the present era (cf. pp. 299ff.). In the same way a contour canal can
serve for the irrigation of otherwise un-utilisable land outside the river-valley in which it
originated. It may also go to feed a reservoir in another valley, and may thus combine the
waters of perennial and inundatory river-systems, as in Assyria and ancient Ceylon.
Connection between two river-systems is finally afforded by the summit-level canal,
which scales the contours directly on each side of a range. If the water-shed was a very low
one double slipways might suffice for handling the traffic, but steeper gradients could not be
attempted until it was possible to build stanches or flash-lock gates with some success; and
such routes did not become fully practicable until the invention of the pound-lock, which
could raise or lower one or two vessels at a time some ten or twenty feet, avoiding haulage over
slopes or against rushing discharges. There was of course always the difficulty,
sometimes overcome by very ingenious expedients, of ensuring an adequate water-supply for the summit
levels. Again this was first accomplished in China, as we shall see (pp. 314, 359).

Half a millennium before the beginning of our era, Chinese rulers and engineers
were conscious of the high mechanical efficiency of water transport. Not until the
coming of the steam locomotive and the internal combustion engine was there any
other satisfactory means of carrying heavy loads from place to place. This may at once
be seen from comparative figures of the loads carried or drawn by a single horse:

<table>
<thead>
<tr>
<th>Load Carried or Drawn by a Single Horse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pack horse</td>
</tr>
<tr>
<td>Horse harnessed to wagon—‘soft’ road</td>
</tr>
<tr>
<td>—macadamised road</td>
</tr>
<tr>
<td>—iron rails</td>
</tr>
<tr>
<td>Horse harnessed to barge—river</td>
</tr>
<tr>
<td>—canal</td>
</tr>
</tbody>
</table>

In the following pages we shall trace the epic development of the transport canal in
China, sometimes evoked by the need for the movement of military supplies, but more
often inspired by the nature of the fiscal system, which sought to concentrate the
product of the people’s labour at the bureaucratic nerve centre of a vast terrestrial
empire.

It only remains to say something about the books and reviews which are available on
the subject of this Section. The outstanding work in a European language on the
history of Chinese hydraulic engineering is that of Chi Chhao-Ting (1), while its
Chinese counterpart is due to Chêng Chao-Ching (2), but the former work is much
more aware of the social and economic aspects of the various engineering achieve-
ments, indeed it was a classic contribution to social as well as technological history.

(a) Problems and Solutions
The most fundamental factor with which those who controlled the waterways had to
deal was the Chinese climate. This has already been briefly sketched in the Section on
meteorology, and towards the end of this work we shall have to speak of it again in
comparing China with Europe, linking it with geographical factors such as the contrast
of continents with archipelagoes, the ‘isolation’ of the Chinese culture-area, and so on.
Here we are concerned with it only so far as precipitation of rain determined the size
and character of the natural rivers.

The rainfall (Fig. 861) has a highly seasonal distribution, some 80% of it occurring
in the three summer months. At the same time the prevailing wind direction changes.
This is the phenomenon of the monsoon. In winter the air masses over inner Asia are
cooled and tend to sink, expelling the moist

\[
\begin{align*}
\text{Sun} & \quad \text{on} \quad \text{day} \\
\text{Moon} & \quad \text{on} \quad \text{night} \\
\text{Water} & \quad \text{on} \quad \text{sea} \\
\end{align*}
\]

The recent monograph of Sung Hsi-Shang (3) forms an excellent companion volume but it
appeared too late to help us much.

(b) Anon. (49, 50). His nephew, Li Fu-Tu (5), has given us an interesting account of the current
multiple-purpose Yellow River Control Scheme.

(c) On irrigation projects see especially Anon. (53). Anon. (74) is an album of photographs
published by the Ministry of Water Conservancy in 1956.
Fig. 861. Rainfall map of China (after Lo Kai-Fu (1), modified by Cedric Dover). The stippled border separating the two great areas indicates very nearly the effective northern limit of wet rice cultivation, though this is to some extent a customary division since rice will mature in all parts of China. The Tibetan region to the west is too high for such agriculture. Extremes of rainfall here shown range from 50 to 2,000 mm. per annum.

Fig. 862. Wind-roses showing percentage wind frequencies according to season in North China. Data from Kendrew (1) and Chi Chhao-Ting (1). Left, winter; right, summer.

North China. An example of the mean monthly precipitation is given in Fig. 863, taken from the records of the Kuangsi Agricultural Experiment Station at Shatang; here the four summer months are much wetter than the rest. This implied that watercourses would often be nearly dry for most of the year, and that flooding would be sudden; it was necessary, therefore, to build works which would withstand torrents much greater than the winter flow. And although the total rainfall was on the whole greater in China than in Europe, its intensely seasonal character set a tremendous problem—the building of enough reservoirs to prevent the water from running uselessly away.

Still greater difficulties were caused by the fact that the monsoon climate shows an annual fluctuation of rainfall much greater than in other parts of the world. Works to control this

\[ \frac{\text{annual rainfall (in inches)}}{\text{Below 2}} \]

\[ \frac{\text{1-2}}{\text{10-20}} \]

\[ \frac{\text{20-30}}{\text{Above 80}} \]
were therefore necessary on a scale sufficient to take care of even the most exceptional
years, and naturally it was a long time before this ideal was achieved. In Europe the
ratio of the wettest to the driest years hardly ever exceeds 2 for any given place; at
Shanghai the ratio for a fifty-year period was 2.24. For individual months it might be
much higher; for example, in 1886 there were only 3 mm. in July as against 106 in
1903. Fig. 863 shows the fluctuation at Shatang in the July precipitation during a
recent eight-year period; here the extremes were 51.4 mm. and 432.6. If all periods of
the year were of equal significance to the farmer, this would not matter so much, but a
dry period of ten days during the rice sowing or re-planting may endanger the whole
year’s crop. Moreover, dykes and similar works had to be ready at all times to receive
heavy and sudden pressure, although with corée labour in most dynasties the neces-
sary maintenance could not always be carried out in time. For most regions of China
the wettest/driest ratio does not exceed 3 (though in India it may reach 9), but owing
to the fact that the time of arrival of rain is almost as important as the total quantity,
this has not prevented many grave famines during the course of Chinese history.

The rainfall dissipates itself through the great rivers of China, and their physical
characteristics have naturally determined both the conditions of life of the people and
the greatest works of protection and control.\(^a\) Of the four river-systems, the Yellow
River (Huang Ho), the most difficult to master, was important earliest in Chinese
history, then the Huai River and the Yangtze, setting serious problems of their own,
and finally the Canton river-system. Though the central and southern rivers flow
through fertile rice-growing regions and became connected by an elaborate system of
canals, Chinese hydraulic engineering served its apprenticeship in the hard school of
the Yellow River valleys, tackling problems which even modern technology has not yet
solved.\(^b\)

The Yellow River rises in the relatively dry plateau of north-eastern Tibet and
descends quickly eastwards through the vast area covered by easily eroded loess soil
(cf. Vol. 1, pp. 55 ff. above). About half-way along its course it comes up against the
Shansi massif and turns south, running on in that direction until its abrupt turn east-
wards at Thungkuan, after which it emerges from the mountains towards Khiateng
and pours over the alluvial North China plain. A glance at a map of the distribution of
the loess\(^c\) shows immediately how the whole of the upper Yellow River basin, the
cradle of Chinese culture, is loess-covered, with the exception of the Orodos Desert
through which it runs at the top of its Great Bend. Similarly, the low-lying plain east
of the mountains is all alluvial loess. By a curious chance, the debouchment of the river
from the mountains brings it out just opposite another massif, that of the Shantung
peninsula, so that it must reach the sea either north or south of that region. It has in
fact taken both of these courses at different times, as we shall see.

From its source to the ocean, the Yellow River is about 2,890 miles in length,\(^d\) with a

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\(^a\) The best recent monograph on the fluvial geography of China is that of Sung Hsi-Shang (1).
\(^b\) One of the best short accounts of the hydrography of this river is that of Chatley (25), and I follow it
here. The most recent researches have been reviewed by Jen Mei-O (2).
\(^c\) For example, Creasey (1), p. 166 (Vol. 1, Fig. 6 above).
\(^d\) But only the lower 500 miles is navigable.
depth of 200 ft., with currents of 10 knots or more. After leaving the gorges at Ichiang, the Yangtze receives several great tributaries:

(a) the Hsiang from Hunan in the south-west, at Yoyang on the Tung-thing Lake,
(b) the Han from the north-west at Hankow,
(c) the Guai from Chiangsi in the south, at Chhiuchiang on the Poyang Lake, and
(d) the Huai from Ichiang near, from Chenchiang below Nanking.

Between Ichiang and Nanking there are wide areas on each side of the river liable to flooding, and after Chhiuchiang there is no more safe high ground before the sea is reached, but the total area which the river can inundate is smaller than that which is at the mercy of the Yellow River. This is good, for the Yangtze valley is the most populous in the world, containing 250 million people, more than a third of China's total, and producing 70% of its rice.

The drainage area of the Huai River (about 106,000 sq. miles) has been included in the figure for the Yangtze, since for many centuries, after the blocking of its own exit to the sea on the coast south of Shantung, it has delivered its waters into the Yangtze. The north-south line of communication so formed became, as we shall see, one of the component parts of the Grand Canal. In comparison with the two great rivers, the Huai, and the West River of Kuangtung (1,220 miles long and draining 269,000 sq. miles) are not considerable, yet the former has set many intractable problems to the experts in water-conservancy. Only in our own time has the Huai valley question been firmly taken in hand, and the construction of a vast system of dams in the headwater valleys is one of the best-known achievements of the present Government.

The paramount social importance of floods and their prevention is seen especially well in ch. 57 of the Kuan Tzu book, a text not one of its older portions, but dating probably from the late 2nd or early 3rd century. Duke Huan is interrogating Kuan Chung on the best location for a State capital, and the minister mentions the 'five harmful influences' (wu hat'), flood, drought, unseasonable wind, fog, hail and frost, finally pestilences and insect plagues—but of these floods are by far the worst.

This helps us to understand the Thang poem of Li Pai entitled Ta'ao Fa Pai Ti Chheng? (Leaving Pai-ti. City at Dawn), in which he says that in a single day one can return to Chhiang-ling? (in Hupe), a thousand li downstream. Pai-ti is in the gorges, in Szechuan, about 1,200 li or some 400 miles above Chhiang-lin, so that if he meant a full twenty-four hour day at the most favourable state of the current his average speed would have been about 164 knots. But he probably meant a day from just before dawn to midnight, perhaps 18 hours, in which case his average would have been over 20 knots, the current being assisted by sail and oar.

The same statement occurs also in a poem by Tu Fu (tr. Alley (6), p. 140), and other elsewhere, e.g. Thang Kuan Shih Fu, ch. 3, p. 216, another 4-8th-century work. It was probably proverbial long before.

b For comparison it may be noted here that the total length of the Grand Canal in its completed form was 1,100 miles.

The Meixiong and the Salween Rivers, each with some 1,200 miles within China's boundaries, stand somewhat outside the picture, since neither is navigable there, and occupying as they do very deep-cut gorges, could only be used on a very limited scale for irrigation purposes.

On the general plan and the Jun-ho-chi control installations see Pu-Tso-Yi (1); Kao Fan (2); Sun Li et al. (1); Chang Han-Ying (1); and Hu Huan-Yung (1). On the Fuhu-tung dam and reservoir see Hanmeng Lu-Sha (2). On the Sampo regular sluice dam near the Hungtse Lake, and the North Chhiiau canal from the lake direct to the ocean, see Anon. (68). On the transverse contour canals and interlocking drainage system of the North Huai valley in Anhui, see Chhen Han-Seng (1).

Thus a characteristic sorites passes smoothly from the hydraulic to the sociological and ends with a twist which gives us the viewpoint of the ancient feudal lords. But there is a way out; men must act in disciplined unity. Kuan Chung goes on to say:

'I should like to hear', said Duke Huan, 'about the harmful influences of water'...

Kuan Chung replied... It is the nature of water to flow, and when it reaches a bend (in its channel) it is retarded, and when the bend is full (the water) behind pulls forward that which is ahead. Where the land slopes downward it flows along smoothly, but where it rises (the water) is impeded. (In some places) where the bank curves (the water) pounds against it and crumbles it away, (in other such places) (the water) becomes agitated and leaps up. When it leaps up it runs to one side. On running to one side it forms whirlpools. After forming whirlpools it returns to its central course. On returning to its central course (and slowing) it deposits its silt, and when this has occurred (the channel) becomes obstructed. Obstruction leads to a change of course. Change of course brings fresh stoppage. Thus impeded, (the water) runs wild. Running wild, it injures men. When it injures men, there arises great distress among them. In great distress they treat the laws lightly. Laws being treated lightly, it is difficult to maintain good order. Good order lapsing, filial piety disappears. And when people have lost filial piety, they are no longer submissive...

Thus a characteristic sorites passes smoothly from the hydraulic to the sociological and ends with a twist which gives us the viewpoint of the ancient feudal lords. But there is a way out; men must act in disciplined unity. Kuan Chung goes on to say:

I request that you establish Water Conservancy Offices (Shui Kuan?) (in each district) and staff them with men who are experienced in the ways of water. There should be one high official (Ta Fu?) and one Deputy (Ta Fu Tso?), with just enough labour corps brigadiers (Shui Fu?), section commanders (Hsiao Chhang?) and administrative assistants (Kuan Tso?) to meet the need. Then for each river on both sides of the area on both sides of each river select one man as chief hydraulic engineer (Tu Chiang Shih Kung?). Order all these to inspect the waterways, the walls of cities and their suburbs, the dykes and rivers, canals and pools, government buildings and cottages—and to supply those who are to carry out the repair work in the districts with just enough men.

Presently there will be a little more to say about the titles and positions of the hydraulic engineers at various times (p. 267); here the military nuance of the nomenclature is worth noting. And indeed the rest of the chapter relates how these officials, working together with the village elders (San Lao?), must not only muster the core of able-bodied men and women, but also summon suitable strengths of armed weapon-bearing soldiers (chia shih?) for the repair and maintenance of the dykes. The number of spades, baskets, earth-tampers, planks and carts for each detachment is specified. The summer and autumn, times of hoeing and harvest, are never to be used for public works. The winter is suitable for inspection and the accumulation of stores, such as brushwood for fascines. Most of the work must be done during the spring agricultural lull when water-levels are low. So much for the first great necessity, protection from...
floods. But there were two other pressing incentives for hydraulic engineering in ancient China.

Chinese agrarian society was from the beginning based upon intensive agriculture, and for this to succeed, irrigation works both small and large were as necessary in its eotechnic culture as coal-mining and iron-metallurgy were for the palaeotechnic age (Fig. 86, pl.). In the north-western loess region, says Chi Chhao-Ting, a teotechnic culture as coal-mining and iron-metallurgy were for the palaeotechnic age and for this to succeed, irrigation works both small and large were as necessary in its eotechnic culture as coal-mining and iron-metallurgy were for the palaeotechnic age. In the Yangtze valley and the valleys of Kuangtung, the main necessity was the construction of works stout enough to withstand or delay the greatest flood volumes, and dams and reservoirs to retain the water of the rainy season and release it gradually. Modern studies of the loess (e.g. Barbour, 1, 2, 3) show that this spongy soil, with its high porosity and great capillary capacity, facilitates the rise of mineral elements from the subsoil to the roots of the plants. Rich in potassium, phosphorus and lime, it only needs abundant water, with the addition of organic manure, to show great fertility.

And what is true of the loess soil in situ is true also of the loess being carried down towards the sea in the form of silt in the great rivers. Chinese peasants and officials appreciated long ago, in the - 1st millennium, the importance of this silt as a fertiliser, and faced very consciously the complex of problems relating to its control, e.g. how to prevent its obstructing the course of the river and necessitating ever higher dykes, how to distribute or retain it by means of sluice-gates, etc. At an early date, too, there was a recognition of the relation of this silt flow to the deforestation and denudation of the mountains. But all such questions were inextricably bound up with social difficulties.

In the north, peasants could not easily be dissuaded from settling on the rich land within the great dykes and only occasionally flooded. In the south, landowners and rich farmers tended to encroach upon the lands recovered from drained swamps and lake bottoms (i.e. land nominally belonging to the State but unclaimed by any individuals), with the result that reservoir space available in flood times was greatly diminished.

Nevertheless, the irrigation and the fertilising properties of silt give the clue to the achievement of China in maintaining so-called ‘permanent agriculture’ over the centuries. Though the periodical floods were tragic, they left the soils, says Wofanger,

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b This can be seen well in projects currently accomplished, such as the Thao River canal (Anon. 60) and the Nieh River canal (Kao Chi-Chai, 1), both in Kansu; as also the numerous contour canals derived from the Tung-foo River in North-western Hopei (Yu Ch'eng, 1).

c This too can be seen in current examples, notably the drainage of the low-lying country in Eastern Hopei near Tsien-tsin (Li Hai-Fan, 1), and the interesting canals of Northern Anhui (Ch'ien Han-Seng, 1). Cf. p. 286 below.

d This again is clear in the new integrated Huai River Project, see Fu Tao-Yi (1); Kao Fan (3); Hainan Lu-Sha (1); Anon. (68); as well as in the Yellow River Projects, see Kao Fan (1); T'eng Tse-Hui (1); Anon. (67); Shang Kai (1). Two works in Northern Hopei, the Kuanting dam (Anon. 60) and the Myi ts'ing dam (Huangfu Wei, 1), exemplify the same principles. Their part in the H'ai-Ho Basin control system as a whole is discussed by Hsiang Wén-Hua (1).

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Hydraulic engineering was doubly demanded in China. While in the north irrigation projects were suggested by the nature of the loess soil, though the main crops were dry, wheat, millet, etc., in the centre and south abundant water was indispensable for wet rice cultivation. All the agricultural treaties (cf. Vol. 4, pt. 2, p. 166ff.) emphasise the interest which the farmer should take in the supply of water to his rice-fields. In +1313 Wang Chen wrote, in the Nung Shu. Cultivators of rice build surface tanks and reservoirs to store water, and dykes and sluices to stop its flow (when necessary). . . . The land is divided into small patches, and after ploughing and harrowing, water is let into the fields and the seeds sown. When the plants grow five or six inches tall, they are planted out. All farmers south of the River now use this method. When the plants attain a height of seven or eight inches, the ground is hoed, and after hoing the water is let go from the fields, so as to dry them. Then when the plants begin to flower and seed, water is again let in...

The regulation of water is indeed the sine qua non of wet rice farming. Many Chinese drawings show work being done on the dykes and channels, a constant occupation of countrymen in off seasons. Throughout Chinese history the taxes essential for unified State power were collected in kind, and most of this was grain. Such grain tribute was the fundamental source of supply for the imperial clan, the central bureaucracy, and the army with its headquarters at the capital. Indeed, throughout the period of bureaucratic feudalism the government generally considered the interests of grain-transport as overriding those of irrigation and flood-control. One can see this particularly well in the case of the Grand Canal, which crossed the Huai valley at right angles, and often interfered with the irrigation systems. As Chi Chhao-Ting puts it, the tax transport was primarily an act of appropriation, connected with the immediate enjoyment of the fruit of rulership and the obvious necessity for the maintenance of power by armed force. Irrigation and flood-control were more a question of peasant welfare, and

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Of course at the cost of (a) periodical devastating floods, (b) a very large labour force, (c) the use of human manure with all its dangers (in the uncomposted state) for human health, and (d) delay of the stimulus to improve crop plant varieties.

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Ch. 7, p. 564; tr. Chi Chhao-Ting (1), p. 27, mod. auct.

As it might often have to be pumped out or in, one can see the importance of the various forms of water-raising machinery described in Sect. 27g above, Vol. 4, pt. 2.

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Vol. 4, pt. 27, Ch. 31, Tsu Tshai, p. 6 (Karlsgren (12), p. 48).
The importance of water-transport was by no means limited to times of peace; even more in times of disturbance and war, whether civil or external, the command of the waterways as supply routes was of inestimable value. After the fall of the Chhin dynasty, Liu Pang, founder of the house of Han, owed much of his success in defeating his powerful rival, Haian Yü, to his control of the region ‘within the passes’ (Kuang-Chung), i.e. the Wei valley. From that secure base Hsiao Ho was able to send continual supplies of grain to the Han armies confronting the forces of Chhu in Honan. When, at the beginning of the Han dynasty, Hsiao Ho received the highest reward, O Chhien-Chhiu spoke of him thus: 2b

When the armies of Han and Chhu held their ground against each other at Jungyang (in Honan) for several years, the army (of Han) had no ready supply of food. Hsiao Ho despatched grain from Kuanchung by water transport, and supplied food (for the army), thereby preventing shortages. Your Majesty lost Shantung several times, but Hsiao Ho continually held Kuanchung at your disposal. This is an achievement which will endure for ten thousand generations.

The pattern was repeated some two centuries later, when Liu Hsiu established the Later Han dynasty. But there was a difference in that the base from which supplies were sent forth by water transport in different directions was no longer Kuanchung with its capital at Chchang-an west of the mountains, but rather Honei, i.e. the lower Yellow River valley, with its capital at Loyang east of the mountains. 3c Here Khou Hain was quite consciously entrusted with the same part to play as Hsiao Ho formerly. 2d

At an earlier stage (Vol. I, pp. 114 ff.) something was said of the conception of ‘key economic areas’ by means of which Chi Chhao-Ting has thrown so much light on Chinese history. At different times State p. 1er in China has been centred on various different regions. These have constituted economic areas the agricultural productivity and strategic communication facilities of which were so superior to all other areas at the time that whoever controlled the key area controlled all China. The power of the Chhin State in the 3rd century was largely built on extensive irrigation works (cf. pp. 285 ff. below) in the Wei valley, and the Chhin and Former Han empires were also based on this upper Yellow River region, Kuanchung. The Later Han, however, established its power on the lower Yellow River valley and that of the Huai, shifting the centre of gravity towards Shantung in the east; but meanwhile there occurred a great development both of Szechuan and of the lower Yangtze and Huai valleys. The result was that in the 3rd century three territories were evenly matched (West, North, and East-Central), hence the Three Kingdoms period. In spite of temporary unifications (e.g. the Chin), the centrifugal tendency continued for another three centuries, during which the north and west were often under the control of semi-Chinese Hinnish or Turkic‘nomadic’ dynasties. The great unification of the Sui and the Thang at the beginning of the 7th century was connected with the fact that the productivity and transport system of the lower Yangtze valley had outstripped all other regions so much that a key economic area on a new level was produced. The whole story of the Grand Canal, which took definitive form first in the Sui, was essentially the building of a main artery to bring tax grain from the economic to the political centre of gravity of the country. The pattern is particularly clear because after centuries of further division between east-central and northern areas when the Sung contended with the Liao and the Chin Tartars, the Yuan (Mongol) unification once again brought the Grand Canal to a high level of efficiency, altering its course however so that it served Peking instead of Loyang. No subsequent disruption occurred.

The military significance of canal-building was not confined to the problems of supply. Networks of waterways and ditches formed a kind of defence in depth which gave almost insuperable difficulties to nomadic armies chiefly composed of cavalry. This comes out particularly well in the wars between the Liao (Chhi-tan Tartars) and the Sung. 2 The former were often under the necessity of losing time while ditches were filled in or bridged, or while barges were built for ferrying, and the walled cities of China with their moats, connected by good canals but inferior roads, constituted an almost ideal series of strong points scattered over the country which it was difficult to reduce. This was very different from the steppes country for which armies of horsemen were well suited.

\section*{(2) Silt and Scour}

Let us now turn to more detailed questions. The fertilising effects of silt on saline and alkali land were appreciated as early as 246, when the Chêngk'uan Canal was completed, the first of a long series of projects for the irrigation of the Wei valley (cf. the quotation below, p. 285). \footnote{Cf. Wittfogel & Ftnog (I), pp. 532, 535.} After the successful inauguration of a later one in the series, every ton of erosion loess silt, according to Kovda (I), p. 469, provides 3.3 lb. of nitrogen, the same amount of phosphorus, and 44 lb. of potassium. \footnote{Chi, ch. 29, p. 34, b. Chhien Han Shu, ch. 29, p. 32.}

\footnote{Shih Chi, ch. 29, p. 34, b. Chhien Han Shu, ch. 29, p. 34.}
In these early days silt was generally regarded as wholly advantageous, but as time went on it was perceived that too much might be a disaster. If it originates from topsoil and is not deposited too thickly it is good, but it may damage land severely when it comes from eroded subsoil (Lowdermilk & Wickes, 1). The dangers of silt can be seen recognised in many official reports, as for example in the late spring and summer the streams dry up, and this is a time of deposition was proportional to the speed of flow. The following account relates to the deposition of silt and the flow of water in canals and rivers. The interests of flood-protection could be at variance with those of irrigation. Seasonal compromises had to be sought. The idea of self-scour is also a key one—the Chou Li, for example, says:

Every canal should be made so as to take account of the characteristic forces of water; every embankment should take account of the characteristic strengths of earth (Fan hou pi yin shui i; fang pi yin ti i'). A good canal is scoured by its own water; a good embankment is consolidated by the sediment brought against it (Shan hou chi, shui tiou chu; fang chi, shui yin chu i). These views, and those of Chang Jung, inspired many great hydraulic engineers in later Chinese history, such as Wang Ching in the +st century (Hou Han Hsi, ch. 12, p. 296) and Chia Lu in the Yuan, Phan Chi-Hsin in Ming and Chin Fu in Chihing.

There is no space for more than a glance at the controversies which surrounded the deposition of silt and the flow of water in canals and rivers. One finds echoes of them everywhere in the dynastic histories, though the full story has never been told even in the Chinese technical literature. Meng Chien, for example, when governor of

The passage continues with the views of another notable engineer Wang Hsing when Huan Tuan became Departmental Director of the Ministry of Works about + he made preparations for dredging and dyke-building, but under Wang Mang nothing could succeed. On Huan Tuan cf. Vol. 5, p. 367, Vol. 4, pt. 2, p. 394; and Pokora (9, 13).

For treatments of these questions by modern engineers, one may consult papers by Griffith (1), Chatley (27, 28, 30, 31, 32, 33).

Done. Although one might not be able to make as many deep channels (for letting away the water) as the 'Nine Rivers' of Yu the Great, still, even only four or five would do much good.

Chang Jung's actual estimate of silt-content (60%) seems at first sight impossibly high, and has often been regarded as a literary exaggeration. But he has been confirmed by recent measurements such as those recorded by Jen Mei-O (1): the highest figure for the main stream is 46.14% at Shen-hsien, but for tributaries 67.6%. Besides, concrete figures of any kind show clearly that efforts were already being made in the Han to gain some quantitative measure of the silt-content of the water in which everyone was interested. He goes on to make his statement about the speed of flow, and connects it with the problem of dredging, that is to say, of keeping the stream beds as low as possible instead of building up ever higher dykes and embankments to contain the flood flow. As our topic develops we shall see what anxiety this decision caused in the earliest stages of Chinese hydraulic engineering, the choice between high dykes or deep beds. Here Chang Jung is arguing that advantage ought to be taken of the swift flow of the flood to scour out the channel, and one can see that the interests of flood-protection could be at variance with those of irrigation.

For a modern treatment, one may consult papers by Griffith (1), Chatley (27, 28, 30, 31, 32, 33).
Chhangchow in the Thang, succeeded in clearing the blocked bed of the Meng River, and at the same time arranged for the irrigation of thousands of acres of fields. The question was of course intimately bound up with the invention and construction of sluice-gates and weirs which could be adjusted to the seasonal levels of the main stream, but these developments also served two other purposes, the derivation of irrigation canals and, with flash-locks, the facilitation of barge traffic. We shall reserve to a later stage (pp. 344 ff.) the detailed development of these inventions, and a comparison with what happened in other parts of the world; for the present it may be taken for granted that adjustable sluices (shai men) had been introduced at least as early as the Chhin and Former Han if not before. Let us listen to two old friends discussing the problems of the silt fertilisation method (yu thien for) in the latter half of the +11th century. In his Tung-Pho Chih Lin, the poet and official Su Tung-Pho wrote,\(^a\) about +1060:

Several years ago the government built sluices (tau men; lit. dipping gates) for the silt fertilisation method, though many people disagreed with the plan. In spite of all opposition it was carried through, yet it had little success. When the torrents on Fan Shan were abundant, the gates were kept closed, and this caused damage (by flooding) of fields, tombs and houses. When the torrents subsided in the late autumn the sluices were opened, and thus the fields were irrigated with silt-bearing water, but the deposit was not as thick as what the peasants call 'steamed cake silt' (chung ping yu) (so they were not satisfied). Finally the government got tired of it and stopped. In this connection I remember reading the Chia J Phan of Pai Chhi-l (the poet) in which he says that he once had a position as Traffic Commissioner. As the Pien River was getting so shallow that it hindered the passage of boats he suggested that the sluice-gates along the river and canal should be closed, but the Military Governor pointed out that the river was bordered on both sides by fields which supplied army grain, and if these were denied irrigation (water and silt) because of the closing of sluice-gates, it would lead to shortages in army grain supplies. From this I learnt that in the Thang period there were government fields and sluice-gates on both sides of the river, and that irrigation was carried on (on a mutual basis) even when the river was high. If this could be done successfully (in old times), why can it not be done now? I should like to enquire further about the matter from experts.

Here the poet's words show clearly the conflict between agricultural and transporta­tion interests, though Su Tung-Pho himself evidently did not quite realise the significance of Pai Chih-l's contention. As a further illustration one may take a passage from the Meng Chi Pha Than of Shen Kua, written some twenty years later.\(^c\)

In the Hsi-Ning reign-period (+1068 to +1077) much emphasis was placed on the silt fertilisation method. Scholars discussed the statement in the Shih Chi\(^b\) that one has\(^d\) of water of the Ching River\(^c\) contains several tau of silt, which will fertilise the crops and make them grow tall. I remember that when I was at Suchow\(^1\) on official business I saw a monument on which there was an inscription recording how certain people of the Thang dynasty had built six sluice-gates (tau men)\(^e\) which distributed silt-bearing water from the Pien River to benefit the inhabitants near the lower reaches. Such were the origins of the silt fertilisation method.

There are contemporary records, too, of farmers such as Hsing Yen\(^4\) coming to the authorities and demanding that silt-bearing water should be diverted to their fields.\(^b\)

When we look at modern studies of fluvial hydraulic and silt-transportation\(^a\) we are likely to feel some surprise at the degree of awareness of the old Chinese engineers (many further examples of which await the reader of the following pages), coupled with a sobering realisation of the prominent part still played by empirical observation and formulation in spite of three centuries of post-Renaissance mathematical hydro­dynamics.\(^d\) Some of Fargue's laws, e.g. that the thalweg (the line of deepest soundings in a river) hugs the concave bank, opposite which shoals form; and that the depth increases with the degree of curvature, they already knew—they knew also that in general the deposition of silt occurred in a manner inversely proportional to the velocity of flow. It was not for them to analyse the forces acting upon individual silt particles (impact, turbulence, drag, friction and hydraulic lift), as we do now, but they consciously sought for conditions which would give the 'silt-stable régime' so that a waterway would neither choke itself up nor erode in a migratory manner. It was not for them to establish the principles of helicoidal flow and centrifugal spin which account for the wave-form of the meander plan, nor to demonstrate its natural appearance in model experiments, but they knew (as we shall see, p. 249 below) that dykes were not as good as dredging, and that training works should encourage the natural scour of shoals. Indeed, even if they had distinguished between bed-load (the traction of the larger particles along the bottom) and suspension-carriage (the flotation of the waterborne smaller ones), they would not have been able to prevent the elevation of the bed of the Yellow River, an almost geological process which can hardly be reversed today. Yet in the debates which we shall mention later between the Chinese proponents and antagonists of the channel contraction method (p. 235), we may find advance echoes of Kennedy's principle today accepted, that shallower sections will take the greatest silt-loads, probably because of the greater vorticity, turbulence and cross-currents engendered in them.

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\(^a\) 'Head-gate' or 'sudden gate': the adjective originally referred to a precipitous drop in space, such perhaps as would be represented by a ten-foot head of water, but later it acquired the meaning of 'suddenly' in time. Hence one cannot be quite sure of the meaning of its application to a sluice-gate, nor does it give us much clue as to the gate's actual construction. Cf. p. 349 below.

\(^b\) It may be held that every social phenomenon can be found in all civilisations and that what is hypertrophied in one organism occurs in rudimentary form in others. France in +1628, Mersenne (+1644), Torricelli (+1644) and Mariotte (+1686). See further Rouse & Ince (12); Leliavsky (3).

\(^c\) Biographies in Chih Thang Shu, ch. 163, Ch'ing Shu, ch. 160.

\(^d\) E.g. Leliavsky (1); Brown (1).

\(^e\) This was the river harnessed in the Chengkuo Canal system, on which see p. 283 below. The hu (bean) was in Sung times a capacity measure equivalent to half the Sung picul (tan), i.e. 5 quarts (tau), or about 79 modern lbs.

\(^1\) In Sung times a capacity measure equivalent to half the Sung picul (tan), i.e. 5 quarts (tau), or about 79 modern lbs.
The sorest point, where all controversies reached their acutest phase, was the handling of the Yellow River on the North China plain. The oldest attempts to control it known to us in historical times were the dykes (yen¹) built along the lower reaches under the superintendence of Duke Huan of the State of Chhi (Chhi Huan Kung²), the ruler who figures so often in the books of the philosophers such as Ch'uang Tzu, Lieh Tzu, and Kuan Tzu.³ This was in the first half of the -7th century.⁴ Though it rests upon local tradition current in the Han⁵ rather than upon documentary evidence, the attribution is quite acceptable. The dykes of Duke Huan had the effect of uniting the nine streams of the previous delta into one, and their remains still existed in Han times.⁶

From the Chhin and Han onwards the greatest possible efforts were made to prevent the river from overrunning the plain during high-discharge periods. It must have been noticed that in the uncontrolled state the river tended to build up a kind of low bank on each side of its winter channel, and so for two thousand years the Yellow River has been enclosed with dykes, constantly increasing in dimensions (Fig. 865). Every few years the river would rise to levels which threatened to overflow them, or else the meanders of the low-water channel would carry the river against an embankment and cause its collapse. Some fifty times or more the river has escaped from all control and formed a new channel on the plain, destroying in the process vast tracts of cultivation and settlement, and burying some land under excessive silt deposits. The earliest accounts we have of these troubles are perhaps in the 29th chapter of the Shih Chi, where Ssuma Chhien speaks as follows:⁷

The Han had been in power for thirty-nine years when, in the time of the emperor Hsiao Wen Ti, the River overflowed at Suan-tao and broke through the 'Metal Dyke' (chin thi³) (in -168).⁸ Great levies of soldiers were raised in the Eastern Commandery to close the breach.

Rather more than forty years later, in the present reign, in the Yuan-Kuang reign-period (-132), the River again overflowed at Hu-tzu, pouring off to the south-east in the Chu-yeh marshes, and communicating with the Huai and Ssu rivers. The Son of Heaven therefore commissioned Chi Yen⁹ and Cheng Tang-Shih¹⁰ to recruit men to close the breach, but it suddenly opened again.

Ssuma Chhien goes on to say that Thien Fen,¹¹ the marquis of Wu-An, whose fiefs (he is careful to add) lay on the north of the river, urged that such great floods were direct acts of Heaven with which it would be unwise to interfere, so nothing was done for

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a For an example already familiar to us see Vol. 2, p. 122.

b It is worth noting that this type of public work seems thus to have begun before the earliest large reservoir dams (cf. p. 371 below, on Sunshu Ao).

c Reported in the Shui Ching Chu, ch. 5, p. 156.


f The lost +7th-century geography, Kuo Ti Chih,¹² says that this was another name for the 'Thousand-Li Dyke'.

g 隻 唐公 ¹³ 金 鎮 ¹⁴ 鐵 靈 ¹⁵ 彭雷峙 ¹⁶ 宋頤

h 商地志

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Fig. 865. A late Ching representation of river conservancy work. A dyke is being strengthened and sandbanks removed; baskets and pummers are seen in use. The picture (from SCCTS, ch. 6, Yi Kung) is intended to illustrate the words 'He (Yü the Great) led out the Hei Shui (Blackwater River) through the Sen Wei (Shan) (Mountains of the Three Dangers) and so into the Southern Sea' (cf. Medhurst (1), p. 110), but it is now thought that the meaning of these passages should be 'He travelled along...'. (cf. Karlgren (13), p. 17). The editors of SCCTS interpreted the Hei Shui as the Salween R., but more probably it was one of the rivers in southern Kansu.
twenty years. Eventually, however, the condition of the provinces became so bad that the emperor, Wu Ti, made a tour of inspection himself; and Shun Chi Chien gives a graphic description of the raising of myriads of men by Chi Jen and Kuo Chiang, the sacrificing of a white horse and a jade ring, and the carrying of bundles of wicker-work and faggots by high officials and commoners alike in order to fill up the breach. Finally the fill at Hsien-fang was successfully accomplished (-109), and a triumphal pavilion erected at the place. It was a triumph destined to need perpetual renewal.

Apparently, in spite of the centralisation of the Han bureaucracy, the level of planning and control for such vast projects still did not suffice. About a hundred and fifty years later, a great Han engineer, Chia Jang, revealed in a famous memorial to the throne (-6) something like chaos in the location of the Yellow River dykes.

At the present time, the nearer embankments stand at a distance of several hundred paces only from the water, and even the furthest are only several from it. South of Liyang the old 'Great Metal Dyke' stretched north-westwards from the west bank of the Yellow River to the southern foot of the western mountains. It also ran eastwards to meet the eastern mountains. People built their cottages on the eastern side of the dyke. After they had been living there a little over ten years, another dyke was thrown out from the eastern mountains southward to connect with the Great Dyke. Again, in the prefecture of Neihuang, a swarm with a circumference of several tens of li was drained by building a dyke round it, and the governor of the district then gave the land within the dyke to the people after they had lived there for more than ten years. Now people build cottages in it. These things I have myself seen. In the prefectures of Tungch'un (Eastern Commandery) and Paima, the old 'Great Embankment' is paralleled by several other embankments (outside it), and people live in between them. From the north of Liyang to the border of (the former State of) Wei, the old 'Great Embankment' lies several tens of li from the river, but inside it there are also several rows of dykes which were built in earlier generations. Thus when the Yellow River flows from Honen north to Leiyang there is a stone embankment (shih tao) forcing it eastwards. When it reaches Tungchun and Phingkang, there is another stone embankment to force it north-west. When it arrives at Leiyang and Kuanhsia it meets a third, changing its flow north-east again. At Tungchun and Chinpei it is diverted north-west, and at Wei-chin and Chaoyang north-east again—all by stone embankments. Thus in a distance of only a little over a hundred li, it is turned northwest twice and eastward three times.

Chia Jang was in fact an advocate of the channel expansion theory, a Taoist in hydraulics, who believed that the great river should be given plenty of room to take whatever course it wanted. Rivers, he said, were like the mouths of infants—if one tried to stop them up they only yielded the louder or else were suffocated. Wu Wei was the best watchword: "those who are good at controlling water give it the best opportunities to flow away, those who are good at controlling the people give them plenty of chance to talk." In the Warring States period, when the oldest dykes had been built, people were allowed to cultivate the silt-laden land within them but not to settle there, for after villages had grown up there was always a natural urge to make new dykes ever nearer and nearer the low-water channel. Chia Jang recommended the wholesale resettlement of the populations of prefectures bordering the river. If the emperor was not prepared to do this, his second plan proposed the making of a great network of irrigation canals to relieve the flood pressure, but these would have to be controlled by sluice-gates (shui men) with stone revetments, much more stoutly built than the affairs of wood and tamped earth which already existed in the irrigation district of Jung-yaung. Last and worst of the three possibilities would be to go on repairing the protective dykes and embankments. Chia Jang's memorial implies a deep distrust of the policy of raising such works instead of trying to lower the bed, but if this was to be done there was urgent need for better co-ordination and effective central direction. Whether the resources available to the government of the young emperor Ai Ti (Liu Hain), hardly more than a boy, could have tackled the radical re-alignment and strengthening that was necessary is very doubtful; in any case a certain amount of resettlement in no way solved the problem and the stage was set for the historic break-out of +11.

If there were hydraulic engineers of Taoist tendency there were also Confucian ones. Those who believed primarily in low dykes set far apart were opposed by those who believed in the main strength of high and mighty dykes, set nearer together. Equally those who believed in giving a river's lower reaches the maximum degree of freedom were opposed by those who believed in contracting the channel so as to make the river dig its own bed. The former argued that with widely separated dykes there would be ample storage space between them for the summer flow. The latter held that with a constricted channel the water, flowing more rapidly, would itself scour out the deep thalweg desired by the former. The contractors generally had the advantage of the expansionists because their plans, though more expensive, raised no difficult sociological parallel was explicitly made in Confucian writing (see Vol. 2, p. 256). The sociological parallel was explicitly made in Confucian writing (see Vol. 2, p. 256).
social problems of resettlement of population. But in so far as the control of the Yellow River today has necessitated, as we shall see, the construction and evacuation of vast retention-basins alongside the main stream, the expansionists have not been entirely unjustified by modern technology. During twenty centuries the two schools contended.

Fig. 866. Bend erosion (from Nung Cheng Chhikm Shu). The picture is entitled yin hou because it illustrates a section concerned with underground afferent or efferent tunnels (cf. p. 353) for irrigation.

and neither proved wholly successful. The deep channel is liable to approach and undermine the dykes at bends, and rises of water-level occur with inconvenient speed. The Chinese were extremely conscious of bend-erosion; in the Section on geology we noted a technical term for the scooped-out bend (khan; 'niche'), and Fig. 866 shows a picture suggesting the effect. On the other hand, the wide separation of dykes allowed so great a deposition of sediment that the storage capacity was reduced very quickly; possession was then taken of the tempting new land, and smaller parallel dykes built to keep out ordinary floods, thereby annulling the whole object originally sought. Modern arguments about the best course, then not finally decided, may be followed in the technical papers of engineers such as Freeman (1) and Todd & Eliassen (1), or Chatley (33), supported by more popular accounts such as those of Clapp (2, 3); or preferably in Chinese books (e.g. Chang Han-Ying (1) and the collective work edited by Hu Huan-Yung, Hou Tê-Fêng & Chang Han-Ying). The theory of channel continuation, the greatest advocate of which was perhaps Phan Chih-Hsin in the Ming (+1521 to +1595), has not been entirely confirmed by modern laboratory experiments on model scale, and while dams and retention-basins are being built research is still proceeding.

What is generally conceded, however, is that the bed of the Yellow River has risen by about 3 ft. per century. In some places it has been necessary to build dykes up 6 ft. per annum for stretches of 20 or 30 miles to combat the huge silt deposits. At the present time, the bed is only a few feet below the level of the plain, and in some places level with it or even as much as 12 ft. above it, but in cross-section this central channel is very small compared with the miles of deposit on either side. At the Chêngchow railway bridge, for example, the bottom of the bed is level with the plain, and the average level of the deposit 24 ft. higher, while the top of the dykes on each side is 30 ft. with an abrupt descent to the plain on their outer escarpments. Consequently when the river in high flood escapes through the dykes, the residual flow in the old channel fills that up with silt, and plugs it against future free flow in that course. It is therefore very difficult to get the river to resume its old course after a break.

To illustrate this, Fig. 869 shows a cross-section at a point just above the railway bridge between Chêngchow and Hainhsiang. The bed bottom is about level with the

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* NCCS, ch. 17, p. 324, reproduced in TSCC, I chu tien, ch. 5, hui khan 3.
* At maximum 19·6 miles (Jen Mei-O, 1).
* An interesting echo of the age-old debate is to be found in the novel Lao-Ts'ao Yu Chhian (The Travels of Lao-Ts'ao), written in 1904 by Liu ë' and now translated into English by Shadick (1). Liu ë' was himself an engineer and promoter of industrialisation projects, as well as a great humanitarian and a brilliant archaeologist (one of the first to recognise the significance of the oracle-bones). The problems of hydraulic engineering form part of the plot of the novel, which takes a permanent place among the literature strongly critical of the old officialdom.
* There is a curious compilation of opinions, mostly of Western advisers, edited by Cross & Freeman.
* Though he expected breakthroughs, and provided for defence in depth by outer parallel reserve dykes.
* Many charts of the Yellow River dykes at different periods are extant, e.g. those reproduced by Chi Chiao-Têng (1), pls. 5, 6. Here we reproduce (Figs. 867, 868, pls.) two original scrolls of late Ming or early Ching date, at one time in the collection of Mr Rewi Alley, showing respectively the lower Yellow River in the neighbourhood of Chi-pan, and its earlier course between the Sin-mên Gorge and Hsia-i city, past Khaifeng. We are much indebted to Mr Alley for these photographs and for the permission to reproduce them. Rather older are the charts engraved on stone steles in the Pei Lin at Sian, which I had the pleasure of studying in 1958 and 1964. One of these Huang Ho Thu, dating from +1553, commemorates the work of the eminent engineer Liu Thien-Ho.

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1 Nung Cheng Chhikm Shu
2 CIVIL ENGINEERING
3 HYDRAULICS
28. CIVIL ENGINEERING

surrounding plain, and on each side huge silt deposits are heaped up, topped at their edges by dykes. For such a situation neither of the ancient methods is really applicable, since the dykes cannot be indefinitely heightened, and the work of removing a 25 ft. deep mass of silt 1,000 miles long and 5 miles broad would not be very feasible or economic even for the most modern excavating machinery. Already when Freeman was writing, the best solution seemed to be the building of retention-basins, i.e. long strips of plain-level 'wash-land' parallel to the river and protected on their outer sides by dykes massive enough and high enough to cope with any probable transient contents. This work is now well advanced, according to recent information (Fig. 870). An outer embankment (the Pei-Chin Dyke) and the northern embankment of the river (the Ling-Huang Dyke) enclose an area of low-lying land 91.65 miles (150 km.) long and averaging 30.5 miles (49 km.) in breadth. This runs across the whole of a new province called Phingyuan in a north-easterly direction and ends at the Tung-phing Lake near the old crossing of the Grand Canal. Formerly, flood crests passed this distance in three days, but now the time taken is as much as eight; thus the speed of flow is greatly reduced, and the danger of dyke-failure almost entirely obviated. Another smaller retention-basin has been built nearer to the mouth of the river. The principle involved, that of controlled silt-deposition, is hardly a new one (cf. the rows of parallel dykes in Figs. 867, 868, pls.), but probably not since the time of Chhin Huang Ti has there been a government sufficiently centralised, and never before sufficiently popular, to organise without excessive social strain the removal of towns and villages which must have been necessary. Modern sluice-gates also matter.

What was the origin of these mountains of silt? The blanket of loess extends for about 150,000 square miles over the drainage area of the Yellow River, with an average depth of 100 ft., varying from extremes of 1,000 ft. to a few inches. As long as it was covered by forests of trees, bush and wild grasses, the soft soil was protected from the cutting effects of the heavy monsoon rains. But with increasing population pressure

Fig. 869. Cross-section of the bed of the Yellow River just above the railway bridge linking modern Chingchow with Hinhaisi; i.e. just west of the mouth of the old Fion Canal.

Fig. 870. The modern strategy of controlled silt-deposition in retention basins parallel with the Yellow River, which retard and lower flood crests. The map (after Kao Fan) shows the basin which has been completed along the left (north-west) bank of the river between its sudden turn east of Khai-feng and the point where it crosses the north-south line of the present Grand Canal north of Tung-phing. The retention basin in Fig. 869 is a projected one.

there has occurred progressive deforestation, denudation and erosion, until today there are few trees to be seen on the uplands of Shensi and Kansu. In north Shensi erosion gullies occupy no less than 50% of the total ground space, and the tracks often make their way along ridges of eroded loess as narrow as 3 or 4 ft. across. I myself have had the experience many times in Kansu of seeing literally torrents of liquid brown mud, the consistency of thin porridge, pouring down gullies and across roads after a cloudburst higher up in the hills. Fig. 871 (pl.) gives some idea of what the eroded countryside looks like from the air. The average annual silt loss for the whole basin is

* From Fisher (1); cf. also the photographs in Koester (1).
estimated at 1.76 mm. as considered as a uniform layer. In a number of papers, Lowdermilk has urged that this erosion has been the dominant factor in the difficulties of control of the Yellow River, and it follows that the vast programmes of re-afforestation of the western provinces now on foot will greatly decrease them. This re-vegetation is being started in the talus slopes of the canyons, using suitable indigenous trees such as willows, black locust and catalpa; and if in time something like the forests, long since destroyed, which Marco Polo passed through near Sian, can be made to flourish anew, the control of the river will be much simplified.\(^6\)

Lowdermilk (3) believes that some agency has caused the Yellow River to become progressively more restless in its bed, and that the excavation of the upper channel has not been enough to account for this. Deforestation and consequent erosion must at any rate have been one of the most important factors. The measure of the river's restlessness is the wanderings of its lower reaches, sometimes flowing into the sea north, and sometimes south, of the Shantung peninsula massif. These unmanageable changes are summarised in Table 69 which should be compared with Fig. 89.\(^6\) A brief study of these shows how slowly the river found out its present route after debouching from the hills; it advanced step by step through a series of five or even small stages each preceding a deflection from the final alignment which it would come to occupy. The chief weakness of Lowdermilk's belief in a progressive restlessness seems to be that we know so little of the movements of the river before the first recorded change of -622; his figure of just over 1,600 years of initial quiescence was based on traditional semi-legendary datings not now acceptable. However, after that there were certainly two long periods of quiescence,\(^6\) bringing us to the end of the +9th century. The Sung was a time of frequent change, but between the Yuan and the latter part of the

\(^{a}\) A full account of the relations surmised between the silting process on the one hand, and deforestation, slope-cultivation, over-grazing and erosion on the other, will be found in Lowdermilk \((1)\) and Lowdermilk & Smith \((1)\). Detailed field studies have been reported for Shanxi by Lowdermilk \((4)\) and for the Huai valley by Lowdermilk, Li Te-i & C. T. Ren \((2)\); and for the Wu-hai Shan area by Lowdermilk & Wickes \((5)\). In this last the field observations were compared with the history of the region drawn in much detail from the local gazetteers (cf. Vol. 3, p. 517). The first wave of deforestation of these beautiful mountains, with their Buddhist abbeys where Ennin had wandered, occurred in the +16th century and was halted by two enlightened officials, Hu Lai-Kung \(^1\) and Kao Wen-Chien \(^1\) in +1780. But in the late +17th and +18th centuries the destruction of the forests was resumed, and by the end of the nineteenth they were completely barren and unproductive. Specific aspects of erosion relating to forestry have been discussed by Lowdermilk \((3)\).

\(^{b}\) We have here a good opportunity for the introduction of a quotation from a recent work on the history and geography of slippery eels. In a recent study of the history of fishes in China, the late Dr. H. Lowdermilk, with the late Mr. L. S. Wickes, has drawn some interesting conclusions regarding the history of the Chinese eel. The eel is a fish of great importance in the diet of the Chinese, and its history and distribution are of great interest to students of the natural history of the country. The study of the Chinese eel has been carried on by many European and Chinese naturalists, and some interesting results have been obtained. The Chinese eel is a fish of great economic importance, and its history and distribution are of great interest to students of the natural history of the country. The study of the Chinese eel has been carried on by many European and Chinese naturalists, and some interesting results have been obtained. The Chinese eel is a fish of great economic importance, and its history and distribution are of great interest to students of the natural history of the country. The

Ching more than 500 years (or at least 300) passed without serious alteration. During this period there was strongly centralised government and considerable improvements in civil engineering technique. Yet after the change of 1852-5 there was a further catastrophic overflow to the south-east in 1887-9, and this pattern was repeated by the deliberate breaking of the dykes for military purposes in 1938. In general, therefore, the restlessness of the river seems to have occurred in a series of waves rather than as a continually increasing quantity.

Bielenson \((2)\) has presented a reasoned and rather convincing case for the view that the change of +111 was the fundamental cause of the failure of Wang Mang to found a long-enduring Hsin dynasty. The Yellow River disaster produced population migrations, widespread famines and all kinds of disturbances, including the rebellion of the 'Red Eyebrows',\(^6\) which permitted the gentry supporters of the Han to regain control.\(^6\) This conclusion has important implications for the social and economic history of the period. But if space permitted, one could illustrate each one of the river's great changes by echoes from Chinese political and literary sources. Those, for instance, who have enjoyed the Ming opera entitled Pai Shih Chuan\(^1\) (The Story of the White Snake Pagoda) will remember the Abbot of Chin-shan, Fa-Hai;\(^6\) withstanding the waves conjured up by the goddesses or serpent-spirits to overwhelm his temple—as indeed in +1114 the full force of the waters did break upon Liangshan before dividing to the north and to the south.\(^4\)

To what extent people were conscious of the dangers of deforestation (Fig. 872) in ancient China is a question hard to answer, for one must beware of reading too much of our own ideas into their words.\(^6\) Still, it is hard to doubt the conservation significance which has traditionally been ascribed to the Mencian edicts.\(^6\)

If the seasons of husbandry be not interfered with, the grain will be more than can be eaten. If close-meshed nets are prohibited in the pools and lakes, the fishes and turtles will be more than can be consumed. If axes and hatchets are used in the mountain forests only at suitable times, there will be more wood than people know what to do with (Fu chin i shih ju shan lin, taih mu pu hao sheng yang ye).\(^1\)

The history of the dyke breakages during the Ching dynasty has been studied from the engineering point of view by Su Tsung-Sung, Hsieh Li-Shan & Lo Tsiang (1). The Yellow River Administration during the same period has been the subject of an interesting paper by Hu Chiang-Tu (4), who believes it possible to trace the catastrophe of 1855 directly to preceding bureaucratic inefficiency. Hou Jen-Chih (1, 2) has written on the outstanding engineers of the earlier period, Chin Fu (d. +1692) and Chien Huang (d. +1688).\(^6\)

\(^{1}\) The first wave of deforestation of these beautiful mountains, with their Buddhist abbeys where Ennin had wandered, occurred in the +16th century and was halted by two enlightened officials, Hu Lai-Kung and Kao Wen-Chien in +1780. But in the late +17th and +18th centuries the destruction of the forests was resumed, and by the end of the nineteenth they were completely barren and unproductive. Specific aspects of erosion relating to forestry have been discussed by Lowdermilk (3, 6). It is often only around famous temples that forests have been allowed to survive in China; I remember particularly the magnificent surroundings of the Twost of Lowdermilk (3, 6). But extensive replanting is now radically altering this picture. In 1945 I had the pleasure of visiting, with Dorothy Needham and Dr. Tsoo Shih-Tsui, the Soil Conservation Experiment Station at Tsinhsui, Kansu, established by Chinese experts in collaboration with Dr. W. C. Lowdermilk.

\(^{2}\) Current progress in the soil conservation of the loess highlands can be followed in papers such as those of Fang Hua-Yung (4) and Chien Hsieh-Nung (4).\(^6\)

\(^{3}\) There are compiled from data given by Tsoo Shih-Tsui, Cheng Po-Ching (2), Chiang Chao-Ching (2), Li Hsiieh (2), and the maps of Kuo Hui-Ling and Nesteruk (1). Cf. also Lowdermilk (3). The pioneer work of Biot (1, 2) is still well worth reading.

\(^{4}\) Followed by Nesteruk (1).

\(^{5}\) From the Chihli Chih period to the end of Early Han (1), and from the Later Han to the end of the Thang (2). Courses of the river are indicated in this way.

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1. 方洪光
2. 蔡文姬
<table>
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<tr>
<th>Stability periods, with</th>
<th>No. of years in each period</th>
<th>Line of flow</th>
<th>Identification no. on Map</th>
<th>References to the sudden changes which opened or closed periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antiquity to - 602</td>
<td>7</td>
<td>Much to the north of the present bed (2), joining the later line of the Grand Canal about Ching-hai-hai's some distance south of mod. Tientain and then flowing out through the Hai-ho estuary. One branch deviated eastwards, crossed the line of the Grand Canal between Tungkung^2 and Tsichow,^3 and emptied into the sea near the subsequent mouth of (3), i.e. probably along the line of the present Sai-ni-siu Ho.^4 Also to the north of the present bed (5), but more easterly than (4), deviating from S^3 near Hua-hai-hai,^5 crossing the later line of the Grand Canal south of its sharp bend near Lin-chhiu,^6 and returning to that line again about the point where the branch of 4 had crossed it, i.e. near Tungkung^6.</td>
<td>Ch, p. 4; Ts, pp. 187 ff., TH, p. 129; Maspero (4b), p. 344 discussing Chiu Ching Chou, ch. 5, p. 164</td>
<td>(2)</td>
</tr>
<tr>
<td>-602 to +11*</td>
<td>613</td>
<td>This period includes the great break-outs of - 165 and - 132 mentioned on p. 230, when there was overflow into the Hsui valley (see courses (3), (4) and (5) below)</td>
<td>Ch, p. 9; Ts, p. 256; TH, p. 620; Bielenstein (2)</td>
<td>(1)</td>
</tr>
<tr>
<td>+ 11 to + 1048</td>
<td>1,037</td>
<td>Almost along the present course (3), but running parallel some distance north of it, and deriving from (1) near Ta-ming and Phuyang. Its vestige is the present Hai-hai Ho.</td>
<td>Ts, pp. 344</td>
<td>(3)</td>
</tr>
<tr>
<td>+ 11 to + 70</td>
<td>59</td>
<td>A downstream derivation from (3), from the north-west of Ta-ming.</td>
<td>Ch, p. 25; Ts, p. 321; TH, p. 1607</td>
<td>(2)</td>
</tr>
<tr>
<td>+ 70 to + 1048</td>
<td>978</td>
<td>A derivation further upstream from (3), passing near Phuyang.</td>
<td>Ch, p. 25; Ts, p. 353; TH, p. 1607</td>
<td>(2)</td>
</tr>
<tr>
<td>+ 893 to + 1099</td>
<td>206</td>
<td>A new deviation to the present course (9) east of Ch'ung-chow, followed by an entirely new channel straight to the sea diverging from the present course (9) east of Khaifing and running approximately parallel with (3) but some distance north of it. Perhaps the present Ma-chia Ho is its vestige.</td>
<td>Ch, pp. 19, 48; Ts, p. 396; TH, p. 1607</td>
<td>(2)</td>
</tr>
<tr>
<td>+ 1080 to + 1099</td>
<td>39</td>
<td>A long additional deltaic channel of (9) formed, running for some distance west of the old bed of (3), and emptying into the sea north of (3). Perhaps the present Sai-ni-siu Ho is its vestige. A new feeder also tapped the residual flow in (9) upstream near Ta-ming?</td>
<td>Ch, p. 30; Ts, p. 426; TH, p. 1607</td>
<td>(2)</td>
</tr>
<tr>
<td>+ 1098 to + 1104</td>
<td>146</td>
<td>Reversion north-westwards (entirely so after + 1099) into the later line of the Grand Canal, new beds forming south-west of Phuyang and between Ta-ming and Lin-chhiu.</td>
<td>Ch, p. 30; Ts, p. 426; TH, p. 1607</td>
<td>(2)</td>
</tr>
<tr>
<td>+ 1104 to + 1288</td>
<td>94</td>
<td>A new deviation to the present course (2) from the points of origin of (7) and (3), but after a short distance the river ran north of the present course, crossed over it and directed itself straight at the Shantung mountain massif. Upon meeting the hill of Liangshan^11 (south of Shouchang^12 and Ching-chia^13) it divided into two almost equal flows and ran out both north and south of Shantung. In the north it ran west of the later line of the Grand Canal, then joined the present course (9). In the south it discharged into the sea north-east of Hsuiyin.</td>
<td>HTCKM, ch. 7, pp. 308 ff.; TH, p. 1603</td>
<td>(2)</td>
</tr>
<tr>
<td>+ 1288 to + 1334</td>
<td>36</td>
<td>Again a new deviation to the present course (9) from the point of origin of (6), but then a great overflow south-eastwards upstream of the Khaifing bend, taking most of the water far to the south to join the Hsui River and flow out through the Hung-tse Lake into the Yangtze. This was partly the line of the new Pien Canal (cf. p. 307). Some flow continued in (6) until + 1405, however.</td>
<td>Ch, pp. 30, 428; TH, p. 1748</td>
<td>(2)</td>
</tr>
<tr>
<td>+ 1324 to 1855</td>
<td>531</td>
<td>South-eastwards from the Khaifing bend, entirely so after + 1405; cutting off the great circuit with Liangshan at its apex, joining the former southern bed (4) near Hatchow (thus following approximately the line of the Lunnghai Railway), and discharging to the sea north-east of Hsuiyin as before. This was close to the route of the ancient Hung Kou Canal (cf. p. 290). Entirely northwards, in the present course, both above and below Khaifing, with the exception of two periods of devastating flow into the Hsui valley.</td>
<td>Ch, pp. 42, 41; Ts, p. 574; TH, p. 1607, 1728, 1818</td>
<td>(2)</td>
</tr>
<tr>
<td>1855 to the present day</td>
<td>110</td>
<td>South-eastward discharge along most of the tributaries of the Hsui River, through the Hung-tse Lake and into the Yangtze.</td>
<td>Ch, p. 91; Ts, p. 574; TH, pp. 1607, 1818, 1918</td>
<td>(2)</td>
</tr>
<tr>
<td>1887 to 1889</td>
<td>2</td>
<td>South-eastward discharge along most of the tributaries of the Hsui River, through the Hung-tse Lake and into the Yangtze.</td>
<td>Ch, p. 91; Ts, p. 585</td>
<td>(2)</td>
</tr>
<tr>
<td>1903 to 1947</td>
<td>9</td>
<td>The same, but brought about for military reasons by the artificial breaking of the dykes at Chung-mou;^18 just west of Khaifing. Northern flow was restored after the Second World War and the Hsui valley set free for extensive control works (cf. pp. 222 and 234).</td>
<td>Anon. (6); Rivière (1); Peck (1); Belden (1); Hsien Shu-P'ei (1); CH, p. 543; Tung Hsin-Kuang (1), p. 5</td>
<td>(2)</td>
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</tbody>
</table>

**Table 69. Changes of course of the Yellow River (see Fig. 859)**

**KEY TO ABBREVIATIONS**

Ch  Chung Chao-Ching (1)
Ch, ch. 7, pp. 308 ff.; TH, p. 1603
Ch, p. 30; Ts, p. 428; TH, p. 1748
Ch, pp. 42, 41; Ts, p. 574; TH, pp. 1607, 1728, 1818
Ch, p. 91; Ts, p. 574; TH, pp. 1607, 1818, 1918
Ch, p. 91; Ts, p. 585
Anon. (6), Rivière (1), Peck (1), Belden (1); Hsien Shu-P'ei (1), CH, p. 543; Tung Hsin-Kuang (1), p. 5

* There is reason to think that the change of course ascribed to +11 had actually begun in + 5 to + 6, and that it involved a temporary discharge into the Hsui valley as in -165 and -132; cf. Bielenstein (a), p. 150; Ching Chao-Ching (1), pp. 10, 191, Tschen Chung-Mien (2), p. 257, commenting on the edict of + 70 in Hou Han Shu, ch. 2, pp. 154 ff., which Bielenstein translates.
Elsewhere Mencius has an interesting passage comparing deforestation to the forcible debauchery of man’s natural goodness.

Meng Tzu said: 'The trees of Niu Shan were once beautiful, but as it was situated near the borders of a large State, they were hewn down with axes and hatchets. How could the forests retain their beauty? Still, through the ceaseless activity (of vegetal forces) day and night, and the fertilising influences of the rain and the dew, they were not without buds and sprouts springing forth, but then came cattle and goats to browse upon them. To these things is it owing the bare and stripped appearance (of the mountain), and people seeing it, suppose that the mountain is denuded of trees by axes and hatchets . Hewn down day after day, how could the forests retain their beauty?'

This shows that Mencius regarded the denuded state as artificial and ominous, and the passage has the added interest that the factor of over-grazing is clearly recognised. The destruction of forests must have been severe in ancient times on account of the practice of burning clearings before planting ('milpa agriculture', cf. Sect. 41 below). To this the Huai Nan Tzu book, in one of its diatribes against the luxurious decadence of feudalism as opposed to the communialism of the golden age, adds deforestation for the needs of metallurgical fuel.

Whole forests were burned for the chase, great tree-trunks being scorched and charred. Bellows were violently worked to send the blast through the tuyères in order to melt the bronze and the iron; metals flowed forth wastefully for hardening and forging—the work did not cease for a single day. No tall trees were left on the mountains, and the silkworm-oaks (tzu ch‘i) and lindera trees (tsin y‘i) disappeared from the groves. (Untold amounts of) wood were burnt to make charcoal, and (great quantities of) plants turned to white ash in bonfires (for potash), so that the anise (mang t‘shao) and the jasmine (pai ts‘h‘u) could never reach their perfection.

Above (the smoke) obscured the very light of heaven, and below the riches of the earth were utterly exhausted. All this (devastation) was due to (the extravagant) use of fire.

By the sixteenth century, however, the direct relationship of denudation, erosion and flood problems was well recognised. The Ming scholar, Yen Sheng-Fang, wrote:

Before the Ch‘eng-T‘ie reign-period (+1506 to +1521) flourishing woods covered the south-eastern slopes of the Shang-ch‘i and Hsia-ch‘i mountains (in the Ch‘i district of Shansi). They were not stripped because the people gathered little fuel. Springs flowed into the Pan-to stream, and passing in long waves and powerful sweeps through the villages of Lu-ch‘i and Fén-ch‘a, entered the Fén River at Shangtuan-to as the Changyuan River... It was never seen dry at any time of year. Hence villages from afar and in the north of the district all cut branch canals and ditches which irrigated several thousand ch‘ing of land. Thus Ch‘i became prosperous.

But at the beginning of the Chia-Ch‘ing reign-period (+1522 to +1566) people vied with each other in building houses, and wood was cut from the southern mountains without a year’s rest. Presently people took advantage of the barren mountain surface and converted it into farms. Small bushes and seedlings in every square foot of ground were uprooted. The result was that if the heavens send down torrential rain, there is nothing to obstruct the flow of the water. In the morning it falls on the southern mountains; in the evening, when it reaches the plains, its angry waves swell in volume and break through the embankments, frequently changing the course of the river... Hence the district of Ch‘i was deprived of seven-tenths of its wealth.

This region of Shansi lies south of Thaiyuan and a good deal south of the Wu-thai Shan mountains to which reference was made a little earlier.

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Fig. 872. Deforestation in the mountains, a picture from the Wang Kung Cheng Ch‘iin Lu, printed about +1556 (from the album of Chu-ch‘ou Ch‘en-To, 5). The artist, Li Wen, was one of the foremost wood-block illustrators of his time. On the procurement of timber see Yang Lien-Sheng (11), pp. 38 ff.

8 Meng Tzu, vi, (1), viii, 1, 2; tr. Legge (3), p. 283, mod. aunt.

9 Illicium religiosum, R 503. Well known in antiquity as a valuable insecticide, cf. Needham & Lu Gwii-Duen (1), also Sect. 38 below.

10 Perilla Foemina spp., R 178.

11 Shaan Ts‘h‘ang Ch‘ih, ch. 56, p. 316, tr. Chi Ch‘iao-T‘ing (1), p. 32. Here we can go no further into forestry matters, and I will only mention the reviews of T‘eng Shu-Ch‘un (1) and F. Y. Chang (1) on the history of forestry in China. Cf. Sect. 41 in Vol. 6.
However, the balance swung between frugality and extravagant use of natural resources during the successive centuries, the Chinese farmers at any rate had always been very conscious of the need for dexterous utilisation of soil moisture. Here we must not anticipate what we shall have to say in Section 41 on agriculture, but a few words on pit-cultivation and terracing are indispensable, for everything that retained water in the upland soils helped the water-conservancy problem of the lower river-valleys. The climate of north China consists of a dry and windy spring, a hot dry summer with showers at long intervals, a very wet late autumn bringing two-thirds of the whole year's precipitation and causing great erosion.

Pit-cultivation can start directly on waste land, without need for any (other) preparatory work. One of the oldest systems for doing this on sloping ground was pit-cultivation (ou thien). Fan Sheng-Chih says:

During the reign of the emperor Thang, there was a long and severe drought. (One of his ministers), Y.Yin, therefore developed the ou thien system (i.e. cultivation of crops in shallow pits and ditches), and taught the people to treat the seeds and carry water for irrigating the crop. Cultivation in shallow pits depends mainly on the fertilising power of the soil (fum chih), so good land is not at all necessary. Mountain-sides, the edges of cliffs, steep places near villages, and even the inside slopes of city ramparts, all can be used for making shallow pits... Pit-cultivation can start directly on waste land, without need for any (other) preparatory work.

And the text goes on to give in elaborate detail the dimensions of the pits, usually some six inches deep, and the ditches running along the contours, adding figures for the number of them which could conveniently be made on different kinds of land. The pits were to be well manured as well as watered, and for some crops, such as melons, an earthen jar to be kept full of water was buried in the centre of each pit. Often mixed cultivation was practised, scallions or beans being planted on pit-cultivation and terracing are indispensable, for everything that retained water in the upland soils helped the water-conservancy problem of the lower river-valleys. The climate of north China consists of a dry and windy spring, a hot dry summer with showers at long intervals, a very wet late autumn bringing two-thirds of the whole year's precipitation and causing great erosion.

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28. CIVIL ENGINEERING

protection and control. But after nine years his efforts were unsuccessful, the water rose as fast as he could build his dykes. On account of this complete failure, Kun's work was not considered praiseworthy; he was exiled, killed by Yao and his body cut into pieces. Very significantly, Kun was later regarded as the patron and inventor of dykes, embankments and walls. He was supposed to have received his instruction from a kite and a tortoise.

Afterwards, Yu, the son of Kun (born from a grain or a stone), was appointed by Shun (successor of Yao), also on the recommendation of the Sa Yo, and in the space of thirteen years by titanic labours he opened the courses of the nine rivers, conducting them to the four seas and deepening the canals. The motive of dredging the beds of waterways is always connected with the work of Yu. That he passed the door of his house many times during this period but never once went in to rest, is a favourite embellishment of his saga of devotion, classical formulations of which are found in Mencius. Yu was supposed to have been fully successful in his operations, and came to occupy the permanent position of irrigation culture-hero which Kun had not attained. Other technical patronages accreted around him; thus he was a map-maker, a maker of bronze weapons, a fighter against pestilence, and so on.

Besides these two chief characters there was a subsidiary figure connected with hydraulic engineering, namely Kung-Kung (literally "communal labour"); whose other name was Chhui (a word related to "ceiver", "tuyere of a metallurgical furnace or forge"). He was proposed, by Sa Yo as usual, to Yao for the office of controller of the waters, and also recommended by Huan-Tou, but rejected by Shun. Finally he was banished and killed.

There is method in all this, if rightly interpreted. Much insight was shown by Granet when he suggested that the contrast between Kun and Yu betrays to us the

existence of two rival schools of hydraulic engineering thought in ancient China. A conflict has existed throughout Chinese history, as he said, between the partisans of high dykes and the partisans of deep channels. Moreover, it took the form of a conflict between two systems of morality, one in favour of confining and repressing Nature, the other in favour of letting Nature take her course, or even assisting her to return to it if necessary. This has only to be stated to show itself immediately in consonance with much that we have already come across. Confucian jurists used the analogy of dykes and embankments when discussing law. The forceful repression of Nature by the erection of convex 'masculine' ridges along the rivers was a case of what the Taoists called 'to' as opposed to 'ini' ("no action contrary to Nature"); cf. Vol. 2, pp. 68 ff. above). The deepening of river beds by excavation of 'feminine' concavities was, on the contrary, a going along with Nature, an epiphany of some of the most famous Taoist archetypes, such as the 'Valley Spirit' and the female receptiveness of water (Vol. 2, pp. 57 ff. above). This appears rather clearly in a long discussion in the Kao Yu (Discourses concerning the Warring States); Kun and Kun-Kung applied force to Nature, hence their punishment, Yu the Great adopted the right methods. That these methods were essentially Taoist throws further light on the role played by that great sect in all early Chinese scientific and technological advances.

Not every school of engineering thought has had its favourite maxims or discovered laws engraved on stone and venerated for centuries. Yet such is the case for the followers of Yu the Great. At the town of Kuanhsien, some distance to the north-west of the capital of Szechuan, Chhengtu, there exists what must be one of the most remarkable applied force to Nature, hence their punishment, Yu the Great adopted the right methods. That these methods were essentially Taoist throws further light on the role played by that great sect in all early Chinese scientific and technological advances.

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but perpetuating, as we know, certain key phrases some of which are attributable to the Ch'in engineer himself. Of these the oldest is the following: Shen Thao Than; T'i Ts'o Yen,' i.e. 'Dig the channel deep, and keep the dykes (and spillways) low.'7 The second may be as old, or nearly so: Feng Chih Chhou Hsin; Yu Wan Chieh Chio,' i.e. 'Where the channel runs straight, dredge the centre of it; where it curves, cut off the corners.'8 Again the teaching of Yü, and measures against erosion at bends. The third is probably a later addition: Khuun Chhi Ti; Htieh Chieh Mien,' i.e. 'Make the (canal) beds broad, with gradually sloping profiles.'9

But now, returning to the legends, we come upon a very curious thing. The unsuccessful, or at any rate disapproved, irrigation engineers are identical with the corps of legendary rebels which we discussed at some length in the Section on 'Taosim (above, Vol. 2, pp. 115 ff.). Kung-Kung, always one of them, is recommended by Huan-Tou, another; and Kun himself is frequently identified with Thao-Wu.4 The suggestion made there was that all these (and related) figures, who fight with the legendary emperors and are overcome by them, constitute the fabulous residuum of those leaders of the people in primitive collectivist society who most strongly opposed the first institution of bronze-age proto-feudalism. It was therefore quite natural that some of them should have become heroes for the Taoists in later ages, since the Taoists opposed feudalism root and branch, urging a return to the collectivist golden age. Consequently it is of great interest that Chhii Yuan, in the Six-Cha Book (c. 300), strongly takes the part of Kun, commiserating with him and saying that his death was unjust, having met with failure through no fault of his own.8 Other examples could be adduced. We are thus led to the suggestion that perhaps the legend of the failure and death of Kun conceals the real failure of primitive collectivist society to cope with the greater problems of river-control and irrigation. Presumably that form of social order was unable to organise the human labour-force, and bring it to bear upon the urgent engineering tasks in view, as effectively as the corvée system under feudal society. If this were so, we might expect to find in the legends distinct traces of the connection of Yü with the origins of feudalism, and this is in fact the case. In the I Chi chapter of the Shu Ching,9 Yü is made to say, for example, that as the result of his work, 'the ten thousand states have become well-governed (man pang tso i)'; and that wherever I went I established the five (classes of) chiefs (feudal lords) (faien chien tu chhang).' This point has already been mentioned above.

8 This is known as the 'Six-Character Teaching' (Liu Tao Chih). It was re-engraved in stone by imperial order in 1972. Another photograph of it is in P'an En-Lin (2), p. 155.
9 This is known as the 'Eight-Character Rule' (Pa Tao Ko). Some of the other inscriptions date from the time of the engineer Lu I (c. 1510).

A few minor points of interest may be added here. The great cut at Kuanhsien reminds us that large cuttings occur also in the legends.6 Yü is supposed to have made them or superintended their making—the Lung Men gorge of the Yellow River, and the gorges of the M'eng Men7 and Lü Liang.4 Many place-names are associated in this way not only with Yü but with Kun.6 A particularly striking legend of a great cut is that of the separation of the mountains Th'ai-Hsing8 and Wang-Wu9 by the giant sons of Khua O (an otherwise unknown character, perhaps identical with the 'Boaster', Khua Fu).10 The story as it is given in the Lieh Tzu book is worth reproducing if only to indicate something of the indomitable spirit with which the Chinese of old approached their great engineering projects.8 For men in community nothing was impossible.
The two mountains Thai-Hsing and Wang-Wu, covering an area of 700 square li and rising to an enormous height, originally stood to the south of Chichow and north of Hoyang. The Simpleton of the North Mountain, an old man of ninety, dwelt opposite these hills, and rising to an enormous height, originally stood to the south of Chichow and north of Hoyang. What say you?' They all assented except his wife, who made objection.

The Wise Old Man of the River-bend burst out laughing and urged them to stop. 'How absurd is your behaviour!' he said. 'With the poor remaining strength of your declining years you will not succeed in removing a hair's breadth of the mountain, much less the whole vast mass of rock and soil.' The Simpleton sighed and said: 'Surely it is you who are hard of heart and narrow-minded. You are not worthy to be compared with this widow's son, despite his puny strength. Though I myself must die, I leave a son behind me and through him a grandson. That grandson will beget sons in his turn, and those sons will also have sons and grandsons. With all this posterity, my line will not die out, while on the other hand the mountain will receive no increment or addition. Why then should I despair of levelling it to the ground at last?' In reply to this, the Wise Old Man of the River-bend had nothing to say.

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The two mountains Thai-Hsing and Wang-Wu, covering an area of 700 square li, were not only a source of water supply but also a landmark. The first time the Simpleton saw them was when he was a young boy. He had heard that the gods lived in the mountains and that they were the protectors of the people. He was determined to make a passage through the mountains.

The Simpleton then set out to make a passage through the mountains. He began by gathering his family together and putting forward a plan. 'Let us,' he said, 'put forth our utmost strength to cut through this obstacle, and make a passage through the mountains to Hanyun. What say you?' They all assented except his wife, who made objections, saying: 'My good-man has not the strength to sweep away a dunghill, let alone two such mountains as Thai-Hsing and Wang-Wu. Besides, where will you put all the earth and stones that you dig up?' The others replied that they would throw them on the phosphate and carry them away in baskets to the Pho-Hai promontory to the north of the Lena Lans.

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One of the serpent-brandishing deities heard of the undertaking, and fearing that it might never be finished, went and told the emperor (of Heaven) who, touched by the old man's sincerity, commanded the two sons of Khua O to transport the mountains, one to the extreme north-east and the other to the southern corner, of Yung. Ever since then, the region lying between Chi in the north and Han in the south has been an unbroken plain.

There were other local culture-heroes besides this Pei Shan Yu Kung. One was Thai-Thai² of Shansi, who made the Fén³ and Thao⁴ Rivers run properly, and became their tutelary god. To this day there is a 'Thai-Thai Tai⁵ (marsh, now reclaimed) near Thayuan. The female pseudo-creator spirit, Nü-Kua,⁶ also comes into

* Commentators refer to the Shan Hai Ching.
* The locust is a species of locust, known as the Thaom, which is a serious pest in some parts of China. It is a large insect with a long, thin body and a powerful hind leg.
* The term 'location' refers to a specific place or area, which in this context could refer to the location of a mountain or a body of water.
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28. HYDRAULICS

The picture, since she used the ashes of reeds (hu¹) for making dykes; this is perhaps an echo of some clay-binding technique.

Relations with afforestation in the legends are also curious. Ancient ideas of the value of vegetation-covered hills have already been noticed (pp. 244 ff. above). But the traditions make Yu the 'attacker' of forests. The Shan Hai Ching has him 'attacking' the Clouds and Rain Mountains (Yün-Yü chih Shan)²⁵ and the Chhengchow Mountains; all commentators suppose that this means cutting down trees, or at least marking them for felling. The Yü Kung chapter of the Shu Ching opens with the statement that he went along the mountains and felled trees (ni shan li mǔ).²⁶ Conceivably forest-removal may have been thought to reduce rainfall and so to make the task of the engineers easier lower down, though it is hard to believe that Brückner's principle could have been in the minds of the ancients.²⁷ The fearful erosion produced was far more important than any slight changes in rainfall which could result from deforestation. One senses a conflict of opinion in the Tso Chuan,²⁸ when in — 525 envoys sent to make a rain-sacrifice in time of drought on Sang Shan²⁹ cut down many trees; the rationalist statesman Tzu-Chhan (Kungsun Chhino)³⁰ said that this was a great evil and had them punished. Yet later, Chhin Shih Huang Ti, who had conceived a grudge against Mount Hsiang, had it completely deforested in — 219.³¹

Another peculiar feature of the legends is the relation of Kun and Yü to some kind of special earth, 'living earth' (hsi thâu ³² or hsi jang³³), which they used for their dykes. Kun was supposed to have stolen it, or not to have known how to use it; Yü was able to use it successfully. Granet thought that it referred to some sort of inexhaustible clay-pit.³⁴ Helbig assumed it to be a Promethean legend, earth taking the place of fire.³⁵ Maspero adduces late authors who suppose that it was a kind of earth which swelled of itself, but this may be only a piece of symbolism comprehensible in view of what has already been said.³⁶ The subject merits further investigation.

All the above is not incompatible with Maspero's conviction that the legends of floods and their control have elements of creation myths, such as he himself transcribed
from the oral traditions of the Thai peoples of Annam. They also spoke of one person failing to control the waters, and a second succeeding. It is certainly interesting that both the Mencius passages begin suddenly with Yao and Yu, omitting the earlier stages invented later, and of course the ancient scholars tried as usual to make history out of myth, suppressing as much as possible of the folk-tale improbabilities. But it would be difficult to accept Maspero’s view that the practical control of Yellow River floods never had anything to do with the corpus of Chinese legend.

The Formative Phases of Engineering Art

At an earlier stage, in connection with roads (p. 4 above), we made the acquaintance of the classification of irrigation canals in the Chou Li. In his commentary on the entry concerning the Sau Hsien (Director of Communications) Chêng Hsian enumerated the five standard categories of canals, and the text itself, when dealing with the functions of the Sui Jen (Grand Extensioner, or Minister of Agriculture) reported the same series in parallel with a set of roadways of standard widths. In its Kha Kung Chi, or ‘Artificers’ Record’ chapter, the Chou Li enlarges further on hydraulic engineering designs, always keeping to the same range of terms and giving dimensional specifications for each, figures which we find again in Chêng Hsian’s commentary on the second passage just mentioned. From Fig. 875, in which these are diagrammatically shown, it seems clear that the literary tradition was rather stylised and schematic, figures being doubled at each step so as to produce cross-sections impractically deep before the days of concrete.

The scale of this diagram in feet is the same vertically as horizontally, and no difficulty of interpretation arises about the intentions regarding the three smaller channels (niu, hou and huih). The largest one, however, the huih, is defined as being two fathoms (hou) broad, and two statures (jen) deep; since the latter measure may have been either 5 ft. 6 in., 7 ft. or 8 ft., the depth of the huih may have been as 11 ft., 14 ft. or 16 ft. and this is represented on the diagram for these varying estimates of the jen.

The channels of water between the Ching are four feet broad and four feet deep, and they are known as conduits (hou). A square piece of cultivated land with sides ten li long is known as a Chêngchêng (lit. achievement), and its exterior artificial watercourse, eight feet broad and eight feet deep, is known as a small canal (hsiu keh). A square piece of cultivated land with sides one hundred li long is known as a Thung (lit. together), and its exterior artificial watercourse, two fathoms (hsien) broad and two statures (jen) deep, is known as a medium canal (huih keh). Only these connect with the great canals (chuan), each of which is given a name of its own.

According to the general constitution of the earth, there will be a (natural) watercourse wherever there is a valley between two hills, and along all such watercourses there will be a way for a road (hsia). When an artificial canal encounters a rise of ground, we term it a ‘point of no flow’ (pu hsia), and when (planned) watercourses are not in agreement with the principles (of hydraulic engineering) we use the same expression. Canals lying in a straight line, with no (derivative) branches, should be doubled in breadth every thirty li. To reduce the speed of a stream, one arranges that it should flow round bends, and these should be like the two limbs of a ringing-stone (musical instrument, the stone-chimes) (i.e. at an obtuse angle), the relation of the two limbs being as 3 to 5. If one wishes to make a pool (for navigation or as a reservoir) (hsuan), one gives a circular form to the bed (so that the current will keep it scourcd out).

These are by no means the only places in the Chou Li which make mention of hydraulic engineering works. For example, the Yung Shih and Phing Shih were both Superintendents of Waterways Police (ch. 10 pp. 59, 44 (ch. 37). Biot (1), vol. 2, pp. 376 ff.). The former kept watch on the canals, organised the carrée for construction works, guarded hills from deforestation, and prevented the pollution of waterways. The latter organised the carrée for urgent flood protection works, kept watch for dangerous places, and protected fisheries out of season. We shall return to these texts in Sect. 44. There was also the Yeh Li Shih, the Superintendent of Traffic Police (ch. 10 pp. 44 (ch. 37). Biot (1), vol. 2, pp. 376 ff.), whose men were in control of traffic on the canals as well as the roads. More will be said presently (p. 267) of the administration of the hydraulic engineering works, from the Chou Li onwards.

Note once again a standardised unit or module (cf. p. 67 above).

Needless to say, they gave rise to a great deal of commentary, much of which is available in translation by Biot (1), vol. 2, pp. 365 ff.

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Some of the entries in the earlier chapters are ad hoc standardised units or module (cf. p. 67 above).

Interpretation here depends on the values of these units. The huih can safely be taken as 8 ft.; but the jen, essentially the height of a man (hence the ad hot term introduced above), is variously defined in ancient texts as 8 ft., 7 ft. and 5 ft. 6 in.

Cities had also encircling drainage canals internally and moats externally (Kuan T’ung, ch. 57, cf. Rickets (1) for a translation).

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by its own water; a good dyke is consolidated by the sedunent
whatever combined labour force may be necessary.
If
were certainly very able experts in dyke and canal buildmg m Chma at

This belongs more properly to the development of land .tenure

since there were certainly very able experts in dyke and canal building in China at that time; yet
even as seen through the redaction of a literary scholar, the passage has its value.

One point which it raises is the question of the Ching, or 'well-field' system (ching
thien). This belongs more properly to the development of land tenure and therefore to
the realm of social and economic history, but it has a certain connection with the
origins of irrigation and therefore demands notice here. In the 6th century, Confucius makes no mention of large irrigation works, but twice refers to 'ditches and conduits' (kou tu) and kou kourek). The classical description of the well-field system
was given by Mencius about 300. The Duke of Theng had sent Fi Chan to ask
him about it, and this was his reply:

Since your prince, wishing to put in practice a benevolent government, has made choice of
you and put you into this employment, you must exert yourself to the utmost. Benevolent
government must begin with land boundaries. If the land boundaries be not defined correctly,
the division of the land into the Well System will be unfair, and the produce available for
salaries will not be equitably distributed. On this account, oppressive rulers and ministers
with foul designs are sure to neglect the definition of boundaries. But if once the boundaries have
been defined correctly, then the division of the fields and the regulation of allowances
can be done while you sit comfortably in your office.

Though the territory of Theng is rather small, its soil is rich. There must be both lords
(chin tsu) and peasants (yeh jen) in it. If there were no lords there would be no one to rule
the peasants; if there were no peasants there would be no one to support the lords.
I would propose to you that in the remoter districts, the nine-lot division be observed,

Note the combination of a triple and decimal system in this and the preceding passage. Each of
the nine lots is divided into 100 squares, and above the level of the Ching the progression is decimal. Hsu
Chung-Shu (6) and Hsi Hsi-Sung (1) suggest that such differences may be vestiges of different metrolo-
gical systems of Shang and Chou.

It is interesting that this classical exposition of proto-feudalism is immediately followed by the
episode of the 'Diggers', on whom see

The translation 'well-field' for ching thien, which has long been customary in
English, is rather misleading, for quite apart from any connection with water-supply,
the Chinese phrase simply signifies a symbol, i.e. the lines of division between nine
square plots, lines which intersect just in the shape of the character ching. According to the lexicographers the word has two distinct meanings—its usual one of a well of
water, and the technical one of a nine-plot land division. The form of the character, strikingly evocative of such a plan, is very ancient, for the graph is found already
in Shang bone inscriptions. It is evidently related to

This is how peasants are

...
Such dots occur also within the spaces of thien. It may well be, too, that the 'ordinate and abscissa' lines in both these characters preserve traces of the layout of the irrigation ditches that ran alongside the plots, as in the Chou Li description. In any case, the topography of north and north-west China is such that it would be quite natural for wells, small reservoirs, dew-ponds or shallow pits supplied by springs of underground water, to become the centres of patches of cultivated land before any extensive efforts had been made to capture the lower waters of natural streams.

Although co-operative work by the peasants on the lord's land is not in doubt, most scholars now regard the details of Mencius' nine-lot system as a schematic, Utopian description rather than a description of a form of land allocation which ever had any real existence. It was of course Utopian only from the point of view of the feudal lords, since one ninth of the produce was due instead of a tithe. Although no doubt rectangular plots were used when possible for convenience of mensuration, in general the division of the land must have followed the contours of the terrain. There is also no reason for thinking that the lord's land was generally central to the village land as a whole. Why Mencius wanted it there may perhaps be explained by a concern, probably very ancient, for mutual aid in tilling the lord's land; and it may be significant that there was an ancient example of a large reservoir dam (p. 279). In Chhu, Wei Yen, being Minister of War, was charged by the Duke of Wei (in the 25th year, c. 460 B.C.) to make a register of arable land. He assessed (the products of) mountsins and forests, collected together the marshes and lakes (for fowling, under the princely authority), distinguished among the hills and valleys (as sites for tombs), marked the dam and briny places (for the extraction of salt), computed (the extent of) land subject to floods on the frontiers of the State, measured the area of the dyked reservoirs (hsue yen chu), divided the flat lands between embankments into fields separated by balks or headlands (thung yuan fung), set apart dry places beside the water for pasture (mu hai hou), and laid out fertile flourishing country in Ching units (ching yen est). He then determined the contributions due, fixed the number of chariots and horses to be raised, (and assessed for each place) its levy in terms of chariot-riders, foot-soldiers, and armoured men with shields. When all this was done, Wei Yen handed in his report to the Premier, and it was approved.

In Chhu, Wei Yen, being Minister of War, was charged by the Premier to regulate the ditches (chu fu) and to count the number of cuirasses and weapons (each of which he had to provide). On a cloudy day, he (began to) make a register of arable land. He assessed (the products of) mountains and forests, collected together the marshes and lakes (for fowling, under the princely authority), distinguished among the hills and valleys (as sites for tombs), marked the dam and briny places (for the extraction of salt), computed (the extent of) land subject to floods on the frontiers of the State (chu ch'ang liao), measured the area of the dyked reservoirs (hsue yen chu), divided the flat lands between embankments into fields separated by balks or headlands (thung yuan fung), set apart dry places beside the water for pasture (mu hai hou), and laid out fertile flourishing country in Ching units (ching yen est). He then determined the contributions due, fixed the number of chariots and horses to be raised, (and assessed for each place) its levy in terms of chariot-riders, foot-soldiers, and armoured men with shields. When all this was done, Wei Yen handed in his report to the Premier, and it was approved.

This shows that in the 6th century a ching-thien (well-system) of some kind, not necessarily identical with Mencius' specification, was in practical use for land settlement. Military service and supplies had long been apportioned on a territorial basis according to ching. In for — 559 the prince of Lu ordered that each chih (16 or 64 ching, according to different authorities) should furnish one chia (a military unit of men with cuirasses).

It is indeed probable that those are right who, with Kuo Mo-Jo and Chi Chhao-Ting, see in the well-field system something essentially similar to that of the manor, demesne or glebe. The word translated above 'allowances' (lu), assuredly meant, in Mencian times and earlier, the income of the feudal lord derived from the land which the peasants worked together for him, i.e. the land referred to later in the same passage as 'public' land. So long as the productivity of labour underwent no change, the feudal incomes would have been determined purely by the number of peasant-serf families under the control of the lord in question. But the introduction of iron about the — 6th
century and its application as cast iron to ploughs soon afterwards, together with other changes such as the greater use of manure, increased agricultural productivity towards the beginning of the Warring States period, and this must have tempted the lords to reduce the size of the ‘private’ fields and increase that of the ‘public’ ones. This may have been what Mencius had in mind when he spoke of oppressive rulers and wicked ministers. Restoration of the original well-field system, with clear definition of land boundaries, would lighten and equalise the burden on the peasant-serfs. Of course, the ‘private’ fields were not private property in the modern sense. From Mencius it is clear that the peasants could not migrate away from their land, which they held only in ‘return’ for labour on the lord’s land and military service. Thus the well-field unit was the lowest economic and administrative cell in the feudal body politic.a

It is now possible to understand more clearly what the Chou Li writer was talking about when he built up his series of technical irrigation terms from the nine-lot Ching or well-field. By his time the well itself had long evaporated to a mere symbol, and the fields were supplied with water according to a system more central or southern than northern in character. Han legend of course attributed even the refinements of this to the teaching of Yii the Great himself.

The basic social prerequisite for large-scale water-control projects was the possibility of extending the ancient cortée system, whereby work was done on the lord’s field, to a vast mobilisation of labour for public works. So long as all peasants were closely attached to well-field units, there could be no great number of surplus and unattached labourers. But the system was already breaking down at the beginning of the -6th century, for it was in - 593, according to the Tso Chuan, that the State of Lu began to levy a tax according to the mou4 of land occupied (chha tshui mou’4), irrespective of the identity of the holder.4 Such a tax would supersede a direct contribution of labour on the lord’s land, and as the productivity of labour increased, there gradually grew up a large labouring population which, at any rate at certain times of the year, could be withdrawn from agriculture for the construction of great engineering works. When Mencius was speaking, about - 300, it was quite natural for him to suggest that in the central regions of the State of Th élect the peasants should pay a tithe of their produce as land-tax. This system of tax, says Chi Chhao-Ting, was the essential device which cut the string tying the feudal lords to the agrarian routine, and freed them from concern over the harmful effects on agricultural production of large-

a Elsewhere in Mencius (v, (4), 2; Legge (3), p. 249) there is an account of the numbers of land units appropriated to the different ranks of the feudal hierarchy, though he says that in his time the old records were no longer available, since the nobles, considering them injurious to their interests, had destroyed them.

b Duke Hsiao (15th year; Couvreur (1), vol. 1, p. 659).

c One mou is now equivalent to 0.164 acre, but in the Chou period it was much smaller, only 0.047 acre. At this rate the nine ching-chhien squares amounted to 44.7 acres.

d Again in the State of Ch’ang in - 557, on the order of Kung-sun Chhio (Tso Chuan, Duke Chou, 4th year; Couvreur (2), vol. 3, p. 87). In both cases there was, as one would expect, great complaint. The Tso Chuan adds regarding the change in Lu that it was not according to good custom, for previously State grain had come only from the ‘public’ fields cultivated by the peasants jointly.
The Chinese genius for organising very large numbers of workers in civil engineering operations illustrated by a unique drawing from the autobiography of the high official and hydraulic engineer Chhen Chi'en. The somewhat enigmatic caption "Wrestling for the Red" when Cutting a Canal (Yin Ho Chhiang Hung) is explained in the accompanying text. When the job is rather more than half done, says Lin-Chhing, the superintendents begin to 'hang up the red', i.e. to organise competitions and upon this lantern the names of the winners are inscribed. This is an old custom, says Lin-Chhing, of work speed for prizes, of meat and wine, of boots and hats. When it is nine-tenths done they all set up Yellow River between Khai-feng and Chingho-w in Honan, doubtless between 1833 and 1842 while Lin-Chhing was Director-General of River Conservancy centred at Huai-an in Chiangsu. Apart from many wheelbarrows, one can see more than a dozen square-pallet chain-pumps in the picture, these being hand-swung buckets for draining the excavation (cf. Vol. 4, pt. 2, p. 331, f.n. 5). The actual work shown in progress was the cutting of a canal at Chung-mou, a place south of the Yellow River between Khai-feng and Chchinghow in Honen, doubtless between 1833 and 1842 while Lin-Chhing was Director-General of River Conservancy centred at Huai-an in Chihienia. Apart from many wheelbarrows, one can see more than a dozen square-pallet chain-pumps in the picture, these being hand-swung buckets for draining the excavation (cf. Vol. 4, pt. 2, p. 331, f.n. 5). At the top on the left one can see a 'theodolite', levelling staff and chain-measure (cf. pp. 229 ff.). Further left, the engineer-in-charge, on a visit of inspection, is riding a horse on the neck of land which will be washed away when the canal is opened. In the foreground there is an altar to the local deity, with some guards on one side and a group of old people on the other.
ment.  This was so for the very simple reason that any effective treatment of the engineering problems set by the rivers, and the desired intercommunicating watercourses, tended, at every stage, to transcend the boundaries of the smaller feudal units.  Take the case of one of the earliest works, successfully executed before the first unification of the empire, the Chêngk'uo Canal; it could not have achieved anything unless its planners were prepared to think in terms of a main course not less than a hundred miles long, with a service area of perhaps fifty miles in breadth.  Fortunately, we have certain statements from the Former Han period which make the point quite consciously.  Thus in the *Yen Thieh Lun* (Discourses on Salt and Iron) of about -80, we find:  

"The Lord Grand Secretary said: ‘The feudal lord, whose fief can be considered as forming but one household, has his concern limited to what is within it.  But the emperor, whose domain is bounded only by the Eight Extreme Limits (of the world), has concerns extending beyond such small areas, indeed far and wide.  Thus under the small (manorial) roof, expenses are trifling, in comparison with the great expenditure necessitated by the immense undertaking (of ruling the empire).  Herein lies the reason for the Government’s opening up of cultivatable land and reservoirs (yuan chhih), and its concentrating under one hand the mountains and the lakes (shan hai) to secure income that can be used to supplement tribute and taxes.  Thus we improve canals and conduits (kou chhih), promote various kinds of agriculture, extend farm and pasture lands, and develop nature reserves and walled hunting-parks (yuan yi).  The offices of the Thai-Phu, the Shui-Hêng, the Shao-Fu, and the Tu-Nung compute annually the revenue derived from farm and pasture, and the rentals from leases of lakes and fishponds (chia chii chih chiao).  Now up to the limits of the empire in the north, superintendents of fields have been appointed, yet with all these efforts, there is still a deficit…"

So also, about thirty years before, there had been an imperial edict which used the following words:  

"Agriculture is the basis of the whole world.  The Springs and rivers, irrigation ditches and reservoirs (chhien tse) make possible the cultivation of the five grains.  In the empire there are innumerable mountains and rivers, but the small (ordinary) people do not understand their proper use (tse chih chhi li).  Hence (the Government) must cut canals and ditches (kou tu) and build dykes and reservoirs (pei tse) to prevent drought…"

This was in -111.  The document was an order to carry out certain improvements to the Chêngk'uo Canal which had been proposed by Erh Khuân.  

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* Of course only up to the point which was possible before the neotechnic age.  
* And also, in later ages, the boundaries of landholdings of any private individuals or groups of individuals.  There is an important contrast between Chinese and European society here, for in Holland and England most of the fen drainage (e.g. Sir Cornelius Vermuyten in East Anglia) was done by private enterprise.  The only analogy to this in China was the quite exceptional province of Shansi, where after the -14th century there were a number of private water-conservancy works (Chi Chiao-Ting) which would have taken place a decade or so before -300, is Pai Kuei, a man from Chou State.  The deliciously Johnsonian flavour of Legge’s translation demands reproduction intact.  
* Pai Kuei said: ‘My management of the waters is (I consider) superior to that of Yü (the Great).’  

Mencius replied: ‘You are wrong, Sir.  Yü’s regulation of the waters was according to the Tao of water.  He therefore made the Four Seas their receptacle.  But you make (the territories of) neighbouring States their receptacle.  Water flowing in a contrary direction (to that in which it ought to flow) may be called an inundation.  Inundations are a vast waste of water, and every benevolent man detests them.  You are wrong, my good Sir.’

Such confusion could not but dispose people to welcome as an essential safeguard the imperial unification of the Chihlin.  All subsequent governments controlled the rivers and canals as parts of a unified system, success achieved varying both with political power, the extent of the realm, and the transcendence of the boundaries of land belonging to ‘small ordinary’ landowners, or formerly to feudal lords, was not the only factor which tended inevitably to centralisation.  At an early stage in the Warring States period, it was realised that water might be a weapon.  The sight of rooftops swirling round in flood-waters, with people clinging to them, in the midst of floating trees and bodies of dead animals, must have suggested to the ‘defence’ authorities of the feudal States that a strategic construction or destruction of dykes and watercourses might bring about gratifying results.  We realise this from another passage in the *Chhiên Han Shu*, an earlier part of the speech of Chia Jiaq already quoted in connection with the Yellow River.  

The building of dykes and embankments began in recent ages during the period of the Warring States, when the various States blocked up the hundred rivers for their own benefit.  (For example) Chhi, Chao and Wei all bordered the Yellow River.  The frontiers of Chao and Wei rested on the foot of the mountains, while that of Chüii was on the low plain.  (The State of) Chhi, therefore, constructed an embankment 25 li from the river, so that when rising waters approached this dyke in the east, they would be held back and forced to flood Chao and Wei.  Whereupon Chao and Wei also constructed an embankment 25 li from the river (to counteract the effect).  

The feudal states also competed violently with one another for irrigation water, and in appropriating draining areas for growing crops.  As Li Hsiieh has pointed out, there is an unmistakable reference to this in Mencius.  One of the characters who appears in the conversations recorded in the *Mêng Tzêu*, which would have taken place a decade or so before -300, is Pai Kuei, a man from Chou State.  The deliciously Johnsonian flavour of Legge’s translation demands reproduction intact.  

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* Here was another trait in Chinese culture which had been characteristic of ancient Mesopotamia also; cf. Drower (1), p. 554.  
* We came upon an example of this at a much earlier stage (Vol. 1, p. 234) when in -101 Chinese hydraulic engineering experts (*shui hung*) called to the army besieging the capital of Ferghana were called upon to deprive the city of water by diverting a river, or to sap its walls by directing a greater stream against them.  They successfully employed the former technique.  
* Cf. the Ming historian Chêng Hiaio (*+1490 to +1566), in *Hsing Shih Chin Chien*, ch. 3, p. 50 (p. 37).  
* *Mêng Tzêu*, vi, (2), xi; tr. Legge (3), p. 319, mod. auct.

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* 自主  
* 水工  
* 顏曉
the arbitrary conditions set by nature. But in times of war, both civil and foreign, there were often severe temptations to undo what had so laboriously been done. In +193 the Later Liang general in the field against the Later Thang, Yuan Ning, broke the Yellow River dykes deliberately. In +1020 Li Chhui suggested a similar use of the flood weapon on the part of the Sung against the Chin Tartars, and just a century later (+1128) this was actually done by Tu Chhung, ruining most of the Grand (Pien) Canal south of the Huang Ho for several years. In our own time the pattern repeated itself. The breaking of the Yellow River dykes in 1938 was undoubtedly a strategic later Liang general in the field against the Later Thang, Tuan Ning, (yu4), and he 'arranged the equitable distribution of water for the farmers by appointed mutual restraints (wu4 min tu4 chin shui yu4 tou4 yu4). Then he set up inscribed stones in the fields, to perpetuate these customs and to avoid disputes. In later times various special devices were used for distributing the water. For instance, during repairs to a 'Nine-Dragon Canal' (Chiu Lung chhii4) in the Thang period (+9th century), a number of bronze dragon-heads were dug out at one point, with an inscription showing that they must have been first set up in +271. It would be interesting to have a comparative study of the water-distribution regulations in different cultures.

The 'Shui-Heng', or 'Water Balancer', the title of one of the imperial accountants, just met with in a quotation from the Yen Thieu Lun, must originally have been concerned with regulation of water-rights. Although this title does not occur in the Chou Li, there are others which may be mentioned. The Chhuan-Heng were inspectors of all rivers and canals; they seem to have been in charge of the river police and canal guards, Phung Shih and Yung Shih, who also (as we have seen, p. 255) patrolled embankments. There was a parallel service of inspectors called Teh-Yu who administered lakes and their fisheries, and lastly, certain Chhuan-Shih officials who concerned themselves with fixing geographical names for all watercourses, and with listing their effects and products. More reliable historically is the title Tu-Shui--Director of Water Conservancy—which seems to date from the beginning of the Han; his office was then called Tu-Shui Thai. In the San Kuo period (Wei) he was Tu-Shui Lang and had only a department in the general secretariat. But as the importance of water-conservancy increased, the controllers and planners grew into an

name of Shao Hsin-Chhien, who was governor of Ling-ling and of Nanyang and held other offices in the decades before his death in +4. His biography in the Chhien Hsin Shu depicts him in an attractive light; he was fond of discussing agriculture with the farmers, he himself ploughed to encourage them, he liked living in cottages rather than in his official residence, and he was always wandering through the farm lands (chhui ju chhien mo). He directed the construction of sluices (hui shi4) for fertilisation by silt (yu4), and he 'arranged the equitable distribution of water for the farmers by appointed mutual restraints (wu4 min tu4 chin shui yu4 tou4 yu4). Then he set up inscribed stones in the fields, to perpetuate these customs and to avoid disputes. In later times various special devices were used for distributing the water. For instance, during repairs to a 'Nine-Dragon Canal' (Chiu Lung chhii4) in the Thang period (+9th century), a number of bronze dragon-heads were dug out at one point, with an inscription showing that they must have been first set up in +271. It would be interesting to have a comparative study of the water-distribution regulations in different cultures.

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* Cs. 99, p. 103.
* On the use of ases for recording traditional water-rights, see also Chhien Chhing (1).
* Ch. 99, p. 283. There is also the question of what time-measuring instruments were used for controlling the switching of the channels. We have touched upon this subject in Vol. 3, p. 315, in connection with sinking-bowl clepsydras; according to Abercrombie (1) these are still used today for this purpose in the Yemen.
* For ancient Ceylon there is an interesting article by Parravini (a). In 1960 celebrations were held to mark the thousandth anniversary of the Tribunal de las Aguas in Valencia where a large irrigation system for fruit-growing orchards goes back to the time of the Cordoban Caliphs. Chhun-Li, ch. 4, p. 354a (ch. 16; Biot (1), vol. 1, p. 374).
* Ch. 99, p. 56; ch. 10, pp. 35, 44 (ch. 34, 37; Biot (1), vol. 2, pp. 217, 329).
* Ch. 99, p. 366 (ch. 16; Biot (1), vol. 1, p. 274).
* Ch. 99, p. 314a (ch. 33; Biot (1), vol. 2, p. 265).
* Although the word tu4 shui can mean 'all', its principal meaning was from earliest times the capital of a State. This is yet another example of the inevitable association between waterworks and political centralisation. Cf. p. 264 above.

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1. 恩巍 2. 李善 3. 杜充 4. 菱亭 5. 橋椏 6. 齊子

28. HYDRAULICS

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28. CIVIL ENGINEERING

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54x478 f...
independent ministry. In the Thang this was at first called Tu-Shui Chien, but changed its name in +683 to Shui-Heng Chien. Among its departments were the Ho Chhi Shu (Bureau of Rivers and Canals), the Chu Chhi Chien (Sub-Directorate of Ports, Ferries and Bridges), and, till +736, the Chou Chi Shu (Bureau of Boats and Oars, i.e. Canal Transport). Among its greatest perambulating officials were the Ho-Thien Chhi Chien (Comptrollers of River and Dyke Works), the strengthening of whose position was one of the first acts of the Chu Chien, the officials in charge of sluice gates. All this personnel was theoretically in the province of the Ssu-Khung, or Minister of Works, one of the four great ancient officers of Sung.

268 28. CIVIL ENGINEERING

and 'blockage' (tiang sai4) are strikingly applied to literary composition and inspiration.

269 28. HYDRAULICS

(Def of the Art of Letters) written by Lu Chi in +302. There the terms 'flow' and 'blockage' are strikingly applied to literary composition and inspiration.

6 (SKETCH OF A GENERAL HISTORY OF OPERATIONS

One of the songs in the Shih Ching contains the words: How the water from the Piao pool flows away to the north! Flood the rice-fields... (Piao chih pei liu, chhin pi tao thien4), Since this may indeed be of the -8th century, it is perhaps one of the earliest mentions of irrigation in Chinese history; but it can only refer to a reservoir on some rather small scale. A couple of centuries later, impressive works were well under way.

One of the larger, or at least longer, works of Chinese hydraulic engineering, however, had the reputation of being so ancient that its first origins were lost in the depths of time. This was the Hung Kou (Canal of the Wild Geese, or Far-Flung Conduit), which connected the Yellow River near Khaifeng with the Pien and Sau Rivers, and ultimately formed the model, as we shall see, for part of the Su Grand Canal.

Although the conduit may have been first made to bring irrigation water to the upper Huai basin rather than for transport, it linked the Huai River with the Yellow River at an early date and permitted the navigation of barges between the east-central and the northern key economic areas (see Fig. 36 (map) and Vol. I, pp. 114 ff.). Ssuma Chien said of it that it connected the feudal States of Sung, Ch'eng, Ch'en, T'ai, Tiao and We. If indeed it began as an irrigation system, its availability as a long-distance transportation channel was ominous for their survival as independent States. Strictly speaking it was a summit canal, but the term would be inappropriate, for the watershed between the Yellow River and Huai basins is extremely low and flat, and the difference in levels was lessened almost to non-existence by the building-up of the Yellow River's bed (cf. p. 237 above), already well advanced. Strictly speaking also the Hung Kou was a complex of artificial waterways rather than a single canal. It took off eastwards from the Yellow River at a point downstream from the entry of the Lo.

* See Hughes (9), pp. 107, 177, 179. Text in CSHK (Chin), ch. 97, p. 306.  
* Miao no. 294; Legge (11), s; Waley (1), no. 110.  
* This pool is perhaps to be identified with a lake which existed for many centuries west of Sian in Shensi.  
* On the hydraulic engineering works of the Chou and Chan Kuoperiod Yang Khuan is a useful companion, but his work came out too late to help us in writing.  
* In spite of Herrmann (12), we do not feel sure that Pien, the name later applied to the canal itself, was ever the name of a river. Sauma Chih is does not mention it; he says that the canal joined the Yellow River to the Chi, Ju, Sau and Huai Rivers.  
* This does not mean that no double slipways (shadai or baul-over) were necessary, together with stop-log gates or bash-lock, but does mean that the routes could be worked for many centuries without bound-lock.  
* Lo Jung-Fang (6), pp. 50 ff., has made a gallant attempt to work out the details, but the historical geography is very difficult. Cf. Twitchett (4), p. 180.

* Shih Wu Ch'ü Yuan, ch. 6, p. 233. This title goes back to the Chin (+3rd century).  
* Later on (Sec. 44) the question will arise of similarities here with the medical theories of the Grecians.

So also the Lü Shih Chhsn Chhus says: The establishment of diseases and the arising of evil are due to a blocking up of the seminal essence (ching) and the chi. If water is stagnant it becomes slimy. If the sap in trees is dammed up, worms find their way in; if grass is similarly affected, it decays. And earlier it was pointed out (Vol. 2, pp. 145 ff.) that the chief purpose of Taoist medical gymnastics was to unblock the pores of the body. Finally, this general cast of thought appears also in literature, as may be seen from the celebrated Wen Fu (Ode on the Art of Letters) written by Lu Chi in +302. There the terms 'flow' and 'blockage' (tiang sai) are strikingly applied to literary composition and inspiration.

It is the nature of water, when free from admixture, to be clear, and when not agitated to be level; while if obstructed and not allowed to flow, it cannot preserve its clearness (yu pi erh pu lio, i pu meng ching). So also the Lü Shih Chhsn Chhus says: The establishment of diseases and the arising of evil are due to a blocking up of the seminal essence (ching) and the chi. If water is stagnant it becomes slimy. If the sap in trees is dammed up, worms find their way in; if grass is similarly affected, it decays.

And earlier it was pointed out (Vol. 2, pp. 145 ff.) that the chief purpose of Taoist medical gymnastics was to unblock the pores of the body. Finally, this general cast of thought appears also in literature, as may be seen from the celebrated Wen Fu.
River from Loyang, just beside the city of Junyang, where there was a great granary in Han times, the hub of the tax-grain transport system. It then swung south in an arc of some 260 miles so as to connect with the head-waters of that gridiron of parallel south-eastward-flowing rivers entering the Huai from the north—the Ho, the Tsu, the Sui, the Kuo and the Ying. This canal, called the Lang-Tang Chhii, following almost imperceptible contours, joined together the upper reaches of the last three of these rivers, not without successive improvements in the form of a number of branches, but it was never the part most used for traffic. That function devolved upon its most northerly branch, the Pien (or Pan) Canal or River, some 500 miles long, which joined the head-waters of the Ho and so passing near Hsuehau10 gave access through the Sau11 to the Huai. From +70 onwards its mouth on the Yellow River was protected by substantial dykes11 built under the supervision of Wang Ching.11 This then was the Hung K’ou proper, or the Pien Canal of the centuries before +600.1

There remains the question of the date of its construction, still very uncertain. So old it was supposed to be that Ssuma Chhien gave it pride of place after the works of the Great Yu himself, assigning no clear origin to it. The diplomatist Su Chhin13 mentioned it about +330 in discussing State boundaries. According to some scholars it was first built between +361 and +353, but Su Chhin does not mention the State of Wei,13 which was not founded until +403, in connection with the canal, but only smaller and more ancient States. Chhien and Ts’ai were absorbed by Chhu in +479 and there coming not only from the more southerly east-central economic area, then imperfectly developed, but also from the northern economic area, collected and despatched from the city of Thao in Shantung.12

[...]

As reported in Chhien Han Shu, ch. 24A, p. 174A, cf. Sung Shih, ch. 93, p. 188B; it brought to the capital in its time, c. +60, some 122,000 tons of grain annually. This was only about a quarter of what the Pien Canal of the Northern Sung could do; cf. p. 311 and pp. 352, 360. On King Shou-Chhang see further Vol. 3, p. 24, etc.15

10. The Ao Tahang.11 It will be seen that this position was very well chosen, for tax-grain could meet there coming not only from the more southerly east-central economic area, then imperfectly developed, but also from the richer northern economic area, collected and despatched from the city of Thao in Shantung.12

11. Cf. the historical account of Chang Chi in +905, preserved in Sung Shih, ch. 93, pp. 172 ff.

12. Cf. p. 308 below, as also Chao Chao-Chang (1), p. 193. At an earlier time those protection works had been the scene of an operation well exemplifying the taste for hydraulic engineering which characterised ancient Chinese generals and strategists (cf. p. 263 above). In +225 Wang Pen,14 one of Chhien Shih Huang T’o’s commanders, broke down the dykes at a flood season so as to inundate the State of Wei15 and sap the city-wall of its capital Ta-lia16 which lay near modern Kaifing beside the Hung K’ou Canal. The scheme was successful and one of the last remaining great competitor States of Chhien was liquidated (cf. Vol. I, p. 94; the story is told in Shih Chi, ch. 6, p. 90, ch. 44, pp. 21A, 22A; tr. Chavannes (1), vol. 2, p. 121, vol. 3, pp. 195, 199; cf. Ching, loc. cit. p. 3). At this distance of time its efficiency is naturally hard to estimate but according to King Shou-Chhang17 (as reported in Chhien Han Shu, ch. 24A, p. 174A, cf. Sung Shih, ch. 93, p. 188B) it brought to the capital in its time, c. +60, some 122,000 tons of grain annually. This was only about a quarter of what the Pien Canal of the Northern Sung could do; cf. p. 311 and pp. 352, 360. On King Shou-Chhang see further Vol. 3, p. 24, etc.


15. See Vol. 2, sub voc.

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early as +487, and Chang to Han by +375.1 He may of course have meant only the country that had belonged to these ancient states, but it is clear that a Confucian dating is by no means excluded.

The date of the earliest known irrigation reservoir, though prior to this, is one which can be accepted with little reserve. In northern Anhui, south of the city of Shou-hsien,1 there still exists a great tank, some 62 miles in circumference, known today as the Anfeng Thang, but anciently as the Sau-Sau Pei1 or Shao Pei1 (Peony Dam). Both Ssuma Chhien12 and the author of the Hsuan Nan Tzu book12 make clear that the dam had first been constructed under the supervision of Sunshu Ao,14 minister to Duke Chuan of the Chhii State when Ting was the reigning Chou High King (+606 to +586). The dam simply flooded a rather flat valley, catching the north-flowing water from a considerable part of the mountains north of the Yangtze, and supplied eventually no less than six million acres. It was repeatedly repaired during the Han and Tang dynasties. Sunshu Ao therefore ranks as the most ancient historical figure among all the hydraulic engineers of China.

In the 5th century, besides the works of Li Khuei already mentioned, of which we know little,13 there were two especially important projects. Hsinwen P’o14 the rationalist statesman who abolished human sacrifices to river-gods,16 organised a diversion of the Chang River, which formerly flowed into the Huang Ho near An-yang, so that it met the great stream, then in course to lower down, i.e. nearer the bend at modern Tientsin.17 Thus the Chang, which rises in mountainous Shansi and flows south-eastwards, was led away north-eastwards as a lateral contour canal to irrigate a large region of Honan instead of wastefully adding to the burden of the Yellow River. This work must have been begun between +493 and +587, when the State of Wei was under Duke Wen.17 But on account of resistance to corvée service or for some other reason, it was not fully completed until the time of the grandson of that ruler (+318 to +296), when Shih Chhi17 was put in charge.18 The people made a song in honour of this which Pan Ku recorded in his history.

The other work of this century was the Han Kou19 (Han-Country Conduit) which connected the Huai River with the Yangtze. It had been initiated earlier by Fu Chhii,19 king of the State of Wu20 at the time, in +486, as a military measure to enable
supplies to reach Wu troops attacking more northern States such as Sung and Lu. This line of communication thus became the second oldest segment of the Grand Canal, but its original route ran to the east of the present one, winding devi­cously through the Shé-Yang Hu⁵ and other lakes. Szuma Chien does not refer to it by name, but after mentioning a canal between the Yangtze and the Huai, adds that the Wu State also initiated many waterways around the Thailhu lake, thus starting the immensely complicated system in modern Chiangsu province.

Not many years after the work of Shih Chi in Honan came the famous system of Li Ping in Szechuan (about - 270) and the Chéngkuo Canal (about - 246), but these were so important that we shall reserve them for fuller description. A third project of the Chhin State and empire, much less well known, deserves a few words. The Yellow River, after passing Lanchow, flows north with the Orods Desert on its right bank for some 350 miles. Near Ninghsia (mod. Yin-chhuan) it traverses a broad valley with low hills to the west, having much land on both sides which is fertile if irrigated. Here was a splendid outpost against the Huns. Accordingly Chhin Shih Huang Ti sent his general Méngh Thien⁷ in - 215 to take possession of the hither ground, and in the following year to pass across, build forts, and make new prefectures with a population of transported prisoners. All this was done, but more also, for derivatory lateral irrigation canals were built, starting from the town of Chung-wei³ and running more or less parallel with the river on both sides (Fig. 878, pl.). With the extensions which were made to them in the Han and Thang, they now cover an area about 100 miles long and 20 miles or so broad. Like the Kuanhsien system, this is clearly visible on small-scale maps, and like it also, is still today in full use.

"If we take water from the Wei River to fill a canal dug from Chiang-an to the Yellow River, running along the foot of the southern mountains for a little more than 300 li (in a straight line), transportation will be greatly eased. Passages would take only three months (instead of six as hitherto). Besides, the people living below the canal would be able to irrigate more than 100,000 ching (about 166,000 acres). Thus in one sweep we shall shorten the time taken by the (grain) transports, reduce the number of men required, augment the fertility of lands within the passes, and obtain fine harvests." The emperor approved the project. He commissioned the hydraulic engineer (shai kung⁸) Hsi Po,⁶ a man from Chhi, to survey the course of the proposed canal, and to recruit all available men, to the number of several tens of thousands, to excavate it. In the course of a few years the work was completed, and great advantage accrued to transportation, which gradually increased in volume, while the people living below the canal found its water most beneficial for their fields.

Several centuries later, the Sui engineers reconstructed this canal and used it as part of their great system whereby Chiang-an was in direct water communication with Hangchow, but we do not know whether they used exactly the same course as that of Hsi Po.⁶ In any case, the work, which received the name of Taohoo④ (Grain Traffic Waterway, par excellence), remains the classical Chinese example of the lateral transport canal.

Not all works of this period were equally successful. Phan Hsi⁵, governor of Ho-tung (Shansi, across the Huang Ho), urged that owing to the famous difficulties of navigation at Ti-Chu⁷ on the Yellow River, it would be advisable to increase cultivated land nearer the capital. He therefore proposed in - 129 that the Fen River, coming down south-westwards out of Shansi, should be made to give rise to canals irrigating both the north and south sides of the valley where it flows into the Yellow River—furthermore, that water from the Huang Ho itself should be led off to irrigate several hien of poor land within the sharp bend where it goes east at Thung-kuan.⁴ Several tens of thousands of men were accordingly set to work but unfortunately a few years later the
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Yellow River changed its course and spoiled the whole scheme. All the land reclaimed by the Fén River Project was thus laid waste.\(^4\)

This is the place to say a few words more about the navigation of the Yellow River upstream from the Hung Kou junction to the great bend at Thung-kuan and then on by the Wei or its parallel canal to the capital at Chhang-an (Sian). Perhaps the most dreadful and perennial headache for the transport authorities century after century was the rocky defile at a gorge called San-mên Hsia\(^1\) (Three Gates). Here the river swings in a broad curve past promontories of porphyritic diorite where two rocky islands divide the stream into three roaring rapids, dedicated respectively to spirits, devils and men. Whenever the presence of the capital graced Chang-an, as notably in the Early Han and the Thang periods, the grain traffic had to be worked upstream by the Wei or its parallel canal to the capital at Chhang-an (Sian). The river is flowing from left to right; the vista on the right is downstream. The thin suspension bridges swings in a broad curve past promontories of porphyritic diorite where two rocky islands divide the stream into three roaring rapids, dedicated respectively to spirits, devils and men. Whenever the presence of the capital graced Chang-an, as notably in the Early Han and the Thang periods, the grain traffic had to be worked upstream by the Wei or its parallel canal to the capital at Chhang-an (Sian). The river is flowing from left to right; the vista on the right is downstream. The thin suspension bridges

\(\text{Fig. 879. The redoubtable gorge of the Three Gates (San-mên Hsia) on the Yellow River, for centuries a grave obstacle to safe navigation and now the site of a great modern dam (redrawn from Anon. 33).}
\)

1. Dressing-table Island (Shu-chuang Thai)
2. Lord Chang's Island (Chang Kung Shih)
3. The Grindstone, rock (TI-chu Shih)
4. The New Canal of the Khai-Yuan reign-period (Khai-Yuan Hsin Ho); a black arrow marks its upper entrance
5. Gate of Man Promontory (Jen Mên Tao)
6. Gate of Man (Jen Mên)
7. Gate of Spirits Island (Shen Mên Tao)
8. Gate of Spirits (Shen Mên)
9. Gate of Devils (Kuei Mên)
10. Gate of Devils Island (Kuei Mên Tao)

The river is flowing from left to right; the vista on the right is downstream. The thin suspension bridges

\(\text{were part of the work for the dam.}
\)

\(\text{As we have just seen, Phan Hai wanted to reduce the traffic past this danger-point by increasing productivity west of it. Other suggestions, many times repeated, envisaged vast detours in order to avoid it. This explains the significance of the proposal we already studied (p. 27 above) for the Pao-Yeh Route. The bold idea of Chang Thang\(^3\) was to bring grain from the south-east (the east-central key economic area) right over the Chhin-ling Mountains, using a road portage between the head-waters of the Pao\(^2\) and the Yeh\(^3\) Rivers. The latter flowed northward quickly into the Wei\(^4\) and so communicated with the capital; the former descended southward to join the Mien\(^5\) and hence the Han, the Yangtze's greatest tributary. It is possible that Chang Thang had in mind to avoid the complicated region of lakes near modern Hankow and the swift current of the great river by making use of a small 'back-door'. Traffic proceeding up the Huai River into modern Honan could turn right into the Ju\(^2\) and then left into the Chen.\(^1\) One had then only to cross a low and narrow watershed to find the Yi\(^1\) (now the Thang\(^3\)) flowing westwards to join the Han River at Hsiangyang, and there is some reason to think that the barrier was crossed by another of the low-gradient summit canals, in this case built as early as \(-653\), when Chhü State invaded Chêng.\(^4\) It would be interesting to know if any traces of it are left today; at any rate, this gap in the hills along the Honan-Hupeh border would have provided a much easier route than the Yangtze itself, even if road portage had always been necessary. Unfortunately the Pao­Yeh route failed in its main object because the canalisation of the Pao and Yeh streams themselves proved too tough a job in the absence of explosives and poundlocks or even sufficiently strong and numerous flash-locks.\(^6\)

\(\text{This detour was a vast southern arc, but a similar conception was attempted in the north. One usually thinks of the province of Shansi as bisected lengthwise by the Fén\(^11\) through this pitiless place, resulting in untold losses of ships, men and produce.\(^8\) The name Ti-chu, which became a byword, was that of a pinnacle of rock which stuck out of the water, with others, upstream of the two large islands, as if placed purposely by Nature to trap the ascending barque which had successfully negotiated the rapids, or, in worse case, carried away from the hauling cables of the trackers (cf. Fig. 879).\(^9\) The place would be fit subject for an epic narrative, not least among the parts of which would be the praise of the enormous multi-purpose dam now being completed at the spot.\(^5\)

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\)

\(\text{Cf. T'ing Tai-Hui (1); Li Fu-Tu (1). With a length of 2,600 ft. and a height of nearly 500 ft., its storage capacity will exceed that of the Boulder and Grand Coulee dams combined. Besides mitigating the risk of floods it will irrigate an area equal to a third of all the arable land in England, make the river navigable up to Lanchow, and produce 1.1 million kilowatts of power.}
\)

\(\text{The Han valley route was used occasionally in later centuries, e.g. around \(-476\), when normal communications were interrupted in the rebellions of An Lu-Shan and others. Cf. Twitchett (4), pp. 91, 359.}
\)

\(\text{Another unsuccessful project concerned the Lo River, which joins the Huang Ho between the Fén and the Wei, but mention of this will come more appropriately in the sub-section on techniques (p. 334).}
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\(\text{\(^{1}\)三門險}
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\(\text{\(^{2}\)卫}
\)

\(\text{\(^{3}\)buquerque}
\)

\(\text{\(^{4}\)The Han valley route was used occasionally in later centuries, e.g. around \(-476\), when normal communications were interrupted in the rebellions of An Lu-Shan and others. Cf. Twitchett (4), pp. 91, 359.}
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\(\text{\(^{1}\)三門險}
\)
River from north to south, but in fact the Fén arises not far north of Thai-yuan, and the uplands above are drained by another river, the Hu-Tho, which skirts the Fén valley in a sickle-shaped valley of its own and falls down on to the Hopei plain to empty into the old bed of the Yellow River (the present line of the Grand Canal) just before the Tientsin bend. Grain having reached the hub point at Jungyang it was therefore possible to take it not directly westwards up the Yellow River, but north-eastwards to the point of entry of the Hu-Tho, after which it could go slowly past Ch'ang-ting up into the hill-country of Shan'ai. In the Early Han (1st century), when the Yellow River was still in course C, an attempt was made to join the headwaters of one of the Hu-Tho's tributaries, the Yeh, with those of the Tung-Kuo Ho, a tributary of the Fén. A summit canal is marked across this pass near Shouyang on contemporary maps, but in antiquity it was not a practical proposition and was soon abandoned, except for portage traffic. Between +69 and +78 a more determined attempt was made to connect the Hu-Tho and the Fén. Further up the Hu-Tho itself, a tributary, the Mu-Ma Ho, led up past Hsin-hsien to the Shih-ling Kuan pass, on the other side of which the Lo-Yin Ho led downwards to the Fén. By this time the Yellow River had shifted to course C, but enough water must have been still flowing in course C to make the detour possible, if not very attractive. After nearly a decade of effort, the attempt was given up, and a portage cart-road substituted. Most probably these audacious schemes were frustrated not only by the inadequacy of the gates and the absence of pound-locks but by the great difficulty of supplying water to the summit levels—nevertheless when we see that both these passes are traversed by railways today we admire the perspicacity of the Han surveyors.

Of course the remedy for all this was not to have the capital at Chang-an at all. It was certainly a material reason why the Later Han dynasty fixed its capital at Loyang, and why in the Tang the imperial seat oscillated continually between the two. To improve transport to Loyang the Fén the Lo River in +48, the Yang Chhiü already noted in the sub-section on bridges (p. 172 above). Its builder, Chang Shun, the Minister of Works at the time, made it terminate at the west of the city, passing south of the walls somewhere near the place where Pi Lan's water-raising installations were to arise a century or so later. The need had been felt for some time, but Chang Shun was successful where Wang Liang had failed. For in +29 Wang Liang had opened a canal to lead the Ku Shun through the narrow of Ti-chu rock until it was almost submerged by the waters, but they could not get rid of it altogether and the river boiled in fury worse than before, so the danger was increased instead of lessened.

The question has been raised whether the technique of steel-making was at this time sufficiently developed to give adequate tools for such an operation; in our opinion it certainly was, but for work at low-water periods time pressed, and the job was surely impossible without explosives. After this the San-men problem was traditionally handled in three different ways, by cutting trackers' galleries in the cliffs, by building detour roads to avoid the passage, and by short-circuiting the rapids with the aid of a rock-cut canal.

At an earlier point (p. 22) we said a good deal about the gallery roads on brackets (chan tao) built anciently through mountain defiles in various parts of China, and these galleries at San-men were a special case. Their remains can still be seen, and the multiform inscriptions they bear have been carefully collected. Wooden planks floored the decks of half-tunnel ways excavated in the perpendicular cliff-faces, widened by wooden baulks supported on projecting beams (Fig. 88, p.), but naturally without balustrades because of the hauling cables. These galleries are generally from 15 to 30 ft. above the average river level. At some places there are sun bollards cut out of the living rock. The oldest inscription, dated +150, bears the name of Li Erh. From the +3rd century (e.g. +221, +240, +260, +281) they are numerous, and the artisans and engineers are given their titles—the Shih Kung (Mason) Liu Fang; the Shih Chiang (Master Mason) Chang Ling-Hsien; the Tu Chiang (Director of Waterways Engineering) Yao Shih; the Chih Ho Tu Chiang (Director of Waterways and River Conservancy Engineering) Tao Kung; all these men of the San Kuo and Chin periods. The galleries were continually being repaired in later times, in the Sui (+595), in the Thang particularly between +684 and +707 by the military engineer Yang Wu-Lien (already met with in other connections, Vol. 4, p. 52, a), again in the Sung (+1066) and even as late as 1899, when chains were added along some sections for the pullers.

As early as +165 Li Yü wanted a road and carts to circumvent the gorge, and Liu Ai supported him, saying that no good junk captains were left, but nothing was done
at that time. The old Han road from Thung-kuan to Loyang (map, Fig. 71) of course remained available, but transport along it was very expensive. About 480, under the Northern Wei, Hsia Chih-chih therefore strongly urged a return to the water route along the Yellow River and through the gorge, together with adequate repair of the Chhuan Canal; this found favour and the necessary work was put in hand though not completed. After fifty years, however, the galleries again fell into disrepair and traffic returned to the road. Not until 656 was a specific short-circuit road around the gorge attempted, when Chhu Lang, made one to the south, but the approaches to the quays were badly planned and swept away in floods. The problem was solved successfully so far as it could be in +723, when Phei Yao-Chching took over as Imperial Transport Commissioner and built not only the six-mile road on the northern side through rock cuttings some of which can still be seen today, but also large granaries one above and one below the gorge as warehouses for the trans-shipment. After earthquake damage the road was restored and double-tracked in +785 by Li Pi and at some periods greatly used, but the land portage remained a nuisance.

It was in order to avoid it that a few years later, in +741, Li Chhi-Wu, Prefect of Shenchow, constructed the remarkable rock-cut canal west of Man-Gate Island (Jen Men Tao) still to be seen (Fig. 881), but soon to be submerged behind the San-men dam. This is a regular steep-sided cutting some 820 ft. long with an average width of 22 ft. and an average depth of 30 ft.; it has a trackers’ gallery in its eastern wall and was crossed by a bridge in Thang or Sung times. Unfortunately it was never deep enough to carry a great deal of traffic, perhaps because Li Chhi-Wu was starved of funds, perhaps because of rapid silting or the excavation of the Yellow River’s own bed, so that it was used mainly during the summer flood season. Here again it is known that ample use was made of fire-setting with vinegar to split the rocks by steam.

On account of its date it was known as the K’ai-Yuan Hsin Ho or, by dedication to a Taoist goddess, the Niang-Niang Ho.

In course of time the navigation of the San-men gorge ceased to occupy its position of central conundrum in the communications network. Significantly the capital of the Chinese empire at the time of the next unification, that of the Sung, was fixed immediately at Kaifeng, just beside the hub of the transport system, and not far away to the west. When it had to be withdrawn to Hangchow it was still at the centre of a great key economic area, even though the northern one fell to the dynasties of Jü-Chin and Liao. In the unifications of the Yuan and Ming the eastern plains continued to be predominant, and the ancient stronghold of Kuan-chung declined steadily to provincial status. The
Yen Nien, of whom otherwise nothing is known. In the Chhien Han Shu we read:

At that time (the second year of the Thai-Shih reign-period) there was concern regarding the Huns (Hsiung-Nu). Those who were eager for achievements and profits, and who discoursed of (possible) advantages, were very numerous. A man from Chhi, Yen Nien, offered a written proposal which declared: 'The (Yellow) River emerges from the Khun-Lun (Mountains) and passes through China to flow into the Pho Hai (Eastern Sea). This is its geographical setting, sloping from the north-west southwards and eastwards; one may observe the nature of the territory according to the maps (fu shu). If now Your Majesty should order the hydraulic engineers (shai heng) to survey the high and low places, and to open a great river which would come forth from the mountains (of Tibet), traverse the middle of the Hu (Huns') country, and flow eastwards to the sea—in this way the land east of the passes would be perpetually freed from flood disasters, and the northern frontier would not suffer from the Huns. Much labour would be saved by not having to make dykes and embankments, and by not needing so many men to guard the frontiers. The Huns robbers are a calamity, invading and plundering us, overthrowing our armies and slaughtering our commanders, so that their bones lie exposed in the wilderness. The empire is always warring off the Huns, but it does not suffer from the hundred Yih (peoples, in the south-east) because streams separate them and cultivated lands divide them. This project will confer the greatest benefit upon ten thousand generations.'

When the proposal had been presented the emperor praised it, replying as follows: 'Yen Nien's suggestion seems to be a thoroughly well-considered one. But the (Yellow) River was directed into its present course by the Great Yu. When sages carry out their enterprises, they act for the benefit of ten thousand generations. Whatever has been done with divine perspicacity is, we fear, difficult to alter.'

If we understand this aright, Yen Nien's project would have been an immense work deriving from the Yellow River at some point between Lanchow and Ninghsia, and rejoicing its lower course above or below the Langmén gorges, at any rate before its great eastern bend at Thung-kuan. It would thus have followed roughly part of the course of the Great Wall, and would have abandoned only the Ordos Desert to the Huns. In a straight line alone the distance would have been 300 miles or more, and the emperor's advisors doubtless felt (quite rightly) that it was far beyond the powers of the empire at the time. What is particularly noteworthy is that Yen Nien saw that a shortening of the river's course through the loess country would lessen its silt-content and make its control much easier, quite apart from the military advantages of having a great river as a frontier.

Towards the end of the Early Han dynasty, a fine work was carried out (38 to 34) by Shao Hsin-Chhen in southern Honan, namely the Chhien-Lu Canal, with the introduction of numerous flash-lock gates. When the Yellow River was out of control, as it had been in +11 (cf. p. 241), there was always a tendency for it to escape eastwards and southwards, flooding the Chhi River and spoiling the works of the canal. Reinforcement of its banks with stone revetments in the years +1 to +5 had not sufficed to prevent this, but now Wang Ching's work was well done and endured for a considerable time. A century later (±189), Chhen Teng built a series of weirs from the city of Shou-haien westwards, collecting the water from 36 streams over an area about 20 miles in diameter, and irrigating 10,000 ching. The remains of some of these structures came to light in 1959 and have since been excavated. It thus appears that they were made of alternate layers of rice straw and clayey soil based upon a gravel foundation, the stalls being laid parallel to the current flow, and the whole supported by wooden piling and coffering denser at the centre than at the ends. Military canals were also built at this time. When Taho Tshao was campaigning against Yuan Shao in +204 he built a whole series of small waterways running along the foot of the Shansi Mountains northward in Hopei, and making use of old Yellow River arms near Ta-ming. Rivers such as the Chang and the Hu-Tho were thus connected by contour canals (with names such as the Li Tshao Chhiü and the Phing Lo Chhiü). After the army of the north had been subdued, these supply routes seem to have played little role in communications and some were overruled when the Yellow River assumed course (Q), but part of the

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system still exists in the form of the Pai Kou⁴ between Peking and Paoting.⁵ In its prime it reached even as far north as Ku-pei-khou⁶ on the Great Wall. In the +3rd and +4th centuries much attention was concentrated on Chiangsu. Chang Khai⁷ built several important reservoirs south of the Yangtze, notably the Hsin-feng⁸ Tank, and Chhen Min⁹ excavated the Lien¹⁰ Lake, both in +321. About +350, Chhen Min greatly improved the communication between the Huai and the Yangtze, by cutting a new canal, the Shan-yang Yiin-Tao,¹² so that the ancient Han Kou fell completely into disuse. Another Chin official, Hsiin Hsien,¹³ built a short canal in Shantung in +352 near Tung-a,¹⁴ using the water of the Wen¹⁵ River.¹⁶ The importance of these works was that they were both destined to become portions of the Grand Canal.

The Grand Canal as a unit was the creation first of the Sui, when it led to Loyang, and then of the Yuan, when it led to Peking. We shall soon give it the attention it deserves. Before proceeding to the more detailed description of such greater works, however, let us take a glance at the historical picture as a whole. It would obviously be impossible in the space available to treat of the works of all succeeding dynasties in detail such as that which has been devoted to those of the Chhin and Han, all the more so since they continually grew in number and extent. However, an interesting attempt has been made to treat the matter statistically. Chi Chhao-Ting worked through the topographical histories (cf. Vol. 3, pp. 517 ff. above) of all the provinces in a systematic way, noting down all references to hydraulic engineering undertakings of whatever kind.¹⁷ The results are summarised from his data in Fig. 882 (an arithlog plot) and the accompanying table.

<table>
<thead>
<tr>
<th>Dynasty</th>
<th>Number of Waterworks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chou</td>
<td>0.175</td>
</tr>
<tr>
<td>Chhin</td>
<td>0.131</td>
</tr>
<tr>
<td>Han</td>
<td>0.454</td>
</tr>
<tr>
<td>San Kuo</td>
<td>0.110</td>
</tr>
<tr>
<td>Chin</td>
<td>0.118</td>
</tr>
<tr>
<td>Nan Pei Chhao</td>
<td>0.932</td>
</tr>
<tr>
<td>Sui</td>
<td>0.88</td>
</tr>
<tr>
<td>Thang</td>
<td>0.245</td>
</tr>
<tr>
<td>Wu Tai</td>
<td>3.48</td>
</tr>
<tr>
<td>Sung</td>
<td>3.166</td>
</tr>
<tr>
<td>Yuan</td>
<td>3.50</td>
</tr>
<tr>
<td>Ming</td>
<td>8.2</td>
</tr>
<tr>
<td>Chhing</td>
<td>12.0</td>
</tr>
</tbody>
</table>

a On this subject see Lo Jung-Pang (6), pp. 48 ff. and Chheng Chao-Ching (1), p. 194.
d The object was military supply, to get Mujung Lan out of Khaifeng.
e (1), pp. 36 ff.

f The breadth of the columns give the number of years of the dynasty, and their height the number of waterworks undertaken.
g Here w is the number of works undertaken and y the number of years.

From this one or two fairly obvious conclusions can be drawn. For the earliest periods records are sparse and all one can say is that the beginnings are there; it was the formative period of Chinese society. The real start came in the Han, especially the Former Han, and the important economic areas of the time are clearly revealed by the fact that Shensi and Honan have a big lead over all other provinces. The Three Kingdoms period, in spite of its short duration, shows a distinct volume of activity, attributable no doubt to strategic motives. Continued unsettlement from the +4th to the +7th centuries explains the somewhat poor performance of the lesser dynasties then regnant, but the unification of the Sui led immediately to a great development of civil engineering, especially with regard to the Grand Canal, and this was sustained
throughout the Thang. By now provinces such as Hupei and Fukien have appeared in the records, and during the Thang for the first time a southern province, Chekiang, outstripped every northern province. The Sung dynasty continued this progress, and works in certain provinces now first reached three figures. The breakdown shows that there was more activity after the removal of the capital to the south than before, so that the nomadic invasions may be said to have stimulated more intensive cultivation of the lower Yangtze valley and the valleys of Kwangtung and Fukien. While northern ‘nomadic’ empires such as that of the Chin (Jurchen) dynasty were not absolutely barren of hydraulic engineering works, the figures indicate that they never understood their importance as did the truly Chinese dynasties. For example, no large water-conservancy project of any kind was put in hand during the two centuries of Liao (Chhi-tan) rule. Yet this does not apply to the Yuan (Mongol) dynasty, which undertook the complete remodelling of the Grand Canal, involving works of great scale, and began irrigation in Yunnan. Heightened technical ability from the 15th century onwards is seen in the large figures for the Ming and Chhing, but the analysis by provinces also shows that these dynasties tried hard to produce in Chihli (Hopei) so as to render the northern capital region as independent as possible of transport from the south and centre.

With this, then, we may begin our tour of inspection of some of the outstanding projects of the past.

(7) The Greater Works

Among the most notable works of Chinese civil engineering three are of Chhin date (the Chêngkuo Irrigation Canal, the Kuanhsien Irrigation System, and the Ling Chhü Transportation Canal). The first two of these were part of the organisation of the key

- An elaborate work has been consecrated by Naba Toshisada (2) to the history of irrigation and water-conservancy during the Thang period; he uses materials from the Tunhuang MSS, and includes information on sluice-gates, water-mills, etc. So also Twitchett (2, 4).

- A particular feature of this period and this region was the drainage of lakes, swamps and bayous (old river-beds), to form reclaimed land (91a thien or sei thien) protected by dykes; cf. Chi Chhiao-Tung (1), pp. 135 ff., who translates the interesting memorial of Wei Chhing (1) on the subject (c. +1100), recorded in the Shih Thung Chhao, ch. 12, pp. 142 ff.; and Sudo Yoshiyuki (1), who shows that the process had begun under the Southern Thang. Governor Chhien (of sea-wall fame, cf. pp. 230 ff. below) was very active in it (Miu Chhi-Yü (1) expounds his work). Chi reproduces two old Chhing charts of the so-called ‘polders’, opp. pp. 116 and 148. Reclamation is still actively going on today (cf. Hung Hsi-ting, 1), no longer causing the severe social stresses that it did in Sung times.

- In Sect. 286 (p. 33 above), we met with a woman road engineer, a Fukienese Taoist of the Chhin-Sung (Chhi-Tan) rule. She was assisted by a local scholar and a military officer. The story has been told by Kuo 3 (to Chhin) to persuade deceitfully (the king of) Chhin to open a canal from the south and centre.

Before the construction work was more than half finished, however, the Chhin authorities became aware of the trick. (The king of Chhin) wanted to kill Chhing Kuo, but he addressed him as follows: ‘It is true that at the beginning I deceived you, but nevertheless this canal, when it is completed, will be of great benefit to Chhin. [I have, by this ruse, prolonged the life of the State of Chhin for a few years, but I am accomplishing a work which will sustain the State of Chhin for ten thousand generations.]’ The king of Chhin agreed with him, approved his words, and gave firm orders that the canal be completed. When it was finished, rich sail-bearing water (chien o chhi shui) was led through it to irrigate more than 40,000 ching (667,000 acres) of alkaline land (lu chih ti). The harvests from these fields attained the level of one ching (64 pecks, tou 11) per mou (i.e. they became very abundant). Thus Kuan-chung (1) (the land within the passes) became a fertile country without bad years. (It was for this reason that) Chhin became so rich and powerful, and in the end was able to conquer all the other feudal States. And ever afterwards the canal (the name of the engineer and) was called the Chêngkuo Canal.

The story of the Chêngkuo Canal is carefully told both in the Shih Chi and in the Chhien Han Shu.

(The prince of) Han, 1 hearing that the State of Chhin was eager to adventure profitable enterprises, desired to exhaust it (with heavy activities), so that it should not start expanding to the east (and making attacks on Han). He therefore sent the hydraulic engineer (shih hung) Chêng Kuo (1) to Chhin to persuade deceitfully (the king of) Chhin to open a canal from the Chhing River, from Chhing-shan and Hu-khio in the west, all along the foot of the northern mountains, carrying water to fall into the river Lo’ in the east. The proposed canal was to be more than 300 li long, and was to be used for irrigating agricultural land.

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- The selection of works for description in this sub-section is of course quite arbitrary. Lack of space has necessitated the omission, for instance, of the elaborate irrigation system of the upper Han valley, near Hanchung; see Chhi-Tse-Jung (1); Yang Ping-Khun (1); Chhing Chih (1). This was started by Hsiao Ho 12 in the —3rd century, and repaired and enlarged in many subsequent ages, e.g. by Chen Mi 14 in the Sung, Phu Yung 15 in the Yuan, Chhiao Chhi-Feng 16 in the Ming, and Chhing Kung-lü 17 in the Chhing.

- The works appear only in the Chhin Han Shu text.

- Saura Chhin’s estimate of the acreage irrigated is considered considerably high by Eliassen & Todd (1), but they grant 400,000 acres as the Han optimum. Today some 85,000 acres are irrigated by 87 miles of main canals. The minimum, in the worst circumstances at the end of the Chhing, was less than 2,000 acres, and this was largely taken from springs.

- For the selection of materials cf. Twitchett (6).
One could hardly have a more interesting record from the beginnings of such a typically Chinese technique as irrigation engineering. The fact that the Han people thought that those of Chhin could be deceived indicates, as Chi Chhao-Ting says, that the pros and cons of large-scale public works were not yet always clear to the feudal rulers. The willingness of the Chhin State to adopt Legalist innovations (cf. Vol. 2, pp. 204 ff. above) perhaps suggested that it would easily swallow a new and grandiose irrigation project which might be unsuccessful. But there is no reason to think that Chang Kuo sabotaged it; he seems to have been professionally honest, and perhaps only realised himself during the course of the work what it would mean for Chhin once it had been completed. Sauma Chhien understood perfectly the fundamental importance of the increase of productivity, the supply potential, for the ultimate political success of Chhin, and must be regarded as one of the first historians to appreciate that the supply potential is at least as important as military power in great international conflicts. Moreover, he was fairly near the events in question, for he laid down his brush in -90, and Chang Kuo's work had been brought to completion in -246, the year which witnessed the crowning of the future First Emperor as King of Chhin.

Only a few years before Sauma Chhien was writing, extensive additions to the Chengkuo Canal had been proposed and carried out by Erh Khuan (-111), supplementary lateral contour branches irrigating land higher than the main canal. Again, in -95, another high official, Pai Kung, pointed out that as the Chengkuo Canal had become so silted up as to lose much of its value, he therefore proposed to tap the Ching River a good deal higher up, and to carry a new canal for some 62 miles following a contour above that of its predecessor. This was successfully accomplished, and we have read at an earlier point the popular song that the peasants made to commemorate Pai's achievement, which they named Pai Chhi in his honour.

Re-cutting the canals and tapping the Ching River higher up was a process which had to be done continuously for twenty centuries. The Wei Pei irrigation area, as it is called (Fig. 883), is unusual in that although one of the first really large projects in China it has existed in use to the present day, and has been thoroughly studied by modern engineers. The re-cutting of the canals has been due to the constant battle

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Fig. 883. Sketch-map of the Chengkuo Canal irrigation system, first completed in -246 and still now in use under the name Wei Pei, or Ching-Hui Chhin, Irrigation Area. The small south-flowing river within the area is the Shih-chhuan Ho. The Lo R. now falls into the Wei R. and not directly into the Yellow River. East of the Lo, within its sharp bend, there is another ancient irrigation system, dating from c. -110 and still in use; this is now called the Lo-Hui Chhii after its main canal. Though not shown here, it is discussed in some detail on p. 333 below. Scale approx. 1:4,200,000.

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Some notes and references:

- "The burden rises to as much as 51% during summer rains. Flood flow is of dramatic onset, rising 50 ft. in 10 minutes.
- "A photograph of what remains of the Chhin or Han head-works is given by Nesteruk (1), fig. 24. A considerable amount of well-cut stone masonry is still to be seen.
- "Sigurd N. Sigurdson's "Wang Chheng-Chi" (1933; he afterwards wrote an important account of the T'ang Dynasty weapon works) was chief engineer of the Wei Pei system. Sigurdson's "Chinese Hydraulic Engineers" (cf. p. 317), chief engineer of the Wei Pei system. Sigurdson's "Wang Chheng-Chi" (1933; he afterwards wrote an important account of the T'ang Dynasty weapon works) was chief engineer of the Wei Pei system.

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With silt, which is never won, and the reason for moving the intake higher and higher up the Ching is that the river has been continually eroding its bed. The original Chhin or Han intake is still identifiable, but this point is now no less than 50 ft. above the present level of the river.
The Kuanhsien division-head and cut (Chhin)

In the country of Shu (Szechuan), wrote Suama Chhiien, Li Ping, the governor, cut through the (shoulder of a mountain, so as to make the) ‘Separated Hill’ (Li-Tui), and abolished the ravages of the Mo River, excavating the two great canals (chhiang) in the plain of Chih-chu.

In these few words, the historian recorded one of the greatest of Chinese engineering operations which, now 2,200 years old, is still in use and makes the deepest impression on all who visit it today. The Kuanhsien irrigation system (Fig. 884) made it possible for an area of some 40 by 50 miles to support a population of about five million people, most of them engaged in farming, and free from the dangers of drought and floods. It can be compared only with the ancient works of the Nile.

In -316 Shu had been conquered by the Chhin generals Chang I and Chang Jo. Li Ping probably helped to fortify its chief cities in -309. In -250 Prince Hsiao Wen appointed him governor of the province. It is not likely that he lived long after about -240, so the great works at Kuanhsien were completed under the supervision of his son Li Erh-Lang, about -230. Li Ping no doubt lived to see the crowning of the ruler of Chhin as king in -246, and his son saw the unification of the empire in -221, but in any case there can be no doubt that the project they carried through was (like the Chhengkuo Canal) one of the greatest of strengths of the Chhin State and Empire.

At Kuanhsien the Min River flows into the basin of Szechuan from its source in the hills of the extreme north of the province surrounding Sungphan. Li Ping decided to divide it into two great Feeder Canals, the Inner (Nei Chhiang) and the Outer (Wai Chhiang), by means of a division-head of piled stones, known as the Fish Snout (Yü T'ai), Fig. 887, pl. 4, about the point where the famous suspension bridge (see p. 192) crosses the river. The general layout of these head-works can be appreciated from the map in Fig. 884, the model in Fig. 888, pl. 4, and the views in Figs. 885 and 887.

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Now a name for a division-head R, then perhaps used for the main stream.

I have had the pleasure and privilege of visiting Kuanhsien twice, in 1943, after which I recorded my impressions (4, 21), and again in 1958. My first visit was made in the company of Prof. Feng Yu-Lan, Prof. Ho Wen-Chin, Dr Pheng Jih-Chun and Commissioner Kuo Yu-Shou; and I learnt much from Dr Pheng Yu-Ling, then resident engineer. On the second occasion I studied the works more fully with my collaborator Dr Lu Gwei-Djen, and we are glad to record our indebtedness to the kind help of Cde. Li Chiin-Chu, the resident engineer, and Cde. Yang Lieh-Chung.

Much has been written on Kuanhsien, even in European languages, e.g. Estner (1); Hutson (1); Little (2); Lowdermill (4, 7); Richardson (1); Worcester (1), pp. 86 ff. But the most authoritative and detailed treatments are of course in Chinese, e.g. Faow Chhiou-Chun (1); Ho Pei-Heng (1); Fang Chi (1), and perhaps best, Anon. (2). A brief history of the works will be found in Jung-Shih, ch. 95, pp. 244 ff.

On the colonisation of Shu by Chhin, see Hisamura Yukari (2).

The names of one or two of their semi-legendary assistants, such as Wang Chao, Commercer of Labourers, have come down to us.

In these datings we follow the 4th-century Hsu Yung Yang Kuo Chhiin, ch. 3, though modern authors often place Li Ping half a century earlier.

An earlier model, photographed in 1943, can be seen in Needham (4), fig. 34.

The rock is a kind of conglomerate which though not extremely hard seems to have weathered very little since Li Ping’s time. Richardson (1) called it a ‘natural concrete’.

The works, dams and spillways are known in general as the Tu-Chiang Yen, or the Dam on the Capital’s River. Its primary feature is the division-head of piled stones which separates the two feeder canals. The inner one is used wholly for irrigation; while the outer one, which follows the old course of the river, and is also known (because it flows due south while the other deviates eastwards) as the Chheng-Nan Chhiang, acts as a flood channel as well, and also carries some boat traffic. In order to construct the inner canal, following a slightly higher contour, Li Ping had to make a great rock cut through the end of a ridge of hills on part of which the city of Kuanhsien is built. This is known as ‘Cornucopia Channel’ (Pao-Phing Khou) (4). The height of the ‘Separated Hill’ on which the temple dedicated to him now stands (Fig. 890, pl. 4) is about 90 ft. from the canal bed, so that the total height of the 90-ft. wide cut would have been 130 ft. or more. Between the primary division-head and the rock cutting the two channels are separated by the Chhing-Kang Thi (Diamond Dyke) and the Fei-Sha Yen (Flying Sands Spillway). The top of the Diamond Dyke is made higher than the flood level of the Min River, to aid in the division of the water, while the lowest part of the spillway is no less than 130 ft.

Fig. 889 (pl. 4) shows a map of the Kuanhsien System painted on a wall in the Temple of Li Erh-Lang at a stone-inscribed plan exists there also (see Hutson, 2). Not all the minor canals date from Li Ping’s time; many were added in the 4th and 5th centuries under Taoh Yu-Yuan. The Kuanhsien works were not by any means the only hydraulic undertakings of Li Ping and his son; all are described in the Hsia Yang Kuo Chih, ch. 3, in a passage which Torrance (2) has translated.

A large protective piece for this in the shape of a tortoise, made of iron and weighing about a ton, was cast and placed in position by Chi Tang-Phu between +1677 and +1694, but before long it was washed away by a flood and now lies buried somewhere in the river-bed. A similar attempt was apparently made between +1543 and +1556 when another engineer-in-charge, Shih Chhiien-Huang, left the secondary division-head (the Taoh-Ying Yü Ts’u) with some 40 tons of cast iron in the shape of two oxen with heads conjointed and tails separated; but this also was washed away.

Yü-lei Shan (Jade Rampart Mountain). Approximate dimensions of the cross-section are given in Fig. 891.

This name is rather evocative. In Vol. 2, p. 142, we read the account of the T’ai-tai priestess in Liuh T’u ch. 5, p. 124, centred upon Amphora Mountain (Hu Ling Shan). This was shaped like a vase (tao chu), and at the top there was an opening (khou) in the form of a round ring called Hydraulica (lit. Aperempt Flood, ka jing) because streams of living water came out of it continually. Li Su-Shun (1) now tells us of the irrigation deity worshipped in Kuanhsien, Khou Khou Ehr Lang, the Younger Son (cf. Li Hsia-Lang himself) of the Irrigation Channel Mouth. This personage is tentatively to be considered the deification of Yang Nan-Tang, a king of the Li Chihang tribal people of Chhiou-chih, who died in +494.

Hence the name Li-Tui mentioned by Suama Chhiien. Kuanhsien (the Irrigation City) must equally have got its name at the same period.
Fig. 884. Plan of the Kuanhsien irrigation system headworks, Tu-Chiang Yen (after Anon. 52). The intake works here shown beside the city and temples of Kuanhsien distribute water in a myriad canals all over the plain of Chh@ngtu in Szechuan.

Plan of the Kuanhsiuen Irrigation System Headworks (Tu-Chiang Yen)

- **a, a** Min Chiang (Min River)
- **b** Han-Chia Chi (Han-family island)
- **c** Pui-Chang Thi (Thousand-foot Dyke)
- **d** Wei Chiang (Outer Feeder Canal; old course of river)
- **e** Nei Chiang (Inner Feeder Canal)
- **f, f** Chin-Kang Thi (Diamond Dyke)
- **g** Phing-Shui Tshao (Water-level By-pass or Adjusting-flume)
- **h** Fei-Sha Yen (Flying Sands Spillway)
- **i** Jen-Tzu Thu (V-shaped spillway)
- **j** Li-Tiu (Separated Hill) and Fu Lung Kuan (Tamed-Dragon Temple; the votive temple of Li Ping)
- **k** Pao-Phing Khou (Cornucopia Channel; the rock cut)
- **l** Kuanhsien City
- **m** Yü-lei Shan (Jade Rampart Mountain)
- **m** Feng-Lou Wu (Phoenix Nest Cliff)
- **n** Phu-Yang Ho (derivative canal)
- **o** Po-Thiao Ho (derivative canal). New sluice-gates were installed across this, as shown, in 1952.
- **p** Tu-Chiang Yu Tsui (Fish Snout; primary division-head of piled stones)
- **pp** Thai-Phing Yu Tsui (left secondary division-head)
- **ppp** Ting Kung Yu Tsui (left tertiary division-head)
- **q** Sha-Hei Ho (right main derivative canal)
- **r** Sha-Kou Ho (derivative canal)
- **s** Hai-Shih Ho (derivative canal). The feed into both of these is assisted by a spillway higher up, overflow rejoining the Cheng-Nan Chiang
- **t** Cheng-Nan Chiang (old course of river, flood course, etc.)
- **u** An-Lan Su Chiao (suspension bridge, cf. p. 192 above)
- **v** Erh Wang Miao (Temple of the Second Prince; the votive temple of Li Erh-Lang)
- **w** Yil Wang Kung (Temple of Yil the Great)

Note (i). The two lines, drawn in the convention usual for railways, which connect the Thousand-foot Dyke (c) and the right bank of the Min R. respectively with the Fish-Snout primary division-head (p), represent the positions of the temporary se-bok dams set up when the water is low for clearing the beds of the Nei Chiang (e) and the Wai Chiang (d), the former in January, the latter in November.

Note (ii). A steel cable, anchored at the point marked with an asterisk, guides rafts, floating treestrunks, etc., into the Phu-Yang Ho (m), avoiding the Tsou-Ma Ho (o).

Note (iii). On the hill above the Temple of the Second Prince (v) there is a small but beautiful Taoist temple to Lao Tzu. An inscription says:

>'The highest excellence does not lie in the highest place;
In changes and transformations let nothing be contrary to Nature.‘
that of the Flying Sands Spillway is adjusted to the elevation required for the optimum
supply of irrigation-water to the inner canal. When flood waters rise above this level,
they overflow and automatically regulate the flow in the Nei Chiang.a Immediately
after passing the city of Kuanhsien, the inner canal begins to give off its laterals and
sub-laterals, of which there are in all 526 and 2,200 respectively.b Some of them pass
through and beside the city of Chhengtu, and all ultimately find their way with the
Min River into the Yangtze (past Chiating).

a An additional spillway, the Jen-Tzu Thi,' takes off excess water just before the Li-Tui hill is
reached, and another (the Phing-Shui Tshao') has been long incorporated in the middle of the
Chin-Kang Thi (Diamond Dyke). This is the last to discharge as flood-level rises.

b Their total length is now well over 750 miles. At the Thai-Phu-Yu Tshu the Nei Chiang divides
into the Phu-Yang Ho on the left and the Tsoo-Ma Ho on the right; almost immediately, at the Ting
Kung Yu Tshu (named after a nineteenth-century engineer), the former gives off to the right the Po-
Thiao Ho. A similar tertiary division-head was introduced in the Tsoo-Ma Ho as recently as 1957,
generating a new feeder stream for the Chiang-An Ho. Formerly the Wei Chiang made no branch until
south of the Li-Tui hill (and this was still so when I first saw it), but now it gives off the Sha-Hei Tsang
Ho opposite the Erh Wang Miao temple, and this in due course feeds the Sha-Kou Ho and the He-Shih Ho.5

Each year there is a cycle of operations corresponding to the flow of water. From
December to March the river is at the low water stage, with an average flow of 200
cumecs (cf. pp. 221, 238), falling sometimes to 150 cumecs. From April onwards, when
planting starts, the flow increases, till at 585 cumecs the full requirements of the works
of both the outer canal (380 cumecs) and the inner one (305 cumecs)6 are satisfied. In
summer, i.e. June and July, high water is reached, with a maximum flow of 7,500
cumecs in the river as a whole, after which there is a slow decline till November, faster
thereafter. Throughout the centuries, the advice of Li Ping to clear out the beds and
keep the dykes and spillways low has been faithfully followed,b and if it has been
possible to preserve the system so closely as he left it, this is partly because the river is
not extremely silt-laden,c and partly because its annual fluctuations have permitted
inescent and effective maintenance. Every year, about mid-October, the annual
repairs begin. A long row of weighted wooden tripods (ma chha') is placed across the
outer feeder canal at its inlet (Fig. 892, pl.) and covered with bamboo matting plastered
with mud to form a cofferdam, thus diverting all the flow into the inner canal.6 The
bed of the outer canal is then excavated very actively to a predetermined depth, and
any necessary repairs to the division-heads are carried out with the aid of gabions (chu
lung). About mid-February, the stockade-dam is removed and re-erected at the
intake of the inner canal, so that all water flows to the right, and similar maintenance of
the inner system is effected. On the 5th of April, the ceremonial removal of the coffer-
dam marks the opening of the irrigation season and gives opportunity for a general
celebration, even in these days of slide-rules and plans for power-stations. What it
was like towards the end of the last century, under the Chhing dynasty, we may
glimpse from the following account:

Generally about the 1st April or, a little earlier, when the repairs are nearing completion,
the Water Inspector (Shui Li Fu) selects a lucky day and invites the Intendant of Circuit
(Lung Mao Tao) to come and open the river. If the latter reckons the day chosen to be an
unlucky one for himself, or for the people, he will choose a more auspicious one. The Water
Inspector then notifies the people by proclamation as to the day and time when the dam will
be opened.

a This is its minimum effective discharge, i.e. its 'duty', but it can and does carry 1,000 cumecs in July.
b Cited above.
c It has been
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repairs begin. A long row of weighted wooden tripods (ma chha') is placed across the
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a This is its minimum effective discharge, i.e. its 'duty', but it can and does carry 1,000 cumecs in July.
b Cited above.
c What it brings down is chiefly bed-load—current-rolled boulders and gravel. Cf. p. 231 above.
d A set of three iron bars, known as the no shih, each 10-12 ft. long and weighing about two-thirds
a ton, is fixed in the bed of the Nei Chiang just below the Feng-Lou Wo cliff as a guide for the
excavation depth; cf. Fig. 893 (pl.), from Lowdermilk (7). These bars are said to be those recovered by
Shih Chihion-Hsiang in the middle of the 16th century, and believed by him to be the originals laid
down by Li Ping or Li Erh-Lang.
e The opening now takes place rather earlier, in March. Pictures taken at the moment of breaching
the dam will be found in Phan En-Lin (1), p. 157, and Lowdermilk (7).
f Hutson (1). Photographs in Lowdermilk (7), pp. 644, 645, taken in 1943, add life to it.
The Intendant of Circuit is met on the day of his arrival by all the city officials, who conduct him over the works, which he officially inspects, eventually escorting him to the residence which has been prepared for him for the night. While there he often receives complaints from the people regarding the supply of water for their fields, and other cases of dispute. The Water Inspector then presents his superior officer with a feast ready prepared, which is generally declined with thanks. The local official then presents his offering, a feast ready prepared, which is received and eaten. All the expenses of receiving, entertaining, escorting, and so on, are borne by the local officials, amounting to about 600 taels. The Water Inspector giving only a few presents amounting to about 100 taels.

The morning after the arrival His Excellency the Intendant of Circuit rises early before dawn and proceeds to the Temple erected for the memory and worship of Li Erh-Lang, and called Erh Wang Miao. Here he burns incense and makes obeisance to the Gods. Afterwards he proceeds to the river-bank, just below where the barrier is erected, and where everything is in readiness for the opening ceremony. A long bamboo tracking-rope has been attached to a few of the tripods, and a band of strong coolies stands at the end of it. An altar has been erected where incense and candles are already burning, and a sacrificial pig and goat are already offered—then, just as the sun begins to show its golden tints over the horizon, the great man kneels down and worships the god of the river, the coolies give one long shout and a great man stands up, and after some solemn words he bows down before a statue of a deity. The Water Inspector then presents his superior officer with a feast ready prepared, which is generally received and eaten. All the expenses of receiving, entertaining, escorting, and so on, are borne by the local officials, amounting to about 600 taels.

In the dry season let the feet be covered, in flood let the level not pass the waist'. This is the ancient prescription, at low water the Nei Chiang should carry 60% of the flow, at high water 40%. According to the ancient prescription, at low water the Nei Chiang should carry 60% of the flow and the Wai Chiang 40%, while at flood time these proportions are reversed. The adjustment must be made by means of the dams, and of course during dredging periods the entire flow passes down one or the other channel completely.

The date of the classic Six-Character Teaching and the Eight-Character Rule, those other Kuanhsien couplets for memorisation, used down to our own time. There is a translation by H. A. Giles (4). Wang Ying-Lin's gift to the young may be dated c. 1270. Cf. Vol. 2, p. 21.

38. CIVIL ENGINEERING

DIG THE CHANNEL DEEP,
And keep the spillways low';
This Six-Character Teaching
Holds good for a thousand autumns.
Dredge out the river's stones
And pile them on the embankments,
Cut masonry to form 'fish mouths' (yü ts'ai),
Place in position the 'sheep-folds' (yang chian),
Arrange right the spillways (phai chih-hieh),
Maintain the overflow pipes in the small dams (lo huan),
Let the (bamboo) baskets (chu lang) be tightly woven,
Let the stones be packed firmly within them.
Divide (the waters) in the four-to-six proportion,
Standardise the levels of high and low water
By the marks made on the measuring-scales (shui hua ju);
And to obviate floods and all disasters
Year by year dredge out the bottom
Till the iron bars clearly appear.
Respect the ancient system
And do not lightly modify it.
Truly an epitome of the hydraulic art. Perhaps one need only add that the benefit which the Szechuanese received from the Kuanhsien works was not limited to irrigation and flood protection. A stone tablet of the Yuan period records that "water-wheels for hauling and grinding rice, and for spinning and weaving machinery, to the number of tens of thousands, were established along the canals (in the plain of Chihêngtu), and operated throughout the four seasons." Thus the economic life of a whole Chinese province at a time contemporary with Villard de Honnecourt and Roger Bacon depended on those noble works of civil engineering among the misty mountains of western Szechuan.

We cannot leave Kuanhsien without alluding to a subject which in some sense oversteps the boundaries of engineering as such. The Chinese were never content to regard notable works of great benefit to the people from a purely utilitarian point of view. With their characteristic ability to raise the highest secular to the level of the religious, they built upon the top of the 'Separated Hill' a magnificent temple, the Fu Lung Kuan, to commemorate Li Ping's heroic virtue; and further back, in a scarcely less beautiful situation, the wooded hillside downstream from the suspension bridge, was the magnificent temple of Li Ping's temple before his impassive statue (Fig. 896, pl.), tended by a learned Taoist, but in its second court were numerous models (cf. Fig. 888, pl.) of temples and mosques. A stele with an inscription by one of his assistants, Chao Tzu-Yuan, commemorates his benevolent administration. A dozen reservoirs with dams in the hills, more than forty sluices, and a network of dyked canals lined with beautiful trees still remain in function testifying to the enlightened rule of Hsien-Yang Wang, as may be seen in the interesting monograph of Vissiere. He was sent to Yunnan as governor in 1274, where he greatly exercised himself to raise the cultural level of the backward population, erecting impartially Confucian temples and Muslim mosques. As one of his assistants, Chao Tsu-Yuan, commemorates his benevolent administration. A dozen reservoirs with dams in the hills, more than forty sluices, and a network of dyked canals lined with beautiful trees still remain in function testifying to the enlightened rule of Hsien-Yang Wang. The second system of works selected for mention here is the Pai-Shih Yai reservoirs in Li Ping's valley. All this was achieved by the Yuan governor of the province, a Persian or Arab by origin, Sai-Tien-Chhih Shan-Sa-Ting (Sa'id Ajall) also called Wu-Ma-La (Umar), in collaboration with a local engineer Chang Li-Tao, and building upon minor works previously carried out by the former indigenous and independent Thai dynasty of Nan Chao.

Sa'id Ajall attached himself to Chinghiz Khan during the Mongol expeditions in the west, and in due course attained to many positions of importance under the Yuan régime, as may be seen in the interesting monograph of Vissiere. He was sent to Yunnan as governor in 1274, where he greatly exercised himself to raise the cultural level of the backward population, erecting impartially Confucian temples and Muslim mosques. As one of his assistants, Chao Tsu-Yuan, commemorates his benevolent administration. A dozen reservoirs with dams in the hills, more than forty sluices, and a network of dyked canals lined with beautiful trees still remain in function testifying to the enlightened rule of Hsien-Yang Wang. The second system of works selected for mention here is the Pai-Shih Yai reservoir system, a contour canal which formerly watered a great space of fertile land (enough for more than a thousand farms) between the mountains and the desert near Shantan in Kansu province. As one travels up the Old Silk Road from the Kansu province towards the end of the second system of works selected for mention here is the Pai-Shih Yai reservoirs (Yuan) and the Shantan system (Ming) as a postscript to the story of Kuanhsien, we shall mention two other projects which, though not so spectacular, greatly benefited smaller circumscribed pieces of territory. One is a reservoir system; the other was a derived irrigation canal issuing from its valley of origin through a saddle in the mountains. First let us consider the irrigation works of the Kunming plain in Yunnan. This plain or basin surrounded by spilling uplands upon the provincial capital and the Kunming Lake, with its western hills crowned with woods and temples. The essential problems here were first the assurance of free passage for the waters of the lake, which were otherwise liable to flood large areas, and secondly the formation of reservoirs and artificial canals so as to distribute as widely as possible the waters of the six small rivers which flow down into the lake. All this was achieved by the Yuan governor of the province, a Persian or Arab by origin, Sai-Tien-Chhih Shan-Sa-Ting (Sa'id Ajall) also called Wu-Ma-La (Umar), in collaboration with a local engineer Chang Li-Tao, and building upon minor works previously carried out by the former indigenous and independent Thai dynasty of Nan Chao.

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[2] This is not in doubt, but a certain amount of indigenous Szechuanese semi-legendary material exists which suggests that there had been attempts earlier than Li Ping's to harness the Min River, notably by Khai Ming, who lived at some time during the Warring States period. Torrance (1) has tried to elucidate this question, but it needs further study. Could it be another case of Xu and Yu? A fine photograph of Li Ping's temple, taken from the Phoenix Nest Cliff above the Cornucopia Channel, will be found in Phan En-Lin (1), p. 160.
[3] Other photographs are in Phan En-Lin (1), pp. 178, 159. This is first recorded in + 2404, but in its present form dates from + 1271 to + 1285 (Shih Wu Chi Yuan, ch. 7, p. 235). How late the admirable system of votive shrines and temples continued may be seen from the fact that Erh Wang Mao contains a chapel to Ting Fao-Chih, the great and good Governor of Szechuan from + 1876 to + 1896. On my second visit in + 1948 all the temples had been excellently repaired and repainted by the government. Material incense, it is true, was lacking, but it will be found necessary, even under socialism, if only to keep down the smell of bats.
[4] Since 1950 modern steel sluice-gates have been installed at the openings of all the main derivative canals.

28. HYDRAULICS

(iii) The Kunming reservoirs (Yuan) and the Shantan system (Ming)

As a postscript to the story of Kuanhsien, we shall mention two other projects which, though not so spectacular, greatly benefited smaller circumscribed pieces of territory. One is a reservoir system; the other was a derived irrigation canal issuing from its valley of origin through a saddle in the mountains. First let us consider the irrigation works of the Kunming plain in Yunnan. This plain or basin surrounded by spilling uplands upon the provincial capital and the Kunming Lake, with its western hills crowned with woods and temples. The essential problems here were first the assurance of free passage for the waters of the lake, which were otherwise liable to flood large areas, and secondly the formation of reservoirs and artificial canals so as to distribute as widely as possible the waters of the six small rivers which flow down into the lake. All this was achieved by the Yuan governor of the province, a Persian or Arab by origin, Sai-Tien-Chhih Shan-Sa-Ting (Sa'id Ajall) also called Wu-Ma-La (Umar), in collaboration with a local engineer Chang Li-Tao, and building upon minor works previously carried out by the former indigenous and independent Thai dynasty of Nan Chao.

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[4] As in private duty bound, for these works were among our first impressions of China when I arrived there towards the end of 1942.


[7] His biography is in Yuan Shih, ch. 155. He is not to be confused with another Shan-Su (Shama Al-Din), the mathematician and geographer, who flourished in the following century, and whose biography is in Yuan Shih, ch. 150.

[8] The Confucian temple at Chheng-kung, south-east of Kunming, a place of great beauty which housed the Institute of Statistics during the second world war, was built by him. Cf. Vol. 1, Fig. 37.


[10] Cf. Beaton (1), p. 3, for a photograph. Prof. Thang Phet-Sung and I have cycled and motored for many miles along these avenues, and bathed in such reservoirs as that near the village of Tapuchi. The system of canals attained its present form substantially by + 1279.

[11] His tomb also still exists in open country south-east of Kunming, and the temple dedicated to him is now in the grounds of the University of Yunnan.
Lanchow, going north-westwards, one has always upon one's right the desert (and sometimes what remains of the Wall), while to the left is the glittering snow-capped chain of the Chhilen Shan (or Nan Shan) mountains. For 200 miles or more in each direction from Shantan, the road passes through steppe country or desert scrub, crossing a great number of watercourses which take their origin in the mountains and run down to lose themselves in the sands of the Gobi. Water and its retention must have been the great problem here for many centuries. Most of what we know about the Pai-Shih Yai Chhü1 is summarised upon a commemorative stele4 erected at Shantan in +1503 by a (Taoist) hermit, Wang Chhin-Thieh.5 The project was a bold one, for it tapped the Ta-Thung Ho River at a precipitous place, the White Rock Cliff, more than 200 ft. to the south-west of the Shantan plain. To understand this, one must realise that the Ta-Thung Ho flows in the deep valley behind the first range of the Chhilen Shan, running south-eastwards parallel with the Old Silk Road, to join the Yellow River above Lanchow. The division-head must thus have been constructed at an altitude of some 13,500 ft., for a pass of this height had to be crossed by the canal before it could descend to the Shantan plain (itself mostly about 6,000 ft.), and the canal must have followed the high contour for a long way before beginning its descent.6 When the works were first constructed we do not know, but by the end of the -15th century they had silted up and ceased to function.7

When asked by one of the provincial officials, Li Kho,5 to take charge of radical repairs; the engineer named Liu Chen4 was then asked by one of the provincial officials, Li Kho,5 to take charge of radical repairs; workers were collected from an area of 1,200 li around, and began operations encouraged by drumming and dancing. In three years, not without some difficulties, everything was perfectly restored. Mr Wang the hermit ended his inscription with a poem:

The White Cliff towers a thousand feet high,
For a hundred years the desert lay waste,
But then came a lover of the people
Calling for a mighty engineer,
And (Li) Ping and Yu (the Great) lived again,
Building new dams, new dykes.
The rolling waters, how everyone longingly wished for them!
Drawn forth in curving course, like the Han river, they came.
And the men of the three Armies could settle on the plain, and plough.

But in after years, during the disturbances of the last century, the works again fell into disrepair, and now there is little trace of them in the neighbourhood of Shantan. The upper valley of the Ta-Thung Ho is only wild mountain pasture, rarely visited save by shepherds and perhaps an occasional geologist, but it would indeed be interesting to seek there for the traces, which must still remain, of the work of Liu Chen and his predecessors.

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**28. CIVIL ENGINEERING**

The Ling Chhü1 (Magic Canal)8 was a work of quite different character, meant to serve, not primarily irrigation, but the need for freight communication across one of the principal ranges of high mountainous country which separate the north and centre from the south. It connected two rivers in Kuangsi, one flowing northwards and one southwards, so that transport was made possible between the Yangtze, the Tunghling Lake, and the West River flowing down to Canton.9

In the Shih Chi there is no mention of the Ling Chhü1 by name, either in the chapter on waterways or elsewhere. But there are accounts of its building, which show that its primary purpose was to keep up a flow of water-borne supplies to the armies which in -219 were sent south for the conquest of the people of Yüeh. It may also have served for the transport of a fleet of war-boats.10 The *Shih Chi* says:11

(Chhin Shih Huang Ti) sent the Commanders (Chao) Tho1 and Thu Chhi1 to lead forces of fighting-men on boats with deck-castles (liou chhuon)12 to the south to conquer the countries of the hundred tribes of Yüeh. He also ordered the Superintendent (Shih) Lu1 to cut a canal so that supplies of grain could be sent forward far into the region of Yüeh.

This may not be the oldest reference to the canal, for the *Huai Nan Tsu* book has a page or two on the First Emperor's campaigns, and gives this statement about the engineer Shih Lu in almost the same words.5 They go back, then, to -120, just a century after the work itself. We also have a passage in the biography of Yen Chu,6 an official concerned with grain transport who flourished about -135. In one of his memorials he reported that 'elderly gentlemen said' that the Magic Canal had been dug by Shih Lu in the first emperor's time.8 Thus the date of the original project may be considered as firmly established.

There are also passages in the annals of Chhin Shih Huang Ti which may refer to it indirectly.8 In the 32nd year of the first emperor, i.e. -215:

He had an inscription carved on the 'gates' of Ch Hein-Shih? (Stone Pillar Mountain), recording how he had broken through (all) walls and defences (of feudal fortresses), and had pushed lines of communication through (all) obstacles and barriers (hung thi fang).13

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a Such was the significance of its name that came down through the ages, and quite rightly so (cf. p. 379), but according to Fang Chhi (3), the original name of the Li River was the Ling, and this was the reason for the appellation in the first place.

b And also, of course, via the Hai, Kou and the Hung Kou (cf. pp. 271, 269), with Kuanchung and the Yellow River valley.

c This it certainly did during the later campaigns of the -1st and +1st centuries, see immediately below, p. 303.

d Ch. 122, p. 106, tr. Aurousseau (2); Watson (1), vol. 2, p. 232, mod. auth. This text is part of a memorial by Yen An directed against Han Wu Ti's aggressive foreign policy. The statement is repeated in Yen An's biography (Chhin Han Shu, ch. 64, p. 30).

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**28. HYDRAULICS**

(iv) The 'Magic Transport Canal' (Chhin and Thang)

The Ling Chhü1 (Magic Canal)8 was a work of quite different character, meant to serve, not primarily irrigation, but the need for freight communication across one of the principal ranges of high mountainous country which separate the north and centre from the south. It connected two rivers in Kuangsi, one flowing northwards and one southwards, so that transport was made possible between the Yangtze, the Tunghling Lake, and the West River flowing down to Canton.9

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Part of the text, as recorded by Ssuma Chhien, ran thus:

The Sovereign Emperor (Huang Ti) ... has overturned and destroyed outer walls and castle keeps, he has opened passages for waterways through obstacles (chüeh thung chhuan fang'), he has beaten down and done away with all difficulties and barriers (tüeh chi liang'), and the face of the earth being well regulated (t'ish chhing), the black-haired people are no longer overwhelmed with corvee labour (shu wu yao) ... 

Most of our information about the Magic Canal is to be found collected in the eighteenth-century commentaries of Chhian Tsu-Wang and Chao I-Chhing on the Shui Ching Chu (Commentary on the Waterways Classic). The text of the Shui Ching itself (perhaps + 3rd century) does not mention it, but Li Tao-Yuan's + 5th-century commentary says that at the headwaters of the Li (Li T'u) River (flowing south) there is a pass (yu huan), and speaks of a Ling Chhi Shui Khou (Magic Stream Water Opening) which must be the canal.

To understand what kind of a work it was (and still is) we must cast a glance at Figs. 898 and 899. The northward-flowing river is the Hsiang, which takes its rise in the high ground of Hai-yang Shan and finds its way down to the plains of Hunan, passing Hengyang and Changsha on its way to the Tungthing Lake and the Yangtze. The southward-flowing one is the Li, which rises in the hills called Yiieh-chheng Ling and joins another stream to form the Kuei Chiang, that particularly beautiful river known to all who have visited Kweit'in city with its landscape of karst pinnacles, a tributary of the West River quickly leading down to Canton. Between the oppositely-facing streams of Hsiang and Li there is a saddle in the hills which gave Shih Lu the opportunity for the first of all contour transport canals. The part of the Ling Chhü which justifies this designation was called the Nan Chhü and branched off from the Hsiang River to run along a suitable level or slightly falling contour for about 3 miles till it met the upper waters of the Li River. These themselves had to be canalised for another 17½ miles downstream as far as the junction with the Kuei Chiang. Meanwhile in the other valley a 1½-mile lateral transport canal (the Pei Chhü) was dug at a more even gradient than that of the untrained Hsiang. How the works were constructed may be appreciated from Fig. 899. A division-head called a 'spade-snout' (hua tsui), reminiscent of those used at Kuanhsien, was built in the middle of the Hsiang and backed by two spillways (Ta Thien-Phing and Hsiao Thien-Phing) discharging into

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a The only photographs at all adequate are those in Wu Lien-Ts (1, 1), pp. 118 ff.

b Places of vivid memory to me, for in 1944 during the second world war I crossed the Hsiang to the west by the last train over the Hengyang railway bridge before it was blown up to slow the Japanese advance. For an eye-witness account of the canal in 1911 see Lapicque (1).

c The greater and lesser 'balancers' or 'level-equalisers'; cf. Vol. 4, pt. 1, p. 24. Length in all 1,443 ft., height of retaining wall of dam c. 8-10 ft. Masonry of 'fish-scale' character.

d Cf. Vol. 1, Fig. 4.

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The greater and lesser 'balancers' or 'level-equalisers'; cf. Vol. 4, pt. 1, p. 24. Length in all 1,443 ft., height of retaining wall of dam c. 8-10 ft. Masonry of 'fish-scale' character.
the river's old bed. The embankment or retaining-wall of the canal was provided with several further spillways as it wandered through the town of Hsing-an, and was crossed by several bridges. In this way a pool was formed on the same level as the smaller of the two, most of the water in the canal (some 3 ft. deep and 15 ft. wide) was derived from it, and the local saying was that three-tenths of the Hsiang water went into the southern or connecting canal (Nan Chhii) while seven-tenths flowed along the northern lateral one (Pei Chhii). All this was in working order, and much used, during the Early Han period, especially for naval purposes between 140 and 87 (with a peak traffic about 111) when Han Wu Ti was campaigning in the south for the final reduction of Yüeh. Another heavy duty period occurred about 40 in connection with the important expedition against Annam, and it is recorded that on this occasion the commander-in-chief Ma Yuan extended the canalisation of the Hsiang; this must mean that he improved its navigation for some distance downstream of the lower entrance of the Pei Chhii.

The most extensive and classical account that we have found is given by Chou Chhü-Fei, in his Ling Wai Tai Ta (Information on What is Beyond the Passes) of +1178. He speaks as follows:

The upper reaches of the Hsiang River flow out into Hunan in the north, and the Jung River (now called the Kuei Chhii) comes south into Kuangsi (and Kuangtung). At the watershed (of these rivers) the highest part lies in the Hsing-an-hien district of the prefecture of Chingchiang.

In olden times when (Chhin) Shih Huang Ti was annexing the frontiers of the Five Ranges in the South, Shih Lu (was sent to) cut a canal to connect a (small) tributary of the Li River with the upper reaches of the Hsiang River. (This canal) traverses Hsing-an district and falls into the Jung River to the south. It was intended to facilitate the transport of army rations.

The situation was that water from the north was flowing southwards (in the Li), but the boats from the north came up against the barrier of the mountain. Shih Lu's method of cutting the canal was as follows. In the upper reaches of the Hsiang River, in the midst of gravel banks and sunken rocks, he caused stones to be piled up layer upon layer making a division-head (au sax), and so on. Thus the water of the Hsiang River was divided into two (branches) by means of these sharp-pointed current-clearing structures. (Then), following round the mountain (contours), he built an embankment (shi) so as to make a smooth-gilding canal, along which the water was skillfully induced to run for 10 li, after which it reached more level ground. From there onwards, the canal was so dug that it continued to wind round the curves of the mountain-side, the whole distance amounting to 60 li (about 20 miles). Thus it came to the Jung River, and so to all the south. This is what is now known as the Kuei Shui.

The reason why the Li River is so called is because it is a stream separate (bi) from the Hsiang (and yet connected with it)—there is the Hsiang and there is the Li.

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\* Pei-Lai Shih, I Shih Thien-Phing, and another in Hsing-an town itself.

\* Including the modern railway bridge on the line between Hsing-yung and Kweilin. I passed over this several times during the war, but unfortunately at that time I had no idea of the interest of the site and did not look out for the crossing. The railway also follows the canal between the hills.

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28. HYDRAULICS

down the northern lateral one (Pei Chhii). All this was in working order, and much used, during the Early Han period, especially for naval purposes between 140 and 87 (with a peak traffic about 111) when Han Wu Ti was campaigning in the south for the final reduction of Yüeh. Another heavy duty period occurred about 40 in connection with the important expedition against Annam, and it is recorded that on this occasion the commander-in-chief Ma Yuan extended the canalisation of the Hsiang; this must mean that he improved its navigation for some distance downstream of the lower entrance of the Pei Chhii.

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Passengers travelling along at certain points are sometimes scared out of their wits, for about 2 li from the intake where the "spade-scuttle" divides the waters and makes one branch enter the embanked canal, there is another spillway (hsih shui shou) which lets off excess water. Without this spillway, the raging force of the spring freshets could damage the retaining-wall and the water would never reach the south. But by its aid, the violence of the water is abated, the embankment is unbroken, and the water in the canal flows smoothly on. Thus the extra water drawn from the Hsiang penetrates into the Jung. This may really be called an ingenious device.

The canal waters meander through Hsing-an district, and (accordingly) the people rely on it for irrigating their fields. The depth of the canal is not (more than) a few feet, and the breadth may be about 20 ft.; it is adequate to float a vessel of 1,000 hu (bushels of cargo).\(^1\)

In the canal there are 36 lock gates (tou men). As each vessel enters one of these lock gates, (the people) immediately restore it (tsou fu cha chih) to its closed position and wait while water accumulates (within the lock), so that by this means the ship gradually progresses. In such a way they are able to follow the mountainside and move upwards.

On the descent, it is like water flowing down the stepped groove of a roof, and thus there is communication for the boats between north and south. I myself have seen (I am happy to say) the historic traces of the work of (Shih) Lu.

The cruelty and suspicion of (Chhin) Shih Huang (Ti) I venture to deplore. But his despotic authority had power to trap the waters permanently, so that vessels could never travel (overland). For ten thousand generations (people) have relied upon (his canal). But the (merit) belongs not only to (Chhin) Shih Huang (Ti)—(Shih) Lu was also a hero—and (on account of all these things) it is called the 'Magic Canal'.

This eye-witness account, with its clear description of pound-locks in the late +1st century,\(^2\) is of great interest, and necessarily raises the question of the time of introduction of gates into the Ling Chhiu system. Chou Chhiu-Fei speaks as though locks of one kind or another had been there since the Chhin, but this can hardly be taken for granted. Although we shall have to return later on to the history of the development of sluice and lock gates in China, it will be best to consider the matter first here while the Ling Chhiu's topography is fresh in the mind. One can have no difficulty in attributing the spillways to an engineer so ingenious as Shih Lu must have been, a younger contemporary, perhaps, of Li Ping, and certainly of his son, who had used them with so much effect at Kuanhsien; there is moreover the close similarity of the division-head 'snout' in the two cases. But whether Shih Lu installed any gates remains uncertain. Evidence will be presented later\(^3\) which shows that sluice-gates were a familiar technique in the - 1st century, and references of that time make clear that the Hung Kou of Han times\(^4\) had flash-lock gates, especially at the junction with the Yellow River near Jungyang. If so, the Hung Kou of Warring States and Chhin times may have had them too, perhaps indeed it could hardly have worked without them, and in that case they may have been well known to Shih Lu. Nevertheless there is no positive textual or other evidence that he installed them in the Ling Chhiu or its approaches.

If he did not, then one has to picture southbound barges being towed up the trained Hsiang River by gangs of trackers,\(^5\) into the Pei Chhiu section, and so into the pool by the great spillway. Having passed the division-head they would reverse into the canal where there was no rapid current, for the level course had been made as winding as possible precisely in order to slow it. No reverse was needed at the other end, where the boats would glide fairly fast down the trained Li. The first information that we have of gates comes from a period still relatively early, the Thang, and concerns the important restoration of the canal carried out in +825 by Li Pho.\(^6\) In the Shui Ching Chu we read:  

During the Thang dynasty, at the beginning of the Pao-Li reign-period (the banks of the canal were collapsed and broken so that boats could not get through. The Inspector-General Li Pho therefore caused stones to be piled up in course to make a dyke like a 'spade snout' to split and divide (the Hsiang River) into two streams. In each stream there were set up stone (abutments for) flash-lock gates (lit. dipping gates, tou men), with one keeper in charge (of each), who let people freely open and shut (as required). When the Li River (gate, or gates, was, or were) open, (the water) all flowed into the Kuei Chiang (to the south); when the (gate or gates, was, or were) closed on the Kuei Chiang side, then all (the water) returned to the Hsiang River (northwards). And moreover at the Hsiang River he cut a 'dividing-water canal' (fen chui chih) 35 paces long (175 ft.), in order to facilitate the movement of the ships.

Taking this last improvement first, the most obvious suggestion is that Li Pho isolated the division-head in the form of an island quay, making a canal behind it along the top of the dam so that it was no longer necessary for the boats to reverse. But the flash-locks were no less important. From other sources we know that there were 18 of them, first set up in rough construction of wood,\(^7\) but then greatly strengthened by Yu Meng-Wei\(^8\) in the further improvements which he carried out\(^8\) in +668. Their exact positions we do not know, but from the text given it seems sure that at least one of them was at the Li end of the canal, and at least one other at the Hsian end. There was more need for them, however, on the graded approaches rather than on the level canal, so it is probable that the majority were erected actually in the course of the Li, the Pei Chhiu section parallel with the Hsiang, and in the Hsiang's course lower down as well. From the +9th century at latest onward, then, barges ascending on either side were hauled through the flash-locks, probably with winches, and towed by a much reduced company of trackers on the relatively level intermediate sections.

Then comes the information that the number of gates was no longer 18 but 36. This is still the approximate number today, and after the account of Chou Chhiu-Fei in  

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\(^1\) I.e. just over 35 tons; cf. pp. 330 and 645.  
\(^2\) Contrast the date of the earliest pound-locks in a European transport canal which surmounted a gradient, now established as those of the Steinkitz waterway, built c. +1395 (Silempton, 4). Cf. pp. 352 ff. below.  
\(^3\) Cf. pp. 244 ff. below.  
\(^4\) Cf. pp. 270, 281 above.  
\(^5\) As the Chou Li said, 'Wherever there is a stream in a valley there will be a place for a towpath' (p. 255).  
\(^6\) Ch. 38, p. 163, tr. auct. The passage comes from Thai-Phung Huan Yu Chi (c. +680), ch. 162, p. 88.  
\(^7\) Feng Chi (5), p. 44.  
\(^8\) Yu Meng-Wei also rebuilt the division-head in better masonry, and left an account of his work with the title Hsii Chhiu Chi. It is preserved in Chhiian Thang Wên, ch. 104, pp. 102 ff. This monograph may be compared with others on particular engineering operations mentioned on pp. 173 and 253.
+ 1758 the same number is repeated in mentions of + 1396 and + 1485 when again the stone abutments were well rebuilt. The doubling of numbers in this way is always strongly indicative of the change from flash-locks to pound-locks, for there was everywhere a natural tendency to make use of facilities already installed, and use each existing stanch as one of the pair of pound-lock gates. The account of a later traveller, Kuang Lu, is also worthy of notice. Writing about +1285, he said: 3

On the Ling Chhii from north to south there are 32 lock-gates (tsou-mei b), i.e. from the Li to the Thung-Ku Shui. 4 From east to west, entering Yung-fu, there are 6. In the winter (the canal) dries up and one cannot pass through. When I made the passage through these lock-gates there was plenty of water, and under the moonlight they looked like steps leading up to some high platform, or like tiers of walls and terraces coming down one behind another from the sky.

One could hardly have a better description of the pound-locks of a summit canal—for into such a waterway had the contour Ling Chhii been converted when pound-locks were installed in its approaches. On the evidence as a whole it seems clear that the + 10th or + 11th centuries are the most probable periods at which we should place the introduction of pound-locks in the Ling Chhii system; and as we shall see later on, this dating fits the rest of the Chinese evidence extremely well.

The significance of the Ling Chhii Canal as a link in a chain of communications altogether extraordinary for the — 3rd century in any part of the world should not be overlooked. By the navigation of the lower Yellow River, the Hung Kou and Han Kou Canals, the Yangtze, the Hsiang River leading south from the Tungthing Lake, the Ling Chhii Canal and the West River, the first Han emperor in — 200 found himself in possession of a single trunk waterway extending from the 40th to the 22nd parallel of latitude, that is to say a distance of some 1,250 miles in a direct line, and doubtless more than double that as the vessels sailed. Few if any other ancient civilisations could show the like. And lastly the Ling Chhii resembles Kuanhsien in that though a work of the — 3rd century it has been repaired and set in order once again in our own time, and continues to carry out heavy duties. Few if any other civilisations could demonstrate a work of hydraulic art in continuous use for 2,185 years.

(v) The Grand Canal (Sui and Yuan)

Our notes on the Grand Canal as a whole (the ‘Traffic River’, Yün Ho, Fig. 899) can be all the more brief because several of its precursor or component sections have already been mentioned. The work of combining these together was done by the Sui

1 Fang Chi (2), pp. 44 ff.
2 Chhii Yu, ch. 2, p. 21 B, tr. auct. What Kuang Lu says about the numbers of the gates agrees with the general conclusion that there were many more locks on the approaches than in the level canal itself, in which it seems to have found three.

The exact date may well be + 585, for we know from Sung Shih, ch. 97, pp. 23, b, 24a, that in that year general repairs were carried out by Li Shi-hu-Chung, who, among other things, Chhii-pi (2), which might mean ‘doubled the openings’.

1 Or Yün Liang Ho (‘Tribute Traffic River’).
2 進雲
3 進門
5 鉤岩水
6 永商
7 逐河
8 持龍河
9 重雲
10 逐龍河
12 坂
20-2

28. HYDRAULICS

dynasty (+ 581 to + 618) when the need to link the capital at Loyang with the key economic area of the lower Yangtze valley became imperative. In the last decades of the + 13th century, under the Yuan emperors, the same need continued, but as the capital was now Peking, a vast remodelling of the canal was carried out, so that it finally formed a continuous waterway following the 11th meridian in an S-shaped course from Hangchow in the south to the furthest northern parts of the North China plain. In order to visualise this major work in its final stages, it is only necessary to remember that it covered 10° of latitude, and would be comparable with a broad canal extending from New York to Florida. Its total length attained nearly 1,100 miles. Its summit, reached when skirting the mountains of Shantung, was some 138 ft. above sea level.

The oldest pioneer section was the Hung Kou, 1 later known as the Pien Chhii 2 Canal, which connected the Yellow River with the Huaii valley. As we have seen, 3 this was at least as old as the — 4th century. Besides civilian transport it saw naval activities from time to time, as in + 280 when a famous fleet and army passed along it in the campaign of Wang Chhün against the State of Wu, and again in + 417 when Liu Yü 4 conquered Yao Hsing 5 of the Later Chhin. 6 But in the course of ages it had silted up so much that about + 600 the chief engineer of the Sui, Yüwên Khai, 7 decided upon an entirely different alignment 8 for the new canal (the Thung Chi Chhün). 9 Broadly speaking, this ran parallel with the Hung Kou but south-west of it after diverging at Chhen-liu (g); 10 passing not Huichow (10) but Suchow (120), and joining the Huaii River directly, west of the Hung-tse Lake, without making use of the Sui 6 River. Its length was some 630 miles. In the north-west, between Chhen-liu, near Khäifeng, and the junction with the Yellow River at Suu-shii 11 just downstream from the entry of the Lo 12 River from Loyang, the course of the Sui Canal was much the same as that of the

1 Much has of course been written on the Grand Canal; for Chinese books, the bibliographies in papers mentioned below should be consulted. The best survey is no doubt that of Chu Hsieh (1), but it reached us too late to be of much assistance. The chief work in a European language is the historical monograph of Gandar (1), but though copious it is confusedly written, and it concentrates almost entirely on the new canal (the Thung Chi Chhün). 1 Broadly speaking, this ran parallel with the Hung Kou but south-west of it after diverging at Chhen-liu (g); 10 passing not Huichow (10) but Suchow (120), and joining the Huaii River directly, west of the Hung-tse Lake, without making use of the Sui 6 River. Its length was some 630 miles. In the north-west, between Chhen-liu, near Khäifeng, and the junction with the Yellow River at Suu-shii 11 just downstream from the entry of the Lo 12 River from Loyang, the course of the Sui Canal was much the same as that of the
Hun Kuo (the old Pien Chhi), if not identical with it, but special works were now erected to protect its opening. In +587 another eminent engineer of the Sui, Liang Jui, built on the south bank of the Yellow River a massive westward continuation of the 'Metal Dyke' (Chin Thi, cf. p. 234 above), which was named in his honour the Liang Kung Yen; it contained lock-gates for regulating the water levels, and double slipways for hauling boats over when the differences were too great for flash-locker erected to protect its opening. In +587 another eminent engineer of the 'Metal Dyke' (Chin Kung Yen;3 it contained lock-gates for regulating the water levels, and double operation. b The main project, the new Pien Chhi Canal, was completed in +605, more than five million men and women having been mobilised under Ma Shu-Mou4 to carry out the excavations. A detailed account of the work has come down to us in the anonymous Khai Ho Chi (Record of the Opening of the Canal).4 An imperial road was constructed along its banks, which were planted everywhere with trees.

Throughout the Thang and the Sung (+7th to +13th centuries) the New Pien, the 'Grand Canal' of the Sui, continued in active, indeed heavy, use. One can penetrate behind the dry statistics of the dynastic histories to the realities of canal life in these times by reading some of the diaries and memoirs, notably those of foreigners such as the Japanese monk Ennin. In +638 he journeyed from the coast to Yangchow on one of the lateral feeder canals from the numerous salt works, which had been built or repaired from the San Kuo to the Sui. On a canal which was straight as far as the eye one could see (like the Bedford Level in the East Anglian fen country), a train of forty boats, many lashed two or three abreast, was pulled slowly but efficiently by two water buffaloes. Once a bank had caved in but Ennin's party got through by digging, and when they came near the Grand Canal, the salt boats, three to five lashed abreast, followed one after the other the continuously mile after mile. In the following year he passed up the Grand Canal to the Huai River, and then towards the end of his stay, in +845, journeyed down the Pien Chhi (the New Pien) from Khaifeng (Chhen-liu) to Yangchow. This took him nine days.

The engineers of the Thang introduced some modifications of the system but no fundamental change. In +689 a branch (the Chan Chhi) was made, striking off north-eastwards from Chhen-liu to connect the trunk waterway with Yenchow in Shantung. Then between +734 and +737 Chhi Huan1 constructed another new canal (the Kuang Chi Chhi), which skirted the north shore of the Hung-tse Lake and brought the traffic from the New Pien Canal directly to Huai-yin, thus short-circuiting the dangerous rapids of the Huai. At the same time he also made a short cut near Yangchow (the I Lou Ho) which saved some 40 li.6 But this was on the more southern section between the Huai River and the Yangtze.

As we saw at an earlier stage, the ancient Han Kuo, first built in the early - 5th century, ran between these points. But its original route was circuitous, connecting several lakes, and an important straightening had been made about +350 by Chhen Min. His Shan-yang Yun-Tao (Shanyang Transport Canal) was restored by the first Sui emperor in +687 as the Shanyang Tu, and then incorporated in the whole system in +605. This is known to have been 40 paces (200 ft.) wide, and bordered with trees like the more north-western sections. Its length was about 120 miles.

The portion of the Grand Canal south of the Yangtze was not an entirely new enterprise of the Sui, because there had been earlier artificial waterways in the region (p. 272), but it took a new course, completed in +610. Eight hundred li in length, it skirted the eastern side of the Thai-hu Lake, and put Hangchow in direct communication with the north, thus enabling the supplies and products of the south-eastern coastal regions to flow to the capital. In order to assure traffic between the Yellow River and Chhang-an, Yuwen Khoi restored the old canal in Shensi which Chêng Tang-Shih and Hâi Po had dug in -133, and renamed it the Kuang Thung Chhi.

Here we may pause for a moment to take notice of the rather intensive development of urban waterways in the Venetian style in these cities, so useful as the capillaries of the traffic system. Many of these may still be seen in Suchow (Chiangsu) today, encircled as it is by the Grand Canal (cf. Fig. 772, pl.), and one can find the remains of...
an elaborate network in Hangchow. Of the docks at Chhang-an (Sian) and the Peking terminal we make mention elsewhere (pp. 273, 313, 355).

The portion of the Canal north of the Huang Ho, rather more than 620 miles in length, was truly a new enterprise of the Sui. It took advantage of a short river descending southwards from the Shansi mountains and falling into the left of the Huang Ho a little east of Sau-shui, namely the Chhin; rendering the lower reaches of this navigable, it struck across country by a short branch to join the head waters of the canalised Wei River which flowed north-eastwards in a long course to the neighbourhood of Tientsin. Water from the Ta Tan and Chhi Rivers also helped. This route, finished in +608, was called the Yung Chi Chhii. At Ta-ming (123) it joined the line of the later course of the Yellow River, and at Lin-chhing (124) the line of the present Grand Canal. Thus the new waterway connected the region of Peking, no less than that of Hangchow, with the capital at Chhang-an (Sian). The immense Y-shaped system so formed extended for approximately 1,560 miles—a distance equivalent to 24 degrees of latitude, and resembling that from Stockholm to Syracuse, or Greece to Greenwich. In Isidore of Seville’s Europe one does not find the like.

During the Thang and Sung dynasties the highest officers of state occupied themselves with the engineering problems involved in conserving the Pien Canal as a great artery of tax-grain transport from south to north-west, e.g. the erection and management of lock-gates at certain points, especially the junctions of the canal with the two great rivers which it crossed. Phei Yao-Chhing (681 to +743) and Liu Yen (715 to +782) were two less than such men, during the administration of the former, about +735, the canal carried annually no less than 165,000 tons of grain. Granaries were established at many places along the route, so that the grain could be stored in good conditions if flood or unduly low water hindered its onward carriage. In +733, as we have seen (p. 278), an arrangement was made whereby the grain was portaged 6 miles overland to avoid the rocks and islands in the Huang Ho at the San-men gorge, which made navigation so dangerous, and granaries were built at each.

* Charts of 1800 and 1900 are in the British Museum, catalogued as Maps Tab. 1, d, 3 & 4. Cf. Moule (13), fig. 1. Unique here was a tidal basin, connecting with the Chhiang-chuen estuary and closed by lock-gates (hen shai chia); this filled at high tide, and after a few hours wait to let the silt settle the water was thence through part of the canal system back to the sea in the north-west (cf. Moule (13), p. 21, earlier version, p. 116). On the origins and development of the famous West Lake at Hangchow, see Chang Hsiang-Chao (4, 5).

* Today (1953) a large scheme has just been completed for bringing the waters of the Yellow River from higher upstream to enter the upper reaches of the Wei; this will irrigate some 70,000 a. acres near Hsiahsiang, and greatly increase the navigability of the Wei River; cf. Kao Fan (1).

* And all completed within a couple of decades; though for five hundred years it was to be the main trunk line of China’s communication network.

* For general accounts of the fiscal and economic aspects of its history in Thang times the monographs of Pulleyblank (1) and Twitchett (4) are valuable.

* Cf. Pulleyblank (1), pp. 34 ff., 109, 189 ff. (where he translates in full two important memorials by Phei); 301 (a biographical notice); Twitchett (4), pp. 87 ff., 302, 306 ff.


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28. CIVIL ENGINEERING

transhipment point. With Liu Yen as Transport Commissioner (+763 to +779) the highest pitch of efficiency was perhaps reached, for special boats were constructed to suit each different section of the canal, and every part of it was kept in good order.

In the Five Dynasties period, which followed the collapse of the Thang, the economic areas served by the Canal were split up into different political units, but there was little or no destruction of the works themselves. The Sung people after +960 intensified the care of the waterway as part of their expanded water-conservancy programme, which outdistanced that of any previous dynasty (cf. Figs. 882 and 900, pl. 9). The capital was moved further east to be fixed logically at Khaifeng, just about the central point of the Y-system, and we have many records of the complicated web of ship canals which ramified through and around the capital from the Pien or Grand Canal itself. But by the +12th century the hold on the capital was becoming precarious. After the collapse of its defence against the Chin Tartars in +1126, the Sung general staff deliberately broke the dykes south of the Yellow River, delaying indeed the Jurchen advance to the Yangtze but also destroying most of the works of the Pien Canal. After the establishment of the Sung capital at Hangchow in +1135, the lands between the Huai valley and the Yellow River became for centuries a battleground, so that the Pien Canal of the Sung must have been in a very dilapidated condition when the Yuan (Mongol) people overwhelmed Chin, Liao and Sung alike, and obliged historians to count the years of their dynasty from +1280.

Since the Yuan empire included so much northern territory which was outside the bounds of China proper, Peking was the natural choice for the capital. But since the long-established pattern of Chinese social and economic life persisted unchanged, simply with the imposition of Mongols (and other foreigners) at the top, Peking could not become the central administrative ganglion without a ‘stream-lining’ of the tax-collecting machinery.

Yet already by about +800, after the rebellion of An Lu-Shan, the annual grain consignment had fallen as low as 28,000 tons (Sung Shih, ch. 93, p. 190).

The reader will remember the interesting passage from the Ming Chi Pi Tham (ch. 25, para. 8), translated in Vol. 1, p. 577, where Shên Kua described his work as hydraulic engineer and surveyor in the restoration of the Pien Canal between Khaifeng and the Huai about +1098, and the Huai about +1091.

If. & JU.
grain vascular system. For this purpose the essential thing was to make a short cut between the open arms of the Y, in such a way as to bring the east-central economic area more directly in touch with the north. From Hangchow to the Hual no great change was needed, but north of the Hual it was necessary to abandon the westward trend towards the age-old hub of Jungyang near Khaïfeng and to plan a more direct route. The line of the old Pien Canal was thus entirely replaced by a more easterly one which made its way over the shoulder of the Shantung mountains and crossed the Yellow River far to the east of the former junction points. This new alignment was truly a summit canal in a way which the Pien Chhîh had never been, and doubtless its planning drew some inspiration from the known success of the Ling Chhîh. Though sea-transport now began to make serious competition, the Yuan dynasty still relied largely on inland waterway traffic, and the remodelling of the Grand Canal which it brought about lasted through the Ming and Chhing periods down to the present day. Who could fail to appreciate the political and economic consequences of so bold a conception—an artificial river running north and south in a country where most of the natural rivers run from west to east (Fig. 901, pl.)?

The Great Khan [wrote Marco Polo] has made very great channels, both broad and deep, from the one river to the other and from the one lake to the other; and makes the water go through the channels so that they seem a great river; and quite large ships go there with the said grain loaded from this city of Caigiu up to the city of Cambaluc in Cathay. The essential point was that while the sea route was certainly capable of delivering a greater tonnage it was expensive, and the canal.

It is near the site of the Battle of Tshai-shih (cf. p. 416 below). The government organised in 1293 under the direction of an old friend of ours, the astronomer Kuo Shou-Ching provided them. Two hundred and fifty years later (1538) a special monograph, the *Thung Hui Ho Chih*, was consecrated to this noble waterway by Wu Chung. It was being written about in Persian within a dozen years of its completion. In +1307, Rashid al-Dîn al-Hamdâni, after giving a good account of Peking with its lakes and streams in his *Famîl al-Tawdrîh*, goes on to say:

We hear that since the river was so narrow, the capital could not be reached by ships, and that people were obliged to use beasts of burden for the transport of merchandise to and from the city of Khanbalîq. However, the geometers and philosophers of Cathay assured the Khan that it would be possible to bring to the capital the vessels of all the provinces of Cathay, and those also from the capital of the kingdom of Mitîchin (the former Sung dominions), and even those from the cities of Khingsai (Hangchow) and Zeitun (Chhun-chow) and other places.

Rashid al-Dîn then goes on to describe the completion of the Thung Hui Ho, and of the whole Grand Canal system, mentioning especially its flash-lock or pound-lock gates and capstan slipways, and the planting and protection of trees alongside. Thus Saracens and Franks alike were impressed by what Chinese engineering could do.

The second part, (6) in Table 70, running from Thungchow to a point near modern Tientsin, had originally belonged to the Sui system, but was greatly improved in Kuo's time, and called the Pai Ho (White River). The third section (c) also followed the Sui route, being no more than the Wei River again made navigable (though it was renamed the Yü Ho, Imperial River); but about half the distance along it, at Lin-chhing (124), an entirely new canal (d, f), the Hui Thung Ho? (Union Link Channel), was thrown off southwards to cross the northern course of the Yellow River at right angles (cf. Fig. 902, pl.). The idea of this had arisen in +1275, when Kubilai's general Bayan had enquired into its possibility; he was assured by Ma Chhîh-Chên whether such a canal was feasible if water from the Wet Ho River was used, and this was confirmed in a preliminary survey made by Kuo Shou-Ching himself. The project then hung fire, partly because of the use of the sea route, until +1289, when it was revived by the magistrate of Shou-chang, Han Chung-Hui, and another astronomer, Shih Pien-Yuan. The latter was authorised, with Ma Chhîh-Chên, to make a definitive survey, and this being quickly accomplished, charts and plans were presented to the emperor. Chang Khung-Sun and a Mongol Loqsi were then placed in charge of the work, which was completed within the year; it had 31 locks (mu chha) in a distance of some 250 li (about 80 miles). It therefore got the popular name of Chha Ho.

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* This is a subject to which we shall return below (p. 355).
* A romantic engraving of this place and its pagoda will be found in Staunton (1), pl. 33.
* Chhîng Chao-Chiang (1), p. 210; Lo Jung-Pang (4). It is very probable that some of these locks were pound-locks, but the facts are not precise on the point. Eight of them were rebuilt with stone abutments between +1296 and +1302, and all by +1327.
* This is a subject to which we shall return below (p. 355).
* Cf. above, Vol. 3, passim.
One reason perhaps for this success was that in the same year a change in the course of the Yellow River occurred (from (2) to (0), cf. the map in Fig. 899), its northern arm being greatly reduced in volume, and most of the water running into the Huai and the Yangtze. The canal crossed the diminished northern arm a at a point south of the city of Tung-a in western Shantung, and reached as far as An-Shan near Tung-phing, b where it met the summit section (f, g) completed six years before. In doing this it was able to incorporate the remains of the short canal called Chhing Chi Tu c which (as already noted, p. 282) had been built by Haun Hsien in Chin times (3-352). b

The important summit section itself was the work of a Mongol military engineer, Oqrulqi, f in + 1283 and the following years, in accordance with plans drawn up by Kuo Shou-Ching; known as the Chi Chou Ho, g it connected Chi-ning with the Chhing Chi Tu and so with the sea by means of the river north-eastwards, a stretch of more than 140 li (c. 44 miles). On the other side, to the south, it linked up with another work of the Chin period, the Huan Kung Kou, h which had been first constructed in + 359, when Marshal Huan Wen i was campaigning northward against Muyung Chhui, j afterwards first king of the Later Yen dynasty. When its original object of carrying military supplies from Huai-yin k as far north as Chi-ning l had been fulfilled it served little purpose in later centuries until in + 1283 it was restored and extended as part of the new north-south system (sections h, i, k). This portion is seen in the Ming or Chhing chart of Fig. 903 (pl.1). Before the Hui Thung Ho was completed, therefore, the Yuan government could bring up grain supplies from the east-central economic area by canal boat as far as the northern mouth of the Yellow River, and then tranship them to sea-going vessels for the rest of the way to Tientsin. The Huan Kung Kou used for its water supply a number of lakes with which it connected on its way up a markedly rising slope (cf. Fig. 906), and covered (excluding them) some 500 li (c. 94 miles). Early in the Yuan its southernmost portion ran near the southern arm of the Yellow River (course (c)), but the change of + 1289 brought those waters to the Huai at a more westerly point, and most of the discharge, after passing through the Hung-te Lake, f accompanied the Shan-yang Yün-Tao to Yangchow (course (0)). In + 1324 the

river reverted north again to course (0), so that once more the canal traffic had to cross it at Huai-yin. f

There is more of interest to be said about the summit section (the Chi Chou Ho) where the water surface attains a height of 138 ft. above the mean level of the Yangtze at the junction point. As Oqrulqi left it, the water supply for the highest levels (always the greatest problem of summit canals) was unsatisfactory—so much so indeed that throughout the Yuan period the canal could not always compete with the alternative advantages of sea transport. After it had long been evident that something would have to be done, the necessary remodelling of sections (d) to (i), which brought the most difficult part of the Grand Canal to a high level of efficiency, was carried out by the Ming engineer Sung Li in + 1411, at the proposal of the Assistant Administrator of Chi-ning, Phan Chheng-Shu. k It is recorded that Sung Li, a former student of the Imperial University, was helped to solve his problems by the advice of an old countryman (probably an irrigation-worker) of Wên-shang, Pai Ying, m who showed how the waters of the Wên n and Kuang o Rivers could be used more effectively (cf. Fig. 903, pl.1). Pai Ying suggested that a new mile-long bund or dam should be constructed on the latter north of Ning-yang to form a reservoir which would always keep the canal full, with the aid of a forking lateral canal from the former, and these major works were successfully completed in 200 days by a force of 165,000 men. d Besides the large reservoir, Sung Li also installed four smaller ones near the canal itself under the name of 'water boxes' (shui kuei). f The Ming Shih has a rather significant passage on this. f

Lake was built; the lake was still being used when conditions were favourable. See Fig. 904 (pl.), from Nienhoff (1), p. 148; cf. van Braam Houckgeest (1); Fr. ed. vol. 1, p. 312, Eng. ed. vol. 2, p. 126.

See, more correctly, leave it there, for traffic followed the river from Hsü-chou (16) to the Huai. The route of the canal shown in Fig. 899 was not opened till + 1069.

Biography in Ming Shih, ch. 533, pp. 19 ff. At this time it was a general practice to use students and former students of the Hanlin Academy and the Imperial University in public works projects design and management (cf. Yang Lien-Sheng (11), p. 12). Sung Li, however, had already been Minister of Works. f

Ming Shih, ch. 83, pp. 483, 533, p. 2a.

The new status of the Grand Canal as a thoroughly practical proposition had a stimulating effect on sailing-large construction (cf. p. 240 below) and a correspondingly inhibiting one on maritime shipbuilding and sea-power in general (cf. pp. 478, 484, 524 below).

We thought for a long time that these were pound-boxes, but they must have been feeder reservoirs. The oldest use of the term shui kuei so far found occurs in a statement concerning the second year of the Sung dynasty (+961). In his Hsii Tso Chh'ing Chhun Chhng Phien of c. +1190, Li Tao f says: 'On a chia-shu day in the second month of the 2nd year of the Chien-Lung reign-period, the emperor went to inspect the repairs being carried out to the shui kuei outside the southern watch-tower (of the capital)' (chs. 2, p. 26). As this was Kaihuting, far from any hill country, the purpose of the 'water box' here is not obvious—possibly it was some kind of dock or lock-basin. One suspects a change in the meaning of this technical phrase between Li Tao and Sung Li. This text was kindly signalised to us by Professor Twitchett. Then in +1607 Su Chh*'f demanded that all districts east of the Pien Canal mouth should build shui kuei reservoirs for its water supply, some of the water being available for irrigation from time to time upon payment of a fee (Sung Shih, ch. 94, p. 64 b). Of course shui kuei often means just tanks, as in the nautical literature. And conversely, as we have noticed already (Fig. 833, above), it was in later times at any rate applied to caiasons that kept water out rather than in.

Ch. 85, p. 54 f. tr. auct. The 'water box' reservoirs with their proper names are mentioned again on pp. 11b, 449, b, and 206. They were repaired and amplified by Wang I-Chh'ii in + 1550, and again in +1615.
He [Sun Li] also made near Wén-shang, Tung-phing, Chi-ning and Phei-hsin artificial reservoirs (lit. lakes), setting up 'water boxes' and sluice gates (tou men); on the west side of the Canal (Tahao Hsii) there are what are known as 'water boxes', on the east side there are what are called 'sudden declivity' sluice gates; the boxes are to store the water supplies, and the gates to let go any excess. Although the exact arrangement could only be clarified by examination of the works themselves, it would seem that the 'water boxes' were something like the side ponds of modern pound-locks (cf. p. 345), perhaps the earliest of the kind, while the sluices were to prevent any excess from running out. But in order not to waste it the provision of better lock-gate equipment on each section was essential. Oqruqči had put in 14 gates on the northern side of the watershed summit (the 'water spine', shui chi), but Sung Li now rebuilt them and increased the number. On the northern side, between An-shan Chen and Lin-chhing, with a fall which he reckoned as 90 ft., he built 17 cha; and on the southern side, between Nan-wang Chen and somewhere about Su-chhien (near Hsíchow), with a fall which he reckoned as 116 ft., he built 21. The sluice gates of the feeder channels were arranged in pairs so as to deliver straight out of the eastern side of the canal; at any rate it is clear that Sung Li secured for the high-altitude levels a permanently adequate water-supply. But in order not to waste it the provision of better lock-gate equipment on each gradient was essential. Oqruqči had put in 14 gates on the northern side of the watershed summit (the 'water spine', shui chi), but Sung Li now rebuilt them and increased the number. A strong bulwark of stone supports the opposite western bank, and the waters of the Luen striking with force against it, part of them flow to the northern part and part to the southern course of the canal. A circumstance which not being generally understood or explained gave the appearance of wonder to the assertion, that if a bundle of sticks be thrown into that part of the river, they would soon be separated and take opposite directions. It is, no doubt, from this elevated surface, that the author of this canal saw... the possibility of forming this important communication between the different parts of the Chinese Empire by measuring from hence the inclination of the ground to the north and south, and uniting the devious streams which descended from the heights on every side, into one great and useful channel; preventing by flood-gates occasionally dispersed upon it, any sudden and useless dereliction of its waters; and supplying the loss necessarily sustained by opening such flood-gates for the passage of vessels through them, from the plentiful source of the Luen, situated higher than the highest part of it, and falling by proportionate divisions into its opposite branches. The Shan-yang Yin-Tao (section j), or Shan-yang Tu, which Staunton and Macartney travelled down a few days later, was of course the improved alignment of the very ancient Han Kou, and incorporated subsequent ameliorations such as the I Lou Ho (p. 309); it was not essentially changed in the Yuan re-organisation. A Ming Ching chart of it is reproduced in Fig. 903 (pl.). The Sui dynasty's Chiang Nan Ho on the south side of the Yangtze (sections f and m) also remained unaffected. Nevertheless constant repairs to all sections, and unceasing maintenance, were necessary during the Yuan, Ming and early Ching periods.

By +1327, then, the Grand Canal had attained definitive form, extending in all to approximately 1,600 miles, distributed as shown in Table 10. Here we see the distances of the various sections, the altitudes reached at each stage, and the average depths of bed. A diagrammatic longitudinal profile is added in Fig. 906. Since the canal crosses or touches five great rivers it would be reasonable to imagine that it crossed four watershed summits, but in fact it only crosses one because the Huang Ho and the Huai River at the junction-points are at considerably higher altitudes than the Hai Ho, the Yangtze or the Chhien-thang River. Nevertheless the summit between sections (f) and (g) is at quite a notable height, the water-level being 13 ft. above the Yangtze mean, and the ground level (pierced by a cutting) 175 ft. Moreover, the northern terminus, Peking, was at sea-level but elevated 118 ft. above it, so that section (a) had to make a considerable ascent. A quite appreciable gradient also existed on the oldest of all the stretches, section (j), and an important cutting was necessary even in the relatively flat country of sections (f) and (m). What all this implied in terms of lock-gate and similar equipment we propose to reserve for the subheadings.

A rather muddled account of this same place was given by the Korean traveller Chhoe Pu (cf. p. 356), who passed it in +1487 (Meskill tr. pp. 109, 151). He was invited to sacrifice to the Dragon King at the Watershed Shrine, but his strict Confucianism prevented him from doing so.

The last name which this section acquired, a name which is still used today, is that of the Inner Grand Canal (Li Yin Ho). At right angles to its course (as already noted, p. 358) there had long been a system of feeder canals connecting it with the coastal areas where sea-salt was made; these Salt Canals (Yin Yen Ho) now reached their fullest development. See Fig. 903 (pl.).
section devoted to that problem (p. 344 below). It may truly be said that the work of Kuo Shou-Ching and Qugući in +1283 constituted the oldest successful fully artificial summit canal in any civilisation; but we may remember that the installation of pound-locks in the Ling Chhü approaches some time between +900 and +1170 had, in a sense, converted that system into one of the summit kind.

Here was a great work of engineering indeed, all the more remarkable when one remembers that in its course it had to connect with two of the greatest rivers in the world and one of the most changeable. Nevertheless, it was primarily a one-way channel, serving essentially the collection and concentration of grain-tax rather than the exchange of products among the masses of the people. The considered judgment of Chinese historians is that the governments in all dynasties invariably considered the interests of tax transport above those of irrigation or flood-control. Fiscal appropriation always came first in their minds. This had consequences particularly disastrous in the Huai valley region, where the ever-higher dykes of the Grand Canal blocked up the outlet of Huai waters, and caused severe floods when periodically swept away. Eventually the canal fell upon very evil times. Today it has come into its own again and is beginning to fulfil under socialism a national and public function not contemplated by its feudal-bureaucratic planners. A 105-mile branch canal from Huai-an to the sea, a 44-mile spur to the north Chiangsu coal mines, and a 94-mile

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Table 70. Details of the Grand Canal in its final form (late Chhing)*

<table>
<thead>
<tr>
<th>Section</th>
<th>Miles (cumulative)</th>
<th>Intervals (in miles)</th>
<th>Surrounding ground (ft.)</th>
<th>Water level (ft.)</th>
<th>Depth of Canal (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peking</td>
<td>0</td>
<td>18</td>
<td>118</td>
<td>112</td>
<td>10</td>
</tr>
<tr>
<td>a</td>
<td>(Chuang Hui Ho)</td>
<td></td>
<td>92</td>
<td>85</td>
<td>10-26</td>
</tr>
<tr>
<td>b</td>
<td>(Pai Ho)</td>
<td></td>
<td>26</td>
<td>23</td>
<td>10-33</td>
</tr>
<tr>
<td>c</td>
<td>(Yu Ho)</td>
<td></td>
<td>118</td>
<td>115</td>
<td>10</td>
</tr>
<tr>
<td>d</td>
<td>(Hui Thang Ho)</td>
<td>335</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e</td>
<td>Yellow River, north side</td>
<td>405</td>
<td>125</td>
<td>115</td>
<td>c. 30</td>
</tr>
<tr>
<td>f</td>
<td>(Hui Thang Ho, Chhing Chi Tu and Chi Chou Ho)</td>
<td>405</td>
<td>125</td>
<td>138</td>
<td>13-14</td>
</tr>
<tr>
<td>g</td>
<td>Nan-wang Chen</td>
<td>448</td>
<td>170</td>
<td>138*</td>
<td>13-22</td>
</tr>
<tr>
<td>h</td>
<td>(Chi Chou Ho)</td>
<td>461</td>
<td>130</td>
<td>115</td>
<td>10</td>
</tr>
<tr>
<td>i</td>
<td>(Huang Kong Kou)</td>
<td>89</td>
<td>118</td>
<td>115</td>
<td>10-33</td>
</tr>
<tr>
<td>j</td>
<td>Lin-chia Pa† (south end of lakes today)</td>
<td>550</td>
<td>60</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>k</td>
<td>(Huan Kung Kou)</td>
<td>705</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>l</td>
<td>(Shan-yang Yün-Tan)</td>
<td>116</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m</td>
<td>Yangtze River, north side</td>
<td>824</td>
<td>16</td>
<td>0</td>
<td>40-50</td>
</tr>
<tr>
<td>n</td>
<td>Yangtze River, south side</td>
<td>846</td>
<td>16</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>o</td>
<td>(Chiang Nan Ho)</td>
<td>875</td>
<td>56</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>Tanyang†</td>
<td>108</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>q</td>
<td>(Chiang Nan Ho)</td>
<td>1,060</td>
<td>12</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>Hangchow</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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* Prepared in conjunction with A. W. Skempton, adjuv. Chhing Chao-Chhing (i).  
† The ground level, not that of the top of the dyke.  
‡ Very variable.  
§ Canal running on an embankment. This is not shown in Fig. 906.  
<table>
<thead>
<tr>
<th>Canalised</th>
<th>Canalised</th>
<th>R. Wei</th>
<th>Hui-Chhing</th>
<th>Huang Kong</th>
<th>Shan-yang</th>
<th>Chhing Nan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peking</td>
<td>Transail</td>
<td>Lin-chhing</td>
<td>Yellow</td>
<td>Chhing</td>
<td>Lakes</td>
<td>Hanian</td>
</tr>
<tr>
<td>Hsia-an</td>
<td>44-mile</td>
<td>105-mile</td>
<td>105-mile</td>
<td>105-mile</td>
<td>105-mile</td>
<td>105-mile</td>
</tr>
</tbody>
</table>

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* At the same time much work was often done in building drainage canals, sluices and flood-gates, as in +1480 after the Ming had come into power, and again in the early Chhing.  
† Carles (a) gives us a picture of the Canal in the days of its decline (-1806). Some parts of it were dry, or held water only a few inches deep; in other parts the current reached 10 knots. Many parts were flooded only to let the grain ships pass, then drained and excavated in readiness for the following year. In spite of all gates, great difficulties were met with when entering and leaving the Yellow River and the Yangtze, owing to differences in water-level and to currents. Haul-over capstans at various places were manned by as many as 400 men. After 1911 only the sections south of Hui-yin were utilisable.  
‡ I regret that in my time in China I have seen so little of the Grand Canal. But even as one views it from the railway in Chiangsu it is much more impressive than anything similar in Europe.  
§ Anon. (68).  
∥ NCNA, 5 Nov. 1961.
In the seventh year of the Hsiao-Fu reign-period (+1045), Chhi Lin,4 who was governor of the region between +84 and +87, History records his work as follows.4

Lastly, a few words about a work of rather different character to any so far mentioned, which Hangchow grew, are associated with the name of Hua Hsin,5 who was governor of the region between +84 and +87. History records his work as follows.4

As the centuries went by, the sea-wall gradually grew,6 and about +436, Liu Tao-Chen,7 who was governor at the time, wrote a book on it, the Chhieng-Than Chhi.8 His successor in +822 was none other than the poet Pai Chi-I,9 and he also added to the wall, extending it to protect the irrigation systems of the region. Without going into too much detail, it may be of interest to give an account of some engineering controversies which centred round the wall, as recorded by an author of the early +13th century. The Feng Chhiuung Hsiao Tu (Maple-Tree Window Memories) says:8

In Hangchow the estuary sea-wall (thai) was really first built by Chihpen Shih-Po10 in the fourth year of the Khai-Phing reign-period (of the Hoo Liang dynasty; +910).... Bamboo gabions filled with stones were used, and large wood baulks set in among them. But after various periods of years it was always severely damaged.

In the seventh year of the Hsiao-Fu reign-period (+1045) Chhi Lun11 and Chhien Yao-Tao12 had a discussion as to whether it was better to use brushwood and earth mixed with straw13 for the protective embankment, (or earth with a stone facing); some thought one way was more convenient and others preferred the other.14 Li Phu15, when consulted, advised that it would be best to follow the old system of Chihpen Shih-Po, and drive piles of wood between gabions containing stones. This plan was followed, but the sea-wall could not be finished, so that finally in some places earth bonded with straw was used.13

In the fourth year of the Thien-Sheng reign-period (+1026), Fang Chhi suggested that the two sluice gates (tou men) should be repaired.4 In the sixth year of the Chhing Li reign-period (+1046), Tu Chhi16 extended the Chhieng-thang Sea-Wall from Kuan-phu to Shih-ching, and it withstood tides and storms.... Thus (we may say that) the sea-wall was first begun by Chihpen (Shih-Po).

In the Chih-Yu reign-period (+1034 to +1037) Chang Hsia,17 an official of the Ministry of Works, used soldiers to pile stones for the facing of the sea-wall.18... (Lastly), in the seventh year of the Chhien Tao reign-period (+1169), Shen Chhiung19 lengthened the sea-wall by 9,400 ft....

The interpretation of this seems to be that there was much reluctance to undertake the very large task of making a cut stone facing throughout; the sources indicate that the reinforced earth type of dam was what Chhien Yao-Tao wanted, as he had found it suitable in other places.8 Ting Chin-Kung,20 however, preferred Li Phu’s opinion, and stuck to bamboo gabions. Some decades later Chang Hsia introduced more durable gabions of wood, and this was so successful for a time that it earned him a votive temple and the grateful title of the 'River-Pacifying Duke'.

It is clear, therefore, that there were three alternatives. There can be no doubt that at the beginning of the +10th century the great Legate Chihpen Liu piled up stone-ties he ruled from Hangchow nominally as governor but in practice as an almost independent sovereign. Chihpen Liu was a remarkable example of the good administrators that some of the former Thang ‘Legates Regulant and Mensurant’ turned out to be when circumstances obliged them to carry on in isolation. Besides his great work on the sea-wall, he gave to the city of Hangchow in the years following +855 new walls and roads which formed the setting for the later Sung capital, and all its descriptions including that of Marco Polo.

a Cf. p. 481 above.  
b Cf. p. 230 above.  
c Perhaps the supply of stone was a difficulty.  
d These were for letting out surplus water except at high tides. They were again repaired and enlarged by the great writer Su Tung-Pho in +1060, when he was Governor of Hangchow. He also did much for the canal system of the city, and greatly improved the navigation of the Chhien-thang River (cf. Tung-Pho Chih-tshu Chi (Tou i chih chi), chs. 7 and 9; summarised by Lin Yu-Thang (3), pp. 266 ff.; 270 ff.). Maps and plans are mentioned in connection with these projects. The most impressive tide-gates, however, are on the south side of the estuary, near Shuo-hsien, with 28 arches; these date from +1357. Cf. p. 310.  

Fang Chi (2)  
Cf. Chi Yu-Ching (1).  
Hence the name ‘Money-Dyke Estuary’.  
There is a detailed map in Moule (3), and a sketch-map in Fang Chi (2).  
Ch. 1, p. 136, tr. suc.  
This Chhien Liu’s (+481 to +533) was a curious and interesting personality. Originally a salt smuggler, his military merits in the suppression of the rebellion of Huang Chhao led to rapid promotion, and in +907 he became Prince of Wu and Yih. In the time of the Later Liang and Later Thang dynas-

28. Hydraulics

28. CIVIL ENGINEERING
filled bamboo gabions (chu lung) after the manner of Kuanhsien, anchoring them with wooden piles (mu chhun) and binding them with iron chains. A second method, later on proposed, was to build the embankment of tamped and reinforced earth such as was used for so many dams and weirs inland; but this though doubtless less expensive, was less long-lasting. Finally, in the +14th century (+1368) a wall of stone rubble was built, but this had the failing that for a long time it was not backed by an earth-fill embankment of sufficient dimensions, so that the facing was often left with nothing behind it—the fault, however, was remedied by the +15th century. At this time too (in +1448), Yang Hsüan introduced the practice of building the masonry in steplike fashion (tieh shih chhi fa), the better to break the force of the waves. Rather later in the Ming period (+1542), Huang Kuang-Shêng made a special study of bonding methods (especially the 'fish-scale bond', yu lin thang), which he described in his H'ai Thiang Shuo (Discourse on Sea-Walls), and these proved effective down to the present time. Many auxiliary techniques, such as the use of iron clamps (thieh run) for the blocks of stone, and the building of groynes (pei thang ho), have been practised since the time of Yang and Huang. Finally, late in the Chhing, and theory of so many centuries was crystallised in the book of Chhen Hsi-Tsong entitled Hsia H'ai Thiang I (Discussions on Sea-Wall Repair and Maintenance).

Some further light is thrown on the sea-wall in the Sung period by Shen Kua, who knew this part of the country well. His passage about it is worth reproducing.

The Chhien-thang estuary sea-wall was originally, in the time of Governor Chhien himself, a stone (gabion) dyke. Along the whole length of the dyke, at its outer edge, were placed more than ten rows of piles, heavy wooden baulks, which were known as 'ocean screen pillars' (huang chu).

In the Pao-Yuan and Chhing-Ting reign-periods (+1038 to +1040), someone suggested that the wooden piles should all be taken out, so that several hundreds of thousands of pieces of good timber would be available. The commanding officer in Hangchow agreed, so this was done, but the timber, once out of the water, proved to be decayed and useless.

After the wooden piles had been removed, the stone dyke began to break and burst every year on account of the force of tides and waves. Men of former times had set these piles in to break the force of the waves. In the Chhing dynasty important histories of the sea-wall were written, notably the well-illustrated Liang Chê H'ai Thiang Thang Chih by Fang Kuan-Chêng and the Hai Thang Lu by Tsê Chün-Lien. In our own time there has been a memorable report on it by von Heidenstam (1). Today it serpentines along both sides of the estuary for just under 200 miles, its masonry rising to an average of 26 ft. above low water level, and efficiently performs its ancient task.

In recent years the benefits of the crescent-shaped outworks (breakwaters, groynes and piers) have been carefully studied, and the harm done by the sea has certainly been reduced. But their efficiency is not as great as that of the old wooden pile (and gabion) system. Unfortunately it would now cost too much to replace all the piles.

According to this, therefore, the original dyke was ruined when in some moment of timber-shortage the wooden piles which anchored the stone-filled gabions in place were all removed. This of course was about the time (+1035 to +1040) when Chang Hsia was replacing the gabions of bamboo by gabions of wood. Tu Chhi then accepted the idea of protective breakwaters jutting out from the shore, (2) and though the opposition of the water-conservancy workers stayed this plan off for a time, (3) it was certainly put into execution during the next two decades, before Shen Kua came upon the scene about +1070.

The sea-wall was visited by Major Edwards in 1865 after it had suffered from neglect to the Taihping revolution and civil war. His criticisms (1) of the traditional engineering represented by the structure were that the lowest stone course was not sufficiently below low water level to prevent serious undermining in several places, that the piles were not stout enough, and that there were no counterforts to break the force of the waves. In the Chhing dynasty important histories of the sea-wall were written, notably the well-illustrated Liang Chê H'ai Thiang Thang Chih by Fang Kuan-Chêng and the Hai Thang Lu by Tsê Chün-Lien. In our own time there has been a memorable report on it by von Heidenstam (1). Today it serpentines along both sides of the estuary for just under 200 miles, its masonry rising to an average of 26 ft. above low water level, and efficiently performs its ancient task.

(5) The Literature on Civil Engineering and Water Conservancy

From all the foregoing material it will have been noticed that the chief sources for information on hydraulic engineering in ancient and early medieval times are the
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dynastic histories. The Shih Chi and the Chhiuen Han Shu contain long chapters on canals and waterworks, while some of the latter ones, such as the Sung Shih, have whole sections incorporating a great bulk of data which has never been fully analysed. Few fragments of Han date, for example, on water conservancy survive, and our knowledge of Han ideas and practice has to come from the speeches and memorials recorded in the histories. Most of the technical literature dates from the +14th century and later, as may be seen from modern descriptive bibliographies such as those of Mao Nai-Wên (1) Cheng Hao-Sheng (2) and Chu Chi-Chien (3). An idea of its extent can be gained from the fact that the first of these lists about 200 books and the second 400.

The Tungs Chih Li Shu bibliography of c. +1150 has a section of 31 books under Chhuan Tu, many of which deal with 'benefit of water', shui li.²

It is hard to make any sharp line of distinction between what we have called 'hydrographic' treatises, and books specifically devoted to the technique of hydraulic engineering, for they overlap, though the latter are commoner in the latest periods. The oldest hydrographic survey which has come down to us is the Shui Ching³ (Waterways Classic), attributed to Sang Chhin of the Former Han, but more probably compiled in the San Kuo time (+3rd century). At the end of the +5th or the beginning of the +6th it was very greatly enlarged by the geographer Li Tao-Yuan,⁴ who entitled it the Shui Ching Chu⁵ (Waterways Classic Commented). But it is primarily geographical, and only incidentally informs us about canals. Three great Ching scholars, Chhuan Tu-Wang, Chao I-Chhing, and Tai Chen, devoted much labour to commenting upon it.⁶

From the Sung dynasty (+10th to +13th centuries) quite a number of relevant books survive. In +1059 the Wu Chung Shui Li Shu³ (Water-Conservancy of the Wu District), by Shan O, appeared; it was the result of many years' study of the canals of Changsu.⁷ In +1242 Wei Hsin produced the Shu Ming The-Shan Shui Li Pei Lan¹⁰ (Irrigation Canals of the Mount Tho District), a historical account of their development in the neighbourhood of Ningpo. From the Sung, though not all easy to date exactly, are the following (among others):

Shui Li Shu¹¹ (Treatise on Water Conservancy) by Fao Chung-Yen¹² (about +1030).⁸
Chhiung-Li Ho Fang Tung¹³ (General Discussion of the Flood-Conservancy Works in the Chhiung-Li reign-period) by Shen Li¹⁴ (between +1041 and +1048).
Shui Li Tho Chu¹⁵ (Illustrated Manual of Civil Engineering) by Chheng Shih-Meng¹⁶ (+1060).¹⁷

² Ch. 91-7. ³ Much fuller detail will be found in Mao Nai-Wên (2).
⁵ Cf. Hu Shih (5).
⁶ Cf. Tung-Pao Chhiai Chh (Tou i chih), ch. 9, for the postscript by Su Tung-Pho.
⁷ Wei Hsin had himself been active in hydraulic work, having organised the repair by Tung Hsing of the canals built as far back as +833 by the governor Wang Yuan-Chang.⁸
⁹ The circumstances in which this work was written are detailed in Sung Shih, ch. 95, p. 228.
¹⁰ See Vol. 3, pp. 260 ff. there is a special study of Shao Su's appeal (arbitrations by Yabuuchi Kiyoshi (23)). He wrote many other books, including a Hri Yu Tho Ching¹⁶ (Illustrated Treatise on the Western Regions).
¹¹ Cf. the study of these books by Yang Lien-Sheng (11), pp. 45 ff.
¹² For information on other civil engineering works of about this date see Hummel (19).
¹³ For Vol. 3, pp. 260 ff. there is a special study of Shao Su's appeal (arbitrations by Yabuuchi Kiyoshi (23)). He wrote many other books, including a Hri Yu Tho Ching¹⁶ (Illustrated Treatise on the Western Regions).
¹⁴ See Vol. 3, pp. 260 ff. there is a special study of Shao Su's appeal (arbitrations by Yabuuchi Kiyoshi (23)). He wrote many other books, including a Hri Yu Tho Ching¹⁶ (Illustrated Treatise on the Western Regions).
¹⁵ For further information on other civil engineering works of this date see Hummel (19).
¹⁶ Ch. 69, p. 542.
¹⁷ For further information on other civil engineering works of this date see Hummel (19).
involved in a great dispute concerning the drainage of the lower Huai area, and constructed a successful 95-mile canal, the Chung Ho.² which short-circuited a bad patch of the Yellow River. Chin Fu wrote the Chih Ho Fang Lüeh (Methods of River Control) in +1690, but though presented to the throne at that time, it was not printed till +1767. The book is regarded as comparable with that of Phan Chi-Hsiin, which it much resembles in contents, and long exerted great authority. Appended to it as ch. 10 is an essay on the techniques of water control (Ho Fang Tê Yao)³ by Chhen Huang,⁴ the eminent engineer who acted as Chin Fu’s secretary and assistant throughout his career. In ch. 9 the two men engage in a discussion of fundamental principles in the dialogue style of the Huang Ti Nei Ching.

The eighteenth century was very rich in books on this subject. Just before it opened, there were the Chih Ho Shu⁵ and the Huang Yün Liang Ho Thu⁶ (Maps and Diagrams of the Yellow River and the Grand Canal) from the pen of Chhing Chao-Piao⁷ (+1690). In +1707 there came the great historical hydrographic analysis of Hu Wei,⁸ the Yü Kung Chih Chih,⁹ already mentioned (Vol. 3, p. 540). Twenty years later Fu Tê-Hung¹⁰ produced his monumental Hsing Shih Chih Chien¹¹ (Golden Mirror of the Flowing Waters), the most comprehensive treatment of all Chinese waterways, natural and artificial. Fig. 508 shows one of his illustrations of a section of the Grand Canal. The book consists mostly of extracts from the chief primary sources, and was more than doubled in size by supplementary volumes compiled by Lei Shih-Hu¹², Yü Chêng-Hsieh¹³ and Phan Hai-En¹⁴ in 1832. About the same time as Fu Tê-Hung’s book came the Fang Ho Yuen¹⁵ of Chin Fu’s successor, Hai Têung-Yün (+1723), a work on the contents of water-conservancy memorials to the throne. Fu Tê-Hung’s descriptive work was continued by Chhi Shao-Nan¹⁶ with his Shih Tao Tê Chiang,¹⁷ printed in +1776. And indeed it has never ceased, since from the following century one might mention the Chiang Pei Yün Chêng¹⁸ (Handbook on the Course of the Grand Canal North of the Yangtze) by Tung Hsin¹⁹ in 1867; while the work in several volumes on the Yellow River by our own contemporaries, Hu Huan-Yung, Hou Tê-Fêng & Chang Han-Ying, has already been mentioned and used.

Of works devoted rather to engineering techniques than historical description, mention should be made of Chang Phêng-Ho’s¹⁰ Ho Fang Chih²⁰ (River Protection Works) of +1725. Towards the end of the century, the mathematician Chheng Yao-Thien,²¹ a friend of Têi Chhen, produced a short theoretical study of canal construction, the Kou Chiieh Chi Li Hsiao Chih.²² Then there was Khang Chi-Thien’s²³ Ho Chhü

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¹⁰ Though during his life he experienced many vicissitudes and trials of favour and disfavour, Chin Fu was posthumously canonised, and shared a temple with three other civil engineers, including Hai Têung-Yün (Vol. 3, p. 873) and Kao Pin (Vol. 3, p. 875). Hou Jen-Chih (1, 2) has written of the Yellow River. Chin Fu wrote the Chih Ho Shu and the Huang Yün Liang Ho Thu (Maps and Diagrams of the Yellow River and the Grand Canal) from the pen of Chhing Chao-Piao (+1690). In +1707 there came the great historical hydrographic analysis of Hu Wei, the Yü Kung Chih Chih, already mentioned (Vol. 3, p. 540). Twenty years later Fu Tê-Hung produced his monumental Hsing Shih Chih Chien (Golden Mirror of the Flowing Waters), the most comprehensive treatment of all Chinese waterways, natural and artificial. Fig. 508 shows one of his illustrations of a section of the Grand Canal. The book consists mostly of extracts from the chief primary sources, and was more than doubled in size by supplementary volumes compiled by Lei Shih-Hu, Yü Chêng-Hsieh and Phan Hai-En in 1832. About the same time as Fu Tê-Hung’s book came the Fang Ho Yuen of Chin Fu’s successor, Hai Têung-Yün (+1723), a work on the contents of water-conservancy memorials to the throne. Fu Tê-Hung’s descriptive work was continued by Chhi Shao-Nan with his Shih Tao Tê Chiang, printed in +1776. And indeed it has never ceased, since from the following century one might mention the Chiang Pei Yün Chêng (Handbook on the Course of the Grand Canal North of the Yangtze) by Tung Hsin in 1867; while the work in several volumes on the Yellow River by our own contemporaries, Hu Huan-Yung, Hou Tê-Fêng & Chang Han-Ying, has already been mentioned and used.

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Fig. 508. A drawing from the Hsing Shih Chih Chien (Illus. p. 141) of Fu Tê-Hung (+1725). The Grand Canal, seen from the south-west, is snaking horizontally across the middle of the picture, and the city in the foreground is Yü-t’ai on the border of Shantung and Chiangsu. The waters of the Chao-Yang Hu (lake) are seen on the right and those of Tu-Shan Hu (lake) above; the canal winds between them to this day. In the background looms the Shantung mountains, above the town of Tsao-haien near the Temple of Confucian at Chhii-fou. The positions of named stop-log lock-gates are marked by a characteristic symbol based on the vertical grooves in which the baulks slide up and down; one such guards an opening in the centre of the picture leading to two watercourses looping to left and right, and each of these again is similarly guarded. The right-hand one is an old disused alignment of the Grand Canal south-west of the lakes, the left-hand one is a parallel stream, the Chhung-thou Ho, coming down from the Nan-Wang Hu (lake) near the summit level and the ‘point where the waters divide’ (see p. 316). Along the stretch of the Canal shown in the picture there are three flash-lock traffic gates and three further side sluice-gates, all termed cha and named. A study of the adjoining pages, on which the chart is continued, shows that Fu depicted, between the Yellow River crossing to the north and the southern end of the lakes at Han-chuang on the Shantung-Chiangsu border to the south, a total of thirty-one flash-lock traffic gates and fourteen side sluice-gates. All but two of these last are called ‘single gates’ (tan cha), which may suggest that some of the traffic ones were double or pound-locks; an impression enhanced by the fact that one pair of traffic gates, those at Nan-wang, are called ‘upper and lower’ (shang hai). On this subject see pp. 355-350.

Chhi Wen (Notes on Rivers and Canals) of 1804, the author of which was a man of great experience in the field as well as in the administrative office. It is considered one of the best books on the subject in the whole Chinese literature. Finally, the Ho Kung Chhi Chhi Thu Shao (Illustrations and Explanations of the Techniques of Water Conservancy and Civil Engineering), compiled by Lin-Chhing and his assistants in 1836, must be commended. Like some of the fore-mentioned books, but even more fully, it is

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Fig. 99. An illustration from the Hsiao Kung Chi Chi Thu Shuo of Lin-Chhing (ch. 3, p. 36). The Hsiao Lung (Wooden Dragon) is a multiple-layer raft (fa) moored by numerous cables alongside a dyke (chhi) endangered by erosion or internal fissures. By means of a derrick arrangement (shian phang chi) a series of bamboo-matting (shui cha) frames (ti chhing chung) is driven into the bed of the waterway through a slot in the raft. The device is thus an ancestral form of sheet-piling. When the frames are in place, a fill (chhien) of fascines, earth, loose stones, etc., is sunk between the dyke and the floating platform; the piles, acting as a temporary cantilever wall, retain in this place until it settles into a compact mass. On the remarkable tensile strength of bamboo laths and cables, cf. Vol. 4, pt. 4, pp. 63 ff., and also pp. 191, 339, 415, 597, 614, of the present volume. The Wooden Dragon could also be used as an ordinary pile-driver.

Lin-Chhing tells us that the method was first employed in the Sung, in + 1021, by Chien Yau-Tso, and then in the Yuan by Chia Lu, c. + 1320; but later it fell into disuse and had to be re-designed at the beginning of the Chhien-Lung reign (c. + 1742). This was done by Li Ping, and Kuo Wen-Ting made very effective use of it, so much so that when the emperor was on a tour of inspection in the south he himself wrote a poem on the Wooden Dragon. Li Ping produced a monograph on the technique, entitled Mu Lung Chhing Kwei, and specialist artisans called Kou shou were trained in its management.
Commandary, breaking the 'Metal Dyke' and overwhelming four commanderies and thirty-two hsien districts. More than 150,000 ching (about 2.5 million acres) were under water, thirty foot deep at the worst parts. Of houses, official and private, some 40,000 were destroyed. This (proved how) mistaken had been the opinion of Yin Chung, the Imperial Censor who had presumably been responsible for the financial stringency, and the emperor reproached him so much that he committed suicide. Fei Tiao, the Minister of Agriculture, was ordered to see to the problem of fair taxation to help the flooded districts, and two Inspectors-General were despatched to arrange for 500 grain-transport ships from Honan and the east to move more than 70,000 inhabitants to the hills.

Wang Yen-Shih, Comptroller of Water-Conservancy Works (Ho-Thi Shih-Châ), was then asked to close the breaches in the river dykes. He used for the fill bamboo 'sausages' containing stones (chu ê; lit: bamboo plugs, or falling bamboo crates); these were 4 chang (40 ft. approximately) long, and 9 spans (arm-stretches, see*) in circumference (of cross-section, i.e. 17.2 ft. diam.) all packed with small stones. They were deposited in place by being suspended between two barges (before dropping). After 36 days the dyke was fully repaired. The emperor thereupon said: 'Although the bursting of the Yellow River dykes in the Eastern Commandary caused floods over two provinces, now our Master-Comptroller (Wang) Yen-Shih has blocked the breaches in (hardly more than) thirty days. Let us change the 5th year of the present reign-period into the 1st year of a new reign-period, to be called Ho-Phing? (The River Pacified) [26-28]. All soldiers who have taken part in the water-control operations shall receive exemption from six months' frontier service. Due to (Wang) Yen-Shih's excellent performance, the expense has been minimal, and the time short. Desiring to encourage him I bestow upon him the title of Kuang-Lu Ta-Fu, with an appanage of 2,000 tan as a Kuan-Nei Marquis, and 100 catties of gold.'

But two years later the river broke out again [26-28], at Ping-yuan, with floods which reached to Chinan and Chhien-chhêng, where half the buildings were destroyed. So Wang Yen-Shih was again sent to control it.

However, Tu Chhin, speaking to the Commanding General Wang Feng, said: 'Formerly, when the Yellow River broke out, the Vice-Minister Wang Yen-ten told me that Wang Yen-Shih really learnt the technique of blocking dyke breaches from him, but nevertheless Yang Yen remained unknown (as a hydraulics expert). Now you are giving the responsibility solely to Wang Yen-Shih, but as he closed the dykes before with such ease, I fear he will not give very serious consideration to the harm (which the River can do). If these things are so, the skill (chhiao*) of Wang Yen-Shih is not as great as that of Yang Yen. Now the effects of water are various, and if their advantages and disadvantages are not the subject of wide discussion, if you give to one man only responsibility for the task, and if he himself is not quite up to the standard called for; then come winter come spring, when the early freshets arrive (thao hua shu i), there will (inevitably) be damage due to excess of silting. Then the spring sowings will have as Tu Chhin suggested, and sent Yang Yen and others to help start the work. In six months it was completed, and again Wang Yen-Shih received 100 catties of gold, and his soldiers, if they had not hired paid substitutes, were granted exemptions as before.

The upshot of this long but entertaining description would seem to be that in the Han there was some realisation of the necessity of associating good mathematicians and engineers with administrators in water-conservancy and control works. The latter alone must have been capable of making gross miscalculations and costly mistakes. Wang Yen-Shih seems to have been a successful career bureaucrat, skilled at retaining the limelight in all circumstances; the others more competent technologists. To some extent a conflict is revealed between the 'boys in the back room' and the regular officials (cf. Vol. 4, pt. 2, pp. 39 ff.). The passage is also of importance in that it is the oldest description of the bamboo gabions filled with stones which played so important a part throughout Chinese hydraulic engineering, and to which we shall return in a moment. That they were unfamiliar about 2,000, two men seeming to claim their invention, may mean that they were really introduced about this time.

One would naturally expect that specimen computations about canals and dykes would be given in the mathematical literature. This is indeed the case; the Han Chih Chou Chiu Shu (Nine Chapters on the Mathematical Art) contains many problems concerning dyke-building, giving results in material, labour, time, and so on. 5 Fig. 56 (in Vol. 3, p. 43) accompanies a discussion of dyke-building in the celebrated Shu Shu Chih Chou (Mathematical Treatise in Nine Sections) of Chhin Chiu-Shao (+ 1427), while Figs. 248 and 249 (Vol. 3, p. 578), from the same work, state a problem in the distribution of irrigation water.

Something has already been said of Chinese survey methods in the geographical Section with relation to the flourishing of the quantitative grid system in cartography. 6 Plumb-lines and the groma, chains, cords, graduated poles and water-levels with floating sights (cf. Fig. 245, in Vol. 3, p. 570) were early in use. 6 A passage from Shen

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5 Cf. Vol. 3, pp. 25 ff., and other details there given, pp. 97 ff., on figures in solid geometry, for the volumes of which there were empirical formulae. A special article has been devoted by Wang Hu-Chen (1) to earthwork estimates in ancient times.


7 Cf. Ch. 13 (vol. 4, p. 334).


9 See also, Vol. 3, pp. 350. We now have also the excellent paper of Shen Kung-Shen (I).

10 Cf. Wu Ching Yuan Yao (Chih Chiu), ch. 11, pp. 20 b, 21 a, b; Ho Kung Chiu Chi Zhu Shoo, ch. 3, pp. 20 a, b, 21 a, b; Hou Pung So Chhîa, etc. How much can be done with the simplest apparatus is seen in Yu Chh'ung's description (1) of the contemporary irrigation works (lateral canals feeding multiple small reservoirs with perennial water, as well as bringing irrigation supply) built by the local people in the Tu-tao River valley near Kuanghsia in N.W. Hupei. A countryman, Li Ta-Choo, who took the lead in this (1957) used successfully as theodolite a split bamboo with septa sights floating on the convex meniscus of water in a rice-bowl (Fig. 910). True, his army service had acquainted him with sights, but the method has an age-old look about it. We have already sung the praises of the bamboo as an invitation to technical advances (Vol. 3, pp. 333, 352, Vol. 4, pt. 2, p. 61 ff.). Cf. p. 415 below.

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Kua about his own work as a surveyor along the Pien Canal about +1070 was quoted, showing the use of graduated poles, and altazimuth sighting-tubes mounted in various ways.\(^a\) Calculations involving similar right-angled triangles were commonly used by the time of Liu Hui, whose book, the \textit{Hai Ta soo Ching} (Sea Island Mathematical Classic) of +265, gives many different examples of them.\(^b\) The \textit{baculum} or cross-staff (Jacob's Staff), generally ascribed to early +14th-century Europe, was shown by another citation from Shen Kua to have been in use in +11th-century China.\(^c\) Yet a third excerpt from the \textit{Meng Chhi Pi Than} (Dream Pool Essays) indicated that compass bearings were also in use for mapping at that time.\(^d\) Whether the hodometer, available from Han times onwards, was actually used in practice for measuring distances, remains uncertain.\(^e\)

\(^d\) Vol. 3, p. 576, from \textit{MCPT}, Pe appendix, ch. 2, para. 56; cf. Hu Tao-Ching (1), vol. 2, p. 991 ff. In Vol. 3, pp. 514 ff., 517 ff., we had a good deal to say of the special geographical literature on water-ways and local topography. From the Sung onwards, starting in Chiangsu, official documents known as \textit{Yu Lin Thu} (Fish-Scale Maps, i.e. dissected cadastral survey charts) were regularly compiled in every district, and in these particular attention was paid to irrigation systems, river control works, and natural products, classes of feature being marked by cartouche inscriptions in different colours. These mapping practices, described in Sung texts such as the anonymous \textit{Chen Hai Thi Kang} (Complete Account of City and County (Government)), and \textit{Lo Pin-Chung's} \textit{Kuan Hase} (Handbook for Magistrates), both of the +12th century, have been studied by Nisida Noboru (2).

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After the route of a canal had been provisionally decided upon, trial borings were made along it to ascertain the nature of the ground. In his \textit{Pei Hsin Jih Lu} (Diary of a Journey to the North) Lou Yo says,\(^a\) about +1169, speaking of the Sung Canal constructed a century previously (see p. 314 above) between the Huai River and the Shantung lakes:\(^b\)

From Hung-T'ai\(^1\) Lake to Kuei-shan,\(^2\) a well was dug every one or two ft to investigate the nature of the earth and bedrock. When the results had proved satisfactory, the emperor was memorialised, and eventually the canal was opened. This demonstrates the careful planning of our ancestors, whose decisions should not be altered lightly. Further, in order to secure adherence to the original alignments, fiducial marks in the shape of stone or iron plates or statues were fixed in the sides and beds of canals as a guide for periodical deepening and silt-removal. We have already seen one case of this at Kuanhsien,\(^c\) and Wang Kung\(^d\) records others for the Pien Canal in his \textit{Wen Chien Chin Lu} (New Records of Things Heard and Seen).\(^e\) A "nilometer" in the stricter sense is the 'Two Fishes' gauge rock which has measured the Yangtze water-levels since +793 at Fou-ling in Szechuan.

(ii) Drainage and tunnelling

From time to time the engineers were faced by difficulties due to springs,\(^f\) underground water-courses, and loose or shaly soil which was prone to landslides. We have an example of efforts made to cope with these things from quite an early time, namely that of Han Wu Ti. Ssuma Chhien writes: \(^g\)

\(^b\) This afterwards became section i (cf. Table 70) of the Grand Canal in its final form.
\(^c\) This is the Lo River in \textit{Shui Chin} (Dream Pool Essays).
\(^d\) Cf. the discussion of the sighting-tube in Vol. 3, pp. 332 ff.
\(^e\) See Vol. 4, pt. 2, pp. 381 ff. In its paddle-wheel form as proposed for ships (Vitruvius X, ix, 5; cf. Diod. (1), p. 69; Tz'U (1), p. 102), it could have been used perhaps as a stationary current-meter. On the history of such hydrometrical devices see Lasser (1), a subject which we have touched upon in Vol. 3, pp. 632, 633. But though the Chinese were the earliest of peoples to make practical use of the ad-aequous paddle-wheel (see Vol. 4, pt. 2, pp. 413 ff.), we have not come upon any such ex-aequous applications of it among them. According to Lellavlevsky Bey (3), p. 467, the hydrometrical paddle-wheel was first mentioned...
which, starting from (the city of) Ch'eng [1], brought the waters of the Lo to the foot of Shang-
yen mountain.

As the banks were liable to slide and crumble easily, (a series of) wells was dug, the deepest
of which was as much as 400 ft.; and there were wells all along at regular intervals. At the
bottom they communicated with each other (by a tunnel) through which the water flowed.
The water came down until it met, and flowed round, the Shang-yen mountain, east of which
the canal continued more than 10 li until it reached the hills. This was the first time that a
subterranean canal with well-openings (ch'ang ch'üün) [2] was built.

While the canal was being excavated, the bones of a dragon were found, hence it was called
the 'Dragon-Head Canal'. More than ten years after its completion, the water was coming
through all right, but very little benefit had accrued from it for agriculture.

Although this work of Chuang Hsüng-Phi's (if indeed he was the engineer) [3] seems to
have had only qualified success, it must be admitted to be of considerable technical
interest. [4] Though the whole length of the canal is not clearly stated, it seems at first
sight to have been an expedient to avoid the collapse of the sides of a cut, perhaps
through some narrow valleys. But one is strongly reminded of the traditional qanats of
Persia, so characteristic a feature from the air when one is flying over the Teheran
region, [5] but also practised in other parts of the Muslim world. [6] The qanat or (Tk.)
qārūt was (and is) a device to utilise mountain water sources which normally sink out of
sight when they reach the foot-hills, losing themselves in the porous valley soil of
confluent alluvial fans. The flow is then tapped near the base of the hills and led along
a subterranean channel above the impervious clay strata and under a succession of
vertical ventilation and excavation shafts, until it debouches into a reservoir from which
fields and settlements can be continuously supplied.

The early history of the Persian qanat seems obscure, but Marco Polo refers to
streams of sweet water running underground in the province of Kerman, and these were
very probably qanats. [7] Underground pipe-lines, perhaps derived from qanats, were also a feature of Iraq. [8] Indeed a work rather like that of Chuang Hsüng-Phi was
carried out during the Sassanian period (+3rd to +7th centuries) at the north-eastern
dge of the Tigris Valley. From the upper waters of the River Diyala (cf. p. 366) a derivate canal was led southwards by a long tunnel through the Jebel

[2] The account in the Ch'ien Hsia Shu gives his name as Yen Hsiang.
[3] For a general history of tunnel engineering see Sandström (1).
[4] Cf. Stein (8); B. Fisher (1); A. Smith (1); Beckett (2); Goliot (1); Wulf (1, 4); Drower (1), pp. 332 ff., fig. 348. Beckett (1) also gives some good photographs, including one of the fireclay rings which are baked on the spot and used for the shaft and tunnel linings. Colour photographs will be found in Eller (1), p. 310.
[5] E.g. in Chinese Turkestan, significantly enough, on which see Golab (1), and in certain Saharan cases, on which see Anon. (10).
[6] The Greeks knew these systems as hyponomoi (Ibriokos); Polybius x, 28, 3 ff., also a 2nd-century reference, like that in the Shih Chi.
[8] In the time of the caliph al-Mutawakkil (+9th century) no less than 300 miles of such subterranean canals were constructed; cf. Ahmed Souza (1); Krenkow (1). A description of 30,000 still exists in the Jibat al-Miyah al-Khafiya (The Bringing of the Hidden Waters to the Surface) by Muhammad Ibn al-
Hassan al-Habib.

(iii) Dredging

In considering problems of scour (cf. pp. 229 ff. above) it was altogether natural that
from time to time the Chinese medieval engineers should have attempted mechanical as
well as hydrodynamical means. A remarkable instance occurred in the Sung, when in
+1073 determined efforts were made to clear the accumulation of silt and bed load in
the Hamrin range of hills so as to bring irrigation water to the land at the edge of the plain below. [9] A Chinese reference of +1259 to qanats occurs in the Hsi Shih Chi [10] (Notes on an Embassy to the West) by Chh'ang Tè, [11] who tells us that in the country of the Malâhida, or Islamiite 'Assassins', otherwise the Elburz Mountains in Kuhistan, 'the land is destitute of water, (so) the local people dig wells at the edge of the mountains, and conduct the water down for several tens of li (to the plain), for the purpose of
irrigating their fields'. [12]

We do not have sufficient information on the topography of Chh'ang Hsüng-Phi's
-8th-century project to see it clearly, but the similarity between Chinese and Persian
techniques is notable and needs further study. At a much earlier stage the attention of
the reader was drawn to possible influences and transmissions in this field across
Central Asia. [13] Which way, one wonders, did they travel? In this case probably
west to east, if Lassee is right in recognising qanats in -8th-century Urartu (Armenia).

Another mention in China (also Shensi) occurs at a much later date. Lu Jung [14] in
his Shu Yuan Ts'ao Chi [15] of +1475 (The Bean-Garden Miscellaneous) tells us that:

In the capital of Shensi there had formerly been very little water within the city, and the
wells were so few that the inhabitants generally fetched their water from outside the west
gate. When Yu Tsu-Chhin [16] became governor of Sian, he reflected that Kuanchung (the Wei
Valley) was a strategic region, and that if the city were besieged for several days, the inhabi-
tants would hardly be able to live. So he bored an underground canal leading the waters of the
rivers Pa [17] and Chhan [18] into the city from the east, and letting them flow out to the west. The
water was obtained by means of a series of shafts with a masonry lining (hsuan chou?), the
water flowing (in the tunnel) below and the ground being quite level above . . .

But the qanat system never became widespread in China proper, presumably because
the physiographic and geological circumstances did not call for it. [18] Yet when the history
of the technique is fully known, China may be found to have made a contribution. [19]
the Yellow River near Ta-ming. After devastating floods in Hopei and energetic promotion by the prime minister Wang An-Shih, a Yellow River Dredging Commission (Chün Huang-Ho Su) was set up with Fan Tzu-Yuan at its head. The candidate-official Li Kung-I then came forward with a suggestion for an ‘iron dragon-claw silt-dispersing machine’ (thieh lung chao yang ni chieh fan), i.e. a weighted and toothed rake trowled by two boats up and down to keep the loose bottom material on the move. A leading eunuch, Huang Huai-Hsin, despatched to report on the proposal, approved of it but thought the specification rather too light, so he and the inventor were charged to produce something more serviceable. The resulting ‘river-deepening harrow’ (chün chhuan pa) was a beam 8 ft. long fitted with iron spikes each 1 ft. long, and sunk to its work by windlasses on two ships. It was confidently affirmed by the local magistrates that either the depth would be too great for the cables or else in shallow places the scarifier would get stuck in the mud, but in spite of adverse reports and some diplomacy on the part of Fan Tzu-Yuan at the capital, several thousands of the scarifiers were made and put into service, Li Kung-I being appointed his assistant. Unfortunately the historians recorded no informed judgment on the success of the operation.

A second example may be taken from a time five centuries later. In +1595, towards the end of the Ming, an Imperial Censor, Chhen Pang-Kho, gave his views on the best ways of keeping rivers clear, and especially the Grand Canal. If, he said, one does nothing but strengthen dykes and allows the bed to build itself up more and more, there will be no benefit of self-scour and every invitation to the flood water to break out. Three methods should therefore be used—first the traditional excavation of the bed as far as possible during low-water seasons (just as at Kuanhsien, cf. p. 293 above), Secondly, let all official and private boats coming and going tow ‘bed-harrowing ploughs’ (pa li), and sail with the wind, scraping the bottom as they go, so that the sand has no peace to sink and settle. Thirdly, imitating the hydraulic mill and the hydraulic trip-hammer, let wooden machines be made which use the current of the water to roll and vibrate, so that the sand is constantly stirred up and cannot accumulate.

The second method was just that of Li Kung-I; the third, more interesting perhaps yet more difficult to visualise, suggests moored paddle-wheel vessels like ship-mills, with bottom-agitating rakes worked from eccentrics, with or without connecting-rods, on each side. Unfortunately again the historian did not record the use, or the efficacy, of Chhen Pang-Kho’s third method. In general, however, this late Ming discussion illustrates again certain perennial engineering convictions which we have already discussed (pp. 234 ff. above). As for the second method, it continued in use down to

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Fig. 911. Towed scrape-dredge or rolling suspensifier, the hun chhing lung illustrated in the Ho Kang Chhu Chu Thu Shuo (ch. 2, p. 310). Drawn along the bottom by a vessel proceeding upstream, it raised clouds of silt from the bed (hence the name), and so increased suspension clearance.
Today one sees dredging operations mainly in harbours. We could illustrate the commonest form of traditional Chinese dredger (chiao ni chhuan) by photographs taken at Canton in 1958, but a sketch (Fig. 912) in the only published account by a Western observer, that of Carmona, is perhaps clearer. Descriptions in the Chinese literature must be very scarce. A large rectangular bucket dredge on the end of a long spar strengthened and shod with iron is let down into the water alongside a barge with a capacious hold, to the forward-stepped mast of which it is loosely attached by a line and loop. The dredge is connected at the front by a cable to a pedal-operated windlass situated at the opening of the steersman’s deckhouse aft, which brings it to the surface when it is full. It is then caught by a hook on the end of a chain hanging from one extremity of a swape-like lever attached to a point near the top of the mast-gantry, and the other extremity of this is hauled down, the dredge with its contents is swung inboard and emptied into the hold. Towards the middle of the 18th century de Bélidor illustrates dredgers with Vitruvian treadmills and just such long-shafted shovelers in his Architecture Hydraulique, but whether they stem from a Chinese or a European original remains uncertain.

Fig. 912. A Chinese dredger of traditional type (redrawn in modified form from Carmona).

Description in text.

8 A double-hulled dredger is also shown in ch. 4, p. 546, b.
9 (1), p. 36. He figures also a good model now in the Maritime Museum at Lisbon.
11 继师船
12 李知盛
13 王足

Reinforcement and repair

The need for internal bonding in structures which ultimately led to reinforced and pre-stressed concrete was of course felt by ancient and medieval Chinese engineers, and we have already seen examples of the methods they employed. Wooden piling was incorporated in walls such as the Great Wall (p. 51) and the Chihien-thang sea-wall (p. 322). But rods and weights of iron were used also when the supply of the metal permitted. In a Thang repertory we are told that in the Liang period great difficulties were encountered with a dam called the ‘Floating Mountain Dam’ (Fou-shan Yen), which was always being rebuilt, and as often collapsing.

Finally, several thousands and ten thousands of catties of iron were placed underneath, and it was successfully completed.

The text goes on to say that in +762 there was similar trouble with a dam south of Haichow, which was not overcome until Li Chih-Yuan acted upon suggestions that iron weights and bars should be incorporated in the foundations.

Without exception, however, the most important material used in China for bonding the interior of solid structures was bamboo. The remarkable tensile strength of plaited strips of this plant stem has already been referred to in connection with tow-ropes, driving-belts, suspension bridges, and so on. Since it was available in such unlimited quantities, the earliest technique was probably to leave in position the baskets or skips in which stones or earth had been carried to the spot, instead of taking them away to fetch more. Then as time went on, the elongated gabion, or sausage-shaped open-work crate of bamboo packed with stones, was developed; and this stage must have been reached by the time of Yang Yen and Wang Yen-Shih (-28) whose breach-blocking achievements have just been quoted. The great advantages of this invention have already been emphasised in the description of the Kuanhsien works; the relative lightness of the gabions permitted their use on alluvial subsoils without deep foundations, and their porosity emphasised them as a most valuable shock-absorbing function, so that surges and sudden pressures did no damage to the defences. It is interesting to find that the same device was employed in Europe, no doubt independently, at least from the +14th century onwards, especially in the sea-dykes of the Netherlands. Here bales of

14 (1), vol. 4, pls. 20, 21, 25. Models worth studying are to be seen in the Tekniska Museum at Stockholm, especially in the Christopher Polhem collections. Cdr. Waters tells us that the R. Thames was dredged for ballast near London in the +16th century by a ‘spoon-and-pole’ method.
15 This dam, in the upper Hsiu valley, had been built by Wang Tzu in +714.
16 Vol. 4, pt. 2, pp. 531 ff., 126, 139 f., 140, 153; here also pp. 191, 328, 415, 466, 597, 664.
17 The dimensions of the gabions used by Wang Yen-Yen-shih seem to have been 40 ft. in length and 17 ft. in diameter. Today 60 ft. lengths are commonly used.
18 On modern Chinese practice regarding gabions see Sung Hai-Shiang (1), vol. 1, p. 44, fig. 4.
19 See Forbes (17), figs. 622, 623. A classical description was given by Andries Vierlingh in +1579. It would be interesting to know how much of hydraulic engineering technique Europe eventually absorbed from China. De Bélidor, for instance, (1), vol. 4, pt. 2, gives excellent drawings of river dykes with fascines, etc., and as his pp. 354 ff. show, he knew a good deal about the Chinese water-ways and their embankments.
compressed seaweed, or a screen of compressed seaweed within piling, or bundles of reeds fixed down with their roots pointing seaward, were used outside the Dutch clay polder dykes. Such shock-absorbers, less resistant to decay than bamboo basket-work, had to be renewed every five years.

Variants of the sausage-shaped stone-filled bamboo crate bear different names; the

commonest is chü lung, but another, perhaps older, term is shui cha. Great use has always been made of them at Kuanshien (cf. Figs. 894, 895, pl.), and they are very noticeable when one travels anywhere in China. Fig. 913 (pl.) shows one of my own photographs of a weir near Chchengtu, in which layers of them can be seen. Fig. 914 reproduces the picture from the Nung Shu a of +1313, which is superior to those of the later Shung Chı̂ng Chhîān Shua b and the Thu Chi Chhîeng. c Elongated gabions formed of wooden slats (yang chih) d are also used (cf. p. 395 above). Gabions are prominent in Fig. 915 (pl.), taken from a painting of +1417 by Ma Wan entitled ‘Yu of the Hsia Controlling the Waters’. e

Besides the gabions, huge fascine bundles of kaoliang stalks fastened with bamboo rope were also developed. These were very convenient when the water was heavily silt-laden, for solid material would quickly be deposited in the interstices of the mass as the water filtered through, and in time it would become very compact. Such brushwood fillers (a Sung invention) were termed tao, f and Fig. 916 taken from a work of c. +1775, the Hsia Fang So Chih g (Brief Memoir on Dyke Repairs) by Li Shih-Lu h, shows a drawing in Chinese style of the method of handling them. i Estler was himself present at the closing of a gap in the Yellow River dykes in 1904, and wrote an impressive account of it. j The dyke was about 30 ft. broad at the bottom and 11 ft. at the top; its height was 33 ft. The gap to be filled was 36 ft. wide at the bottom and 54 ft. at the top, with water pouring through it. Gabions and fascines were used, handled by 20,000 men hauling on cables 100 ft. long—eotechnic but on the heroic scale. Fig. 917 (pl.), from Todd (l), shows the use of giant bales of kaoliang stalks (cross-section 20 x 50 ft.) for stopping a breach. k The technique may be studied in more detail in the report of Todd & Eliasse, who give also some archaeological data on what breakthroughs and washouts have revealed of the dyke construction of the +10th and +11th centuries. It seems that there was little or no stone facing used at that time (cf. the story of the seawall), but kaoliang fascines, bamboo and stone gabions, hemp rope, willow stakes, and bags of clay, were employed on an almost incredible scale to supplement and strengthen the earthen dykes themselves. l

Fig. 914. A drawing of bamboo gabions in the Nung Shu of +1313. The shui cha, or ‘water palisades’, are acting as a small weir.

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a Ch. 18, p. 2a.

b Ch. 17, p. 30a.

c ch. 91, p. 10b. These are perhaps identical with what Sung Shih, ch. 91, p. 10b, calls mu lung. But in Ho Kung Chhi Chi Chu Shuo, mu lung is a pile-driver raft used in dyke repairs (ch. 3, pp. 30a, b fl.); see Fig. 909.

d The origin of the term soo is interesting. The word occurs in the Shih Ching as the name of a kind of plant which grew on walls and fixed itself so tightly that it was impossible to pull it out. Hence its adoption by the engineers as a technical term. On the various kinds of soo see Ho Kung Chhin 3oo, ch. 2, pp. 11a fl.; ch. 2, pp. 11a fl.; Chih Shih-Chu Shao, ch. 2, pp. 1a, b.

e (3), p. 141.

f Cf. Anon. (75), no. 10, a contemporary Chinese painting, and Nesteruk (1), p. 19, fig. 7.

g In the Sung Shih we have an account (ch. 91, pp. 8b fl., 11b fl.) of the extraordinary preparations of materials—beams, bamboo ropes, piles of brushwood, etc.—accumulated at various Conservancy yards along the dykes (sou). When the country people were not busy with farming they were drafted to do this kind of work. The description applies to the period between +1027 and +1021. Different categories of

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1 竹篩 2 水槽 3 草席 4 修防成志 5 修防 slain 6 水槽 7 水篩
A graphic description of a closure of breaches in the Yellow River dykes occurs in the *Meng Chhi Yi Tuan* of Shen Kua, and is worth reproducing in full.  

In the Chhing-Li reign-period (+1041 to +1048) the (Yellow) River burst through its dykes at Shang-hu near the northern capital, and for a long time no closure could be made. Shen Kuo-Shen-Hsi, Vice-Minister of Finance at the time, went there to take charge of operations himself.

Now in closing gaps made by a river in embankments, success chiefly depends on the filling of the final gap when the last gabion or fascine bundle (sao) is (placed in position). This is called 'Closing the Dragon Gate' (Ho Lung Men). Sometimes many unsuccessful efforts have to be made.

(In this case) the sao (prepared for closing) the 'Dragon Gate' was (no less than) 60 paces (about 300 ft) in length. Kao Chhao, one of the assistant engineers (shui kung t), offered a suggestion. He said that the sao was too long, so long that it was beyond the power of human material mentioned are given special technical names, such as chhun chin, ('spring supplies', etc., and the different kinds of timber needed are distinguished. A mass of information on the technical terms of traditional Chinese hydraulic engineering, never yet properly studied in the West, though of comparatively recent date (+887), is contained in the interesting book of Chhiu Pu-Chou entitled *Ho Kung Chian Yan*, already several times quoted.

Unfortunately it is impossible to tell from the account whether the three sao were to be placed in the gap on top of another, or side by side. The word 'upper' in the last sentence might perhaps mean 'earlier placed in position'.

In this connection it is interesting to note the remarkable upsurge of invention and technical innovation among the masses of the Chinese people. Country folk working on irrigation and conservancy projects in recent years have developed many useful devices such as semi-mechanised earth-pounders, self-cleaning conveyors and the like (cf. Yang Min, a). We have touched upon this subject before (Vol. 4, pt. 2, pp. 173 ff.).

From the +10th century onwards there was a succession of great engineers who achieved remarkable results in controlling the Yellow River, and brought the utmost ingenuity to bear on the closing of dyke breaches. Gabions and fascines were delivered from boats, boats were filled with stones and sunk where necessary, and mobile scrap-dredgers were (as we have seen) constructed. The first of the series was Li Ku, who

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*Fig. 916. Manhandling a giant fascine bundle into position; a sketch in traditional style, entitled chhun sao chu, from the *Hsueh Fang So Chih* of Li Shih-Lu (c. +1773). The nine hauling ropes (liang sheng), with their hauliers, are seen on the left, the side towards the water. The five 'end-head bundle cables' (chhou chou sheng) pass through the centre of the fascine, and being slowly paid out, act as brakes. The seven 'overhook cables' (chhou hou chiai), continuous with the seven 'underhook cables' (li hou chiai), form a safety cage in which the fascine bundle (sao) can roll; they would have to be re-pegged from time to time.*
worked for the Northern Chou (c. +954), while after the Sung had come into power, Tu Yen-Chün (fl. +994) was also successful in river control. The most eminent man about the time Shen Kfa was describing, in the passage above, was Li Chung-Chuang, but the greatest reputation was won by Chia Lü, who repaired dykes and made relief canals during the Yuan period (+1350 to +1360), and whose methods were described in a work already mentioned, the Chih Chéng Ho Fang Chi, by one of his assistants, Ouyang Hsiian. In the Ming, Liu Ta-Hsia (+15th century), and Liu Thien-Ho, Ong Ta-Li, Li Hua-Lung and Wan Kung (+16th) were all famous, but their acknowledged past-master was Phan Chi-Hsin about whom something has already been said.

How far would now be called river-training was included in their art is a question in need of deeper study than we have been able to devote to it. Revealing accounts are to be found in the sources however, and we would guess that the empirical knowledge was very considerable. For example, in +1015 an imperial edict laid down that in certain sections the depth of the Pie Canal was to be no less than 7 ft. 5 in., but the greatest reputation was won by Chia Lü, then Vice-Director of the Court of Imperial Sacrifices, urged that 5 ft. would be enough as long as an average breadth of 50 ft. was adhered to. Besides towpaths (tso tao) he made 'horse-heads' (ma-thou'), i.e. jetties, groynes or spurs, and 'towards the secluded parts of the banks where the water was shallow, he made saw-teeth (chi-yú) in order to restrain (or control) the force of the water (i shu shii shih)'. Elsewhere we encounter the same objects, together with wooden piling along the banks (ma an'), with the purpose of restraining the current and protecting the embankments (tsii shii shih hu thi'). The simplest interpretation of these works would suggest river-training projections or spurs, submerged or clear-standing, placed suitably to direct the force of the current away from the concave eroding bend so as to scour the shoals on the convex side, with the result of saving the banks and improving the fairway for vessels. An abundance of such deflecting groynes, semi-diagrammatically drawn, can be seen in Figs. 867, 902 (pls.). All this was certainly standard practice during the Ming and Chihing.

(v) Sluice-gates, locks and double slipways

After it was realised that water, even on a large scale, could profitably be made to run along channels between permanent ridges, the need must soon have been felt for some kind of obstruction which was not permanent, but readily movable at will. Thus did the water-gate come into being. From the irrigation and flood-control function of hydraulic works derived the sluice-gate, while their transportation function gave rise to the lock-gate. The only essential difference between the two is that the latter must be so built as to allow the passage of shipping. In elucidating the invention of the lock several stages have to be considered, first the placing of widely spaced 'flash-lock' gates along canals or canalised rivers, then the appearance of the pound-lock not much longer than the barge or boat which it is intended to raise and lower (an arrangement which obviously greatly reduces the time which the boat must wait while the water-level changes before it can proceed); and finally, improvements to pound-locks, such as the mitre type of gate construction, closing so as to oppose maximal strength to the current, or ground sluices, or side ponds.

It may be significant that no mention of gates occurs in the Shih Chi, either in the chapter on rivers and canals, or elsewhere. But in the Chihhien Han Shu there are references, some of which we have already quoted. In the last few decades of the -1st century (c. -36) Shao Hsin-Chhen incorporated a number of sluice-gates (shui men) in his Chhien-Lu dam (p. 280 above) and canals near Nanyang. Moreover, the following speech of Chia Jang in -6 shows that the use of gates could not have been a new idea at that time. As we have already seen (p. 233) the emperor had issued an edict inviting useful suggestions about the control of the Yellow River and Chia Jang submitted a written memorial containing three plans in preferential order. His second alternative was a network of irrigation canals.

Now we can make [he said] a dyke of stone from Chhi-khou eastwards and build many sluice-gates (shih men)... I fear that critics may think that the (Yellow) River is too large to be controlled. However, we can predict (our chances) by (our experience of) the Pien Canal (Tshao Chhi) at Jung-yang. There the lock or sluice gates were built only of wood set into the earth (dyke); and yet they lasted for a long time without being destroyed. Now if we build stone dykes in this place, where there are firm foundations, we shall certainly be safe. The (derivation) head (gates) of the canal at Chichow should be modelled on those at Jung-yang. The proper way of controlling the flow in canals involves more than merely digging out earth ... During the dry season, the lower or eastern sluice-gates should be opened to divert and drain away some of the river ....

For our purpose it is not necessary to examine the details of the system which Chia Jang proposed; the point is that he envisaged sluice-gates large and small, set in stone piers, the system being operated in the Sui period (581-618)....
28. CIVIL ENGINEERING

not as a new suggestion, but as an improvement on wood and earth ones which had long been used. How far back the practice dated from remains uncertain. Nor is the silence of the Shih Chi conclusive, for it says nothing directly about the 'Magic Canal' of Shih Lu (see pp. 209 ff. above). It is true that the first definite evidence of flash-lock gates which we have for this canal is from the +9th century, and pound-locks were certainly established flash-lock gates along the Pien Canal in the -2nd or -1st centuries, and perhaps also at various points along its course, there remains always a

The whole pattern of the countryside was whelmed in the midst of the river. There is no need to labour this, but a few more touches may be brushed in. When the emperor Ming Ti inspected the repaired Pien Canal in +70, the work of Wang Ching, he issued an edict reading in part as follows:1

Since the (dykes at the opening of) the Pien Canal burst, more than sixty years have elapsed. During some of this time the rains have not confined themselves to their proper seasons. The stream of the Pien encroached eastwards, conditions worsening day by day and month by month. The old emplacements of the flash-lock gates (shih mai3) were all forlorn in the midst of the river. Vast sheets of water overflowed so that one could not recognise where the banks had originally been. The whole pattern of the countryside was whelmed in chaos. But now (the workers) have rebuilt the dykes, repaired the canal, cut off the waters, and established flash-lock gates (li mai3). The (Yellow) River and the Pien Canal (Canal) flow separated and are again in their old beds... Therefore (We) have sacrificed excellent jade and pure animals to the Spirit of the River.

This makes clear the fact that at least by the end of the -1st century there had been flash-lock gates along the Pien Canal, and that Wang Ching restored them and increased their number. Then seven centuries later it is interesting to find in the MS. Ordinances of the Thang Department of Waterways many articles dealing with sluices and flash-lock gates. One reads: 'To the east of Lan-thien where there are water-mills, the mill-owners should be made to construct gates to regulate the flow of water, and allow free passage along the waterway (for traffic).' This belongs to +737, but it was just the arrangement in +16th- and +17th-century Europe, where mill weirs were accompanied by stanches or flash-lock gates to permit vessels to pass up or down stream.2 The 'flash' of water released by opening the gate was often essential for taking a barge over the shallows lower down, but after opening there might be a wait of a couple of hours for the 'abatement of the fall' before a barge could go up.3 The Lan-thien Canal was built in +623 by Yen Hsia4 in connection with a road across the Chihling Mountains still more easterly than the Tzu-wu Tao described above (p. 22). It was in effect the canalisation of an upper tributary of the Chhant River (cf. pp. 150, 335), which brought boats down to the close outskirts of Chiang-an.

There are plenty of poetical references to flash-lock gates in later literature. Thus about +1200 Song Tsu5 has a poem written beside a river or canal near a temple at Ling-yin Shan, when the gate was opened to let a sampan through, the water came pouring down with a thunderous noise.6

In the seventeenth century foreign travellers began to take notice of the flash-lock gates in use on the Grand Canal and other Chinese waterways,7 and there are many graphic nineteenth-century descriptions.8 The practice was to haul vessels through upstream, generally with manned capstans and tow-ropes, against currents of as much as nine or ten knots, and in the reverse direction to let them 'shoot the rapids'. In Fig. 918 (pl.) we reproduce the drawing appended to Staunton's account of the Macartney embassy of +1793.

There is no doubt that throughout Chinese history the most typical form of sluice- and lock-gate was what is called the stop-log gate. Fig. 919 shows a small field example of it from the Thien Kung K'ai Wu, and Fig. 920 (pl.) the larger version used for flash-locks in canals and canalised rivers.9 Two vertical grooves fashioned in wood or stone face each other across the waterway, and in them slide a series of logs or baulks, let down or withdrawn as desired by ropes attached to each end. Windlasses or pulleys in wooden or stone mountings like cranes on each bank helped to fit or remove the gate planks. This system was sometimes improved by fastening all the baulks together to form a continuous surface and then raising or lowering it in the grooves by means of

a Hence perennial conflicts between millers and transport officials, often echoing in the dynastic histories (cf. Sung Shih, ch. 94, pp. 73, 85, for +1082; ch. 96, p. 74, for +1097). We have already touched upon this matter (cf. Vol. 4, pt. 2, p. 402).
6 Cf. Macartney (I), pp. 169 ff.; (2), p. 268; Staunton (I), figs. 34, 35; Davis (I), vol. 1, pp. 141, 143. Dr Herbert Chatley told me that he had often waited at the gates on Chinese canals, commonly placed about a kilometre apart.
7 Cf. Lecomte (I), p. 104; de Navarrete (I) in Cummine ed. vol. 2, pp. 225 ff.
8 Cf. Skempton (5). An example of a similar kind, but with what was probably a pound-lock, will be mentioned on p. 354 below.
9 Ch. 1, p. 158. The oldest illustration of this kind that we have found is in the Nung Shu, ch. 18, p. 48, the date of which (+1313) deprives Jacopo Mariano Taccoli of the honour of having been the first to illustrate a dam with a sluice-gate (MS. of +1435) given him by Sarton (I), vol. 3, pp. 151a-khai chafang san-pan.'
10 Attention may be drawn in passing to the gangway which was rolled across the gangway which was rolled across the channel on grooved rails; this seems not to have been noticed so far by writers on the history of railways, e.g. Lee (1). Further description in Gandar (I), p. 59. Cf. also pp. 153 above.
11 Hence perennial conflicts between millers and transport officials, often echoing in the dynastic histories (cf. Sung Shih, ch. 94, pp. 73, 85, for +1082; ch. 96, p. 74, for +1097). We have already touched upon this matter (cf. Vol. 4, pt. 2, p. 402).
12 From How Han Shu, ch. 106, p. 73, we know that Wang Ching established one every 10 li. From p. 270 above we can see that he must have built at least 202 gates, quite a considerable operation. His interest in this technique is shown from the fact (p. 68) that he had a yan liu fa (method of measuring out the flow), which Wang Wu, the Inspector-General of Works (Chiang-Tao Yeh-Chi4), also used. These flash-lock gates were further strengthened with stone abutments in +171 (Sung Shih, ch. 93, pp. 172 ff.).
13 In +71 he was made Inspector-General of Rivers and Dykes (Ho-Thi Yeh-Chi4). Besides rich presents of silk and money, chariots and horses, the emperor presented him with a number of books, including the Shan Hai Ching (cf. Vol. 3, pp. 103 ff.), the Ho Chhau Shu, i.e. Su-ma Chhien's work on the rivers and canals now incorporated in the Shih Chi, and a set of maps illustrating the 'Tribute of Yu' chapter of the Shu Ching entitled Yu Kung Thu.
14 Nos. 1, 2, 4, 6, 7, 8, 10; see Twitchett (2).
counterweights on the ends of the cables. Pulleys mounted on stone crane arms, obliquely set, can still be seen at many places, e.g. at Kao-pei-tien near Peking (Figs. 921, 922, pls.). That grooved gates were nearly always used is suggested by many of the illustrations in the *Hsing Shui Chin Chien* (e.g. Fig. 908), where grooves are shown in plan to mark symbolically the location of locks and sluices. Apparently gates swinging laterally, such as those familiar to us because usual in European practice, were not employed in China until modern times. Today, however, counterweighted steel shutter gates rising and falling after the Chinese style are used on waterways all over the world.

Fig. 910. The stop-log gate. A small example in a dyke, hence the caption pet, forming part of a minor irrigation system. From the *Thien Kung Khi Wu* (+ 1637), in versions after + 1726.

The simplest name for water-gate in Chinese literature is just that, *shui mên*. As time went on, many other terms were introduced, e.g. *tou mên* (dipping gates), and then *tou mên* (sudden declivity, or 'head of water' gates), the latter arising, it might be permissible to infer, at some time when a difference of levels between 10 ft and 20 ft made the structure particularly impressive. We also find the term *cha* for a lock (etymologically, armour in a gate), and *pan cha*, a lock-gate made of boards, i.e. a stop-log gate. Then comes *chha* (or *cha*), an 'inserting' gate, the phonetic being an old word for a grain-husking pestle and mortar, *K631*, with its combinations, *thi chha* (a gate in a dyke), *tsiu chha* (a gate for water), and *pa chha* (a gate in a dam). The term *hsian mên*, or 'hanging gate', first found (so far as we know) in + 584, is significant as indicating the permanent installation of windlasses. Indeed it is interesting to study the whole course of chronological distribution of these technical terms. There can be no doubt that *tou mên* was the most ancient phrase, current in the Han and San Kuo periods but not much used thereafter. The expression 'dipping gate' (*tou mên*), which followed, became obsolete in its turn by the + 14th century. All these could be used indifferently for sluices and flash-lock gates. In the Sung period, about the beginning of the + 11th century, *cha* and *chha* both make their first appearance. They do so just about the time of the invention of the pound-lock, but the correspondence seems to be coincidental. The term *tou mên* is tardy in general use, if not in first

* See, e.g., *Chien Han Shu*, ch. 29, p. 155 b, ch. 89, p. 148. *Chih Hou Han Shu*, ch. 2, p. 154 a, ch. 106, pp. 6a ff. The term is used for the sluices in *Min Ai* (1) damas, r. + 235.

* See, e.g., the M.S. Ordnances of the Waterways Department of + 727 (tr. Twitchett, 2). The term is quite common in Thang texts. The *Shu Han Chih Nan* (+ 1120), ch. 14, p. 69, defines the use of sluices (*tou mên*) as 'gathering the waters and releasing them according to the seasons' (*chih chih chung hsieh*), a phrase which occurs in the biographies of Kao Yu (*Chiu Thang Shu*, ch. 162, p. 78, *Hsin Thang Shu*, ch. 171, p. 6b), who in + 768 built 1350 li of irrigation reservoir embankments. *Chang Ya Lin*, ch. 3, p. 29b, on canal sluices at the capital. The early + 13th-century *Ssu Chhao Wên Chien Lu*, ch. 2, p. 46b, tells of a city canal with sluices or flash-locks in + 208 at Chiang-chêi. About + 1100 Lu Yu says that there were more than 170 *tou mên* sluices in the Chungkou canal system (*Lao Hsia An Pi Chi*, ch. 5, p. 15a). In the *Chi Shan Chi* (ch. 4, p. 1a) there is a description of eight flash-lock gates built by Wang Ling-Chih in a canal in + 1202, and rebuilt as *pa chha* with 24 stop-log baulks each by Phi Hou-Yuan in + 1395. The term *tou mên* is used for sluices set up by Hsieh An in connection with double slipways on the Shan-yang Yin-Tao section of the Pién or Grand Canal as early as + 138.

* According to *Chiu Chin-Shuang* (1), the word was originally a verb meaning to open a closed door.

* In ancient texts the word means a wooden partition.

* *Cha* is found in MCTP, ch. 12, par. 1, the passage translated immediately below, i.e. +1066 referring to + 1025, on pound-lock gates. Flash-lock gates on the Pien Canal are mentioned repeatedly in travel diaries, e.g. in + 1169 the *Pi Hsing Hsü Lu*, ch. 2, p. 130 a, and in + 1170 the *Jui Shu Chi*, ch. 1, pp. 30b, 78a, 10a. Some of these may well have been pound-locks. But the term is also clearly applied to sluice-gates, as in an irrigation system in Changtsu c. + 1200, by Kung Ming-Chih in his *Chong Wu Chi Wen* (ch. 1, p. 140), and for the gates controlling the lake levels at Hangchow around + 1270 (*Wu Lin Chiu Shih*, ch. 5, p. 23a, and *Ming Liou Lu*, ch. 11, p. 140). A similar usage occurs in connection with watercourses near Kweilin c. + 1385 (*Chhao Ye*, ch. 2, p. 18b). *Chha* is rather less common, but lock-gates in *Shu Shih*, ch. 91 ff., are often so termed (+ 1345). An early + 13th-century occurrence is in *Fung Chhunng Hsiao Tu*, ch. 1, p. 12a, which tells how the egregious Chu Mien (*cf. Vol. 4, pp. 201, 202) broke down lock-gates and bridges in transporting huge pieces of stone to the capital in + 1213 for Hu Tsung's gardens and collections. Cf. the painting reproduced in Paris (1), vol. 1, pl. 59.
occurrence,^ rather rare before the Ming. Amidst much terminological fluctuation it is hard to ascertain whether precise technical differences were at any time implied by the different words, and if so what they were. Possibly cha, or at least chha, meant stop-log gates with permanently fitted windlasses, as opposed to the simpler forms in which each bar had to be manhandled in and out of its grooves.® In the absence of any qualification of the terms, flash-lock gates may generally be assumed (unless the context indicates pound-locks clearly), for in the description of the latter further adjectives enter in, as we shall see.

The invention of the pound-lock is a question of substantial importance in the history of civil engineering. Industry and commerce in palaetechic Europe were greatly affected by the simple and convenient device of arranging gates so close together as to admit only one or two barges, changes of water-level taking thus a minimal history of civil engineering. Industry and commerce in palaeotechnic Europe were hard to ascertain whether precise technical facts it is possible to show that the pound-lock actually originated in China earlier than civilisations. The fact that foreign travellers on the Grand Canal from the seventeenth to the nineteenth centuries spoke only of flash-lock gates or double sluipways® has seemed to some sufficient evidence that pound-locks were never developed in China. But this would be to fall into the trap of supposing that inventions once made were necessarily utilised in Chinese culture whether or not the need for them continued. In fact it is possible to show that the pound-lock actually originated in China earlier than anywhere else, but was little used in later times because the need for the device ceased as conditions changed. We may be able to suggest how it was that this happened.

The oldest example of a pound-lock or locks in China dates from the beginning of the Sung dynasty, and is connected with the name of Chhiao Wei-Yo,ä Assistant

28. Civil Engineering

Commissioner of Transport for Huai-nan in +983, a man who deserves to be remembered. He was concerned with the barge traffic problem at the northern end of the Shan-yang Yin-Tao section of the Pien or Grand Canal between the Yangtze and Huai-yin, and it is interesting to find that his invention arose from a social cause, his exasperation with the thefts of tax-grain made possible by the high casualty-rate of ships crossing the double sluipways. The Sung Shi$h$ says that in +984:

Chhiao Wei-Yo also built five double sluipways (lit. dams, yes?) between An-pei and Huai-shih (or, the quays on the Huai waterfront). Each of these had ten lanes for the barges to go up and down. Their cargoes of imperial tax-grain were heavy, and as they were passing over they often came to grief and were damaged or wrecked, with loss of the grain and peculation by a cabal of the workers in league with local bandits hidden near by.

Chhiao Wei-Yo therefore first ordered the construction of two gates (tou men?) at the third dam along the West River (near Huai-yin). The distance between the two gates was rather more than 50 paces (250 ft.), and the whole space was covered over with a great roof like a shed. The gates were 'hanging gates' (hsuan men?); (when they were closed) the water accumulated like a tide until the required level was reached, and then when the time came it was allowed to flow out.

He also built a horizontal bridge between the banks, and added dykes of earth with stone revetments to protect their (or its) foundations. After this was done (to all the double sluipways) the previous corruption was completely eliminated, and the passage of the boats went on without the slightest impediment.

Such were the first pound-locks in the history of any culture. Large enough to take several vessels at a time, they must have been somewhat similar to those depicted in a well-known illustration by Zonca in +1607 showing a lock basin on the canal which connected Padua with the River Brenta. With hanging or 'portcullis' gates, they must have resembled more or less those drawn as flash-lock gates in another familiar picture, the canalised river of the Laurenziano Codex produced about +1475. The arrangement implies pulleys, windlasses and perhaps counter-weights.

Contrary to an impression that has sometimes prevailed, Chhiao Wei-Yo's pioneering led to a great wave of interest in the new technique. This we know partly from an informative passage in Shen Kua's Meng Chi Pi Than, finished in +1086. In this book, so often quoted by us,® he says:

On the Grand Canal (the Pien Canal) in Huai-nan, double sluipways (tair) were built to prevent wastage of water. No one knows when this method was first invented. According to

* One finds it in the description of Sung Lu’s water-supply gates (cf. p. 316 above), Ming Shih, ch. 87, p. 56; as also in the account of the pound-locks on the approaches to the Ling Chhi (cf. p. 306 above) written c. 1485 (in ChhYa, ch. 2, p. 21 b). But it also occurs in MSCP. ch. 24, para. 10, with reference to irrigation sluice-gates from the Pien Canal, and apparently even in a 'T'hang inscription there (cf. p. 231 above).

* Wang Pi-Wen (x) has given us an interesting account of the regulation methods of the Chhings for designing locks and culverts. All the former were stop-log types.

* Shortage of water in the upper levels was a chronic malady of the medieval Chinese canals. Sometimes it was necessary to have recourse to batteries of square-pallet chain-pumps (cf. Vol. 4, pt. 2, p. 339), 'pedalling up the water' from the neighbouring land to let the boats pass, hence the expression chiu shu chia (see Sung Shih, ch. 96, p. 59, for a case in +1089, and p. 108, note a, for another in +1120; cf. Chhng Chao-Ching (2), p. 210). It was said that 'water was like gold' (loc. cit. p. 1 b), and gates were allowed to be opened only once in three days. The expression jue shu so (here also found, may mean that at some pound-locks chain-pumps mounted on pontoons were permanently stationed, and water returned to the upper level at each passage.

* A graphic account of +1689 will be found in Lecomte (1), pp. 104 ff., he disliked the flash-lock gates but rather admired the double sluipways. So did Dr Dinsdie, in a note which Ambassador Macartney (+1793) appended to his Observations (a), p. 286. There are many references to the flash-lock gates in his Journal, (1), pp. 169, 171, 173, etc. He speaks of 'sluices and bridges of singular workmanship and beauty'. Occurring, he says, at the distance of one another, the sluices 'properly form locks of that distance. The boats collect in great numbers at the sluice, the valves open, and in a few minutes the whole fleet passes through; the flood-gates are then let down and the canal soon recovers its former level.' For Dinsdie on flash-lock gates see Preudfoot (1), p. 59 ff.

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* Ch. 307, pp. 1 b ff., tr. auct.; cf. ch. 96, p. 1 b. See also Chhng Chao-Ching (1), p. 207.

* So acknowledged by Skempton (a), p. 439, following valuable discussions between Professor Skempton and ourselves in 1955.

* Cf. Beck (1), p. 316; Parsons (a), p. 396; Forbes (17), fig. 625. See also Skempton (a), p. 451, and +16th-century locks in figs. 284, 285.

* Cf. Parsons (2), fig. 132; Forbes (17), fig. 626; Skempton (a), fig. 281. This codex (Ashburnham no. 361), entitled 'Trattato dei Ponti, Levi e Tirari', has MS. notes in Leonardo's own hand. It is now considered the work of Francesco di Giorgio (fl. +1464 to +1497) whom we meet elsewhere in other connections; cf. Poppini (1), vol. 2, pl. 292.


* Ch. 12, para. 1, tr. auct.; cf. Hu Tao-Ching (1), vol. 1, pp. 432 ff.; Fang Chi (2), p. 53. See also Hu Tao Chhng Chien Chiang Pien, ch. 104, p. 834A.

* At the southern end and intermediate points on the Shan-yang Yin-Tao section.
tradition the Shao-po\(^2\) (now Shao-po\(^3\)) double slipway was built by Hsieh Kung\(^2\) (i.e. Hsieh An,\(^3\) premier of Chin, in +388).\(^a\) But from the account of Li Ao\(^1\) (who described his journey over this part of the canal in +809) in his *Lai Nan Lu*\(^6\) (Record of a Journey to the South)\(^b\) it was still a plain waterway in Thang times without any haul-overs, so it seems impossible that this double slipway was built in the time of Hsieh Kung.\(^c\)

In the Thien-Sheng reign-period (+1023 to +1031), the Transport Commissioner and Palace Intendant stationed at Chen-chou\(^7\), Thao Chien,\(^8\) suggested that 'double gates' (fu cha\(^9\)) should be built both to prevent waste of water and to save the labour of hauling the barges over. At that time the Director of the Ministry of Works, Fang Chung-Hsin,\(^10\) and the Fine Craftsmanship Bureau Commissioner, Chang Lun,\(^11\) were appointed as Chief and Deputy Industrial Transport Commissioners respectively, and were authorised to proceed with the construction (of double gates). They began with the locks (cha\(^9\)) at Chen-chou\(^7\).\(^f\) (It was found that) the work of five hundred labourers was saved each year, and miscellaneous expenditure amounting to 1,250,000 (cash) as well. With the old method of hauling the boats over, burdens of not more than 300 tan of rice per vessel (21 tons) could be transported, but after the (double) gates were completed, boats carrying 400 tan were brought into use (28 tons), and later on the cargo weights increased more and more. (Nowadays) Government boats carry up to 700 tan (49t tons), and private boats as much as 800 bags each weighing 2 tan (i.e. 1.13 tons).

From that time onwards, at Pai-shen, Shao-po, Lung-chou and Chu-yü, the double slipways were all disused, and one after another replaced (by double, i.e. pound-lock gates). The advantages of this have continued down to the present day.

Once during the Yuan-Feng reign-period (+1078 to +1085) I myself passed through Chen-chou, and saw an overturned monument lying among dungheaps at the back of the River Pavilion. This stele bore an inscription by Hu Wu-Phing\(^12\) about the (first) building of the Chen-chou (double) lock gates, entitled *Shui Cha Chi*\(^13\). It was not very detailed but it did record the affair.

Hu's inscription, more poetical than precise, has in fact been preserved,\(^h\) and we can share to some extent Shen Kua's disappointment at its lack of technical information. He starts with a concealed reference to Chhiao Wei-Yo, saying that in the first decades of the dynasty those concerned with canal traffic were becoming extremely dissatisfied with the double slipways worked by ox-whim capstans (niu tai\(^14\))\(^i\), and the water wastage of the flash-lock gates which led in most years to the drying-out of the canal so that it looked like a thousand-li wall. But after Thao Chien insisted that double gates

\(^a\) Cf. Chêng Chao-Ching (1), p. 197.
\(^c\) In spite of Shen Kua's scepticism, there is good ground for believing that Hsieh An's nephew, the general and philosopher Hsieh Hsian,\(^8\) built 7 double slipways on the Ssu River section of the Pien Canal in +384. Cf. p. 363.
\(^d\) Mod. I-ching\(^16\) on the Yangtze upstream of Yangchow and Kuachow (cf. p. 309).
\(^e\) Etymologically, fu is the lining, the doublure, of a garment.
\(^f\) Presumably those at Kuachow connecting the canal with the Yangtze, which varied considerably in level.
\(^g\) His primary name was Hu Su.\(^19\) An official meritorious for building schools and conservancy works, he was also a naturalist with views on earthquakes, and took an interest in alchemy, which he studied with a monk.
\(^h\) In ch. 35 of his collected works, reproduced by Hu Tao-Ching, loc. cit. p. 435.
\(^i\) Witness also an eloquent speech by Chhiao Tsung\(^18\) in +1028 (Sung Shih, ch. 99, p. 16).

Fig. 815. Chariot and horseman crossing a pile-and-beam bridge with balustrade; scene on a moulded brick of Han date from Chhêngtu, Szechuan (Anon. 22). Cf. pp. 150 ff.
Fig. 816. The Feng R. bridge near Sian to the north-west, a pier-and-beam structure of Han type (orig. photo., 1964). Each pier consists of three pairs of pillars built of stone cylinders like threshing-rollers, and based on three discoidal roller-mill base-plates (hidden in the photograph by later added concrete), these in turn supported on cypress piling.

Fig. 817. Detail of the Feng R. bridge (orig. photo., 1964). Each pair of columns is capped by an oblong stone plate, bearing two transverse wooden beams upon which the nine longitudinal beams of the deck are laid.

Fig. 818. A wooden beam bridge the centre span of which is topped with a pavilion. This type of structure, humped slightly to facilitate the passage of craft under the central span, was perennial through the ages in China; the present example is from a painting by the eminent Southern Sung artist Hsia Kuei (+1186 to +1230). Anon. (32).
Fig. 819. A stone beam bridge near Hangchow (photo. Mirams).

Fig. 820. Combination of nine stone beam spans and an arch; the Thai-Phing bridge over the Grand Canal extension near Shao-hsing in Chekiang (orig. photo., 1964). The arch has a particularly elegant T-shaped double staircase giving access from the towpath.

Fig. 821. Megalithic beam bridges of south-east China; the Chiang-Tung or Chhien-Tu bridge across the Chiao-Lung R. upstream from Amoy in Fukien (photos. Ecke, 3). Built +1214 to +1237; length 1100 ft. Cf. pp. 153 ff. and Table 66.
(a) Stone beam span at the sixth pier, from the north-east.
(b) Another pier, from upstream (north-west).
Fig. 824. Horizontal-cantilever and strainer-beam bridge of six spans over the Lu-Shui R. at Li-ling in Hunan (photo. Boerschmann, 303). Cf. Fig. 823 on p. 153.

Fig. 825. Horizontal-cantilever bridge of four spans over the Lin-chhi R. north of Sun-chiang in northern Kuangsi (Anon. 37). This structure, the Chheng-Yang bridge, is notable for the elaboration of features also used elsewhere, the crowning of the piers by pavilions with many-tiered roofs, and the provision of a spacious roofed gallery over the deck.
Fig. 826. The great bridge at K'ai-feng in the scroll of Chang T'ieh T'uan, Ch'ing-Ming Shang Ho Thu (Going up the River at the Spring Festival), painted about +1125. Photo, Ch'eng Ch'en-To (J).

So far as is known, there are now no examples of this multi-angular soaring cantilever construction extant in China, but in pre-Ming times there seem to have been many. A towpath gallery can be seen under the bridge along the further abutment, and the stern-sweep of a great barge which has just passed under the bridge appears on the near side of the river. Cf. Fig. 823 and p. 165.
Fig. 829. An arch bridge at Khunshan (Quinsan) in Chiangsu, showing the ends of the shear-walls in the piers (photo. Mirams). See pp. 167 ff.

Fig. 830. A small arch bridge at Suchow in Chiangsu, illustrating the degree of deformation which structures with shear-walls can stand without collapsing (photo. Siren).

Fig. 831. The San-Hsing bridge at Wan-hsien in eastern Szechuan, a tall arch spanning a seasonal torrent and capped with a covered gallery (photo. F. T. Smith, in Carey, 2). A trace of pointedness is detectable.

Fig. 832. Bridge with three pointed arches north of the Sword-gate Pass (Chien-men Kuan) between Szechuan and Shensi (orig. photo., 1943).
Fig. 834. The Pao-Tai bridge (+865) alongside the Grand Canal south of Suchow in Chiangsu (orig. photo., 1964). It crosses an arm of the Thai-Hu Lake, and aroused the admiration of many foreign travellers from Marco Polo's time onwards.
Fig. 836. One of the Renaissance segmental arch bridges of Europe; the Castelvecchio bridge at Verona, built +1354 to +1357. Longest span, 160 ft. From Uccelli (1), p. 288, fig. 65.

Fig. 837. A modern railway bridge with arches in the spandrels, like Li Chhun's. The bridge at Salcano in Italy (now Slovenia, Yugoslavia), near Gorizia north of Trieste, built c. 1900; span just under 280 ft. From Uccelli (1), p. 694, fig. 92. This graceful segmental arch was destroyed in the first world war but afterwards reconstructed. During the twenties and thirties many beautiful variations of the same design were built all over the world in ferro-concrete.

Fig. 840. A Chinese segmental arch bridge of the +12th century, the Yung-Thung bridge near Chao-hsien in Hopei, built by Phou Chhien-Erh in +1130 under the J/Chin dynasty. Span 85 ft. From Mirams (1).

Fig. 841. The Lu-Kou bridge across the Yung-ting R. a short distance west of Peking, at the small town of Lu-kou-chhiao, to which it gives its name. About 700 ft. in length, it is carried on 11 segmental arches with an average span of 62 ft. each (photo. Siren, 1). This was the bridge which Marco Polo thought the finest in the world, partly because of its breadth and the elaborate carving of its stone balustrade; in modern times foreigners in China have called it after him. In 1937 it was the scene of incidents which started the Sino-Japanese hostilities preluding the second world war. The bridge is still in heavy use for general traffic, though built in +1189 under the J/Chin dynasty as part of their improvements of the metropolitan area.
Fig. 842. The earliest forms of suspension bridge; a double rope bridge at Lo-ta (Lo-ndu) crossing the Mekong in Nakhki country (northern Yunnan), from Rock (4), pl. 152. Here the separate cables are arranged so that their arrival points are much lower than their points of departure, crossing being effected by the attachment of men or animals to tubular runners of bamboo or wood greased with butter or oil. The runners are then returned by means of a separate cord. See pp. 184 ff.

Fig. 843. The suspension bridge approximating to a cable railway; a crossing on the Tibetan border. The two ends of the bamboo cable are at approximately equal heights on each side of the river, and the tubular runner carries a kind of rope cradle to support the passenger, as well as cords on each side to pull it to and fro. The photograph was taken in the course of a Chinese scientific expedition to the border country about 1947 led by Dr Tseng Chao-Lun. The botanist, Dr Phei Li-Chhin, is beginning the crossing, advised by one of the local tribesmen.

Fig. 844. A vine or creeper bridge characteristic of Yunnan and the Burma border. Two bamboo cables form the handrails and a third the deck or tread-ropes, then creepers are thickly plaited so as to form a walking way of V- or U-shaped cross-section.
Fig. 846. The bamboo-cable suspension bridge at Kuanhsien in Szechuan, crossing the Min Chiing (cf. Fig. 884). One of the bridge-head buildings (west side), from which the hand-rail cables can be seen issuing on the right (photo. Boerschmann, 3/a). Cf. pp. 192 ff. and Fig. 884 on p. 290.

Fig. 847. Four of the capstans for the rail cables within the bridge-head building on the east side (orig. photo., 1958). The deck cables themselves are tightened by winches underneath the floor-boards.

Fig. 848. General view of the An-Lan suspension bridge at Kuanhsien, with its eight major spans, totalling rather over 1050 ft. in length (longest span, 200 ft.), taken from the hill overlooking it to the east (orig. photo., 1958).
Fig. 849. A closer view from nearer water level, showing the nature of the decks and the capped trestle piers (orig. photo., 1958).

Fig. 850. View on the Kuanhsien An-Lan suspension bridge looking eastwards along the eastern-most span (orig. photo., 1958). The fastenings of the hand-rail cables and deck planks are clearly seen.

Fig. 851. Under surface of the An-Lan suspension bridge; the fourth span from the east, photographed from the island (orig. photo., 1958).

Fig. 852. The Chi-Hung iron-chain suspension bridge in one of the gorges of the Mekong R. (photo. Pepper, FZ 287). With its bridge-head anchor-houses towering out of the swirling waters, the taut catenary of its deck, and the temples to the tutelary deities of the place visible on the left, it again affords an example of the beauty of traditional Chinese bridge-building. Cf. pp. 193 ff. and Table 68.
Fig. 853. A small single-span iron-chain suspension bridge over a tributary of the Chin-Sha Chiang, at Chi-tsu Shan near Pin-chhuan in Yunnan. Here the hand-railing is all of woodwork.

Fig. 854. A traditional iron-chain suspension bridge of the Chhing period, the Chin-Lung or Tzu-Li bridge (Dsi-Li Shu-er Nido in Nalchi) linking Lichiang with Yungpei across the Chin-Sha Chiang (the Yangtze) in Yunnan (from Rock (1), pl. 111). Eighteen chains carry the road across a single span of 328 ft. The great river is here running at an altitude of 4600 ft. and the masonry of the bridge-heads is built up, as can be seen, to withstand an annual rise and fall of some 60 to 70 ft. or more.

Fig. 856. The invention of the flat deck suspended from the catenary; the suspension bridge across the Brahmaputra at the Chak-sam-chii-lamaery, Tibet, first built in about + 1420.

(a) Photograph from the south, c. 1900. The river having flooded the flat ground beyond the island, the bridge was out of use and the deck had been removed.

(b) Drawing made in 1878 when the bridge was in full use.

Both taken from Waddell (1).
Fig. 858. A more or less imaginary drawing of the Lan-Chin bridge near Ching-tung in Yunnan, over the Mekong R. (actual span c. 250 ft.), set among alpine scenery, in an architectural work of the European eighteenth century, J. B. Fischer von Erlach' Historia Architecur (1725), pl. 15. The oldest suspension bridges in Europe date from the two subsequent decades.

Fig. 864. Irrigated fields depicted in a Han tomb model of black pottery from Phêngshan (Chêkiang Provincial Museum at Hangchow, orig. photo., 1964). From the reservoir on the left, identifiable because of two fishes carved in the clay (not well visible here), a channel runs to the right between four fields in which are piles of rice-straw. It is led under the low embankments by two culverts, perhaps sluice gates.
Fig. 867. Part of the lower Yellow River conservancy shown in a scroll map of late Chching date formerly in the collection of Mr Rewi Alley. We are looking down on the northern course of the great river, course ④, in Shantung, from the north-west, with the large city of Chinan on the far side and two smaller cities on the nearer side, to the right Chi-ho and downstream to the left Chhiyang. Dykes and embankments, often as many as three in parallel, are shown as dark bands, and especially along the further (south-eastern) shore they generate an abundance of masonry groynes, some long, some short, designed to prevent bank erosion. Opposite Chi-ho a tributary, the Wang-fu Ho (now called the Leshui) falls into the river. The depots (Ho Fang Ying) of the Conservancy Authority are shown as square enclosures with a symbolical phai-lou in front and a flag on a flagpole; no less than eight of them can be seen along this stretch, mostly on the further shore. Photos. Alley, kindly communicated. See pp. 220, 232 ff.

Fig. 868. Part of the middle Yellow River conservancy shown in a scroll map of Chching, possibly late Ming date, formerly in the collection of Mr Rewi Alley. We are looking down on the great river from the south, as it flows towards the right of the picture; to the west one sees the mountains of western Honan and Southern Shanxi. The famous Sun-sets Hsia gorge (cf. p. 374 and Figs. 875, 881) is just outside the field of view to the left. In the left half of the picture the Lo River and its tributaries enter the Yellow River from the south, with the ancient capital city of Loyang between the two. Continuing to the right, south of the Yellow River, one can make out the origin of the old Pien Canal (cf. pp. 269, 307), conspicuous because crossed by three bridges, while the old granary centre of Jung-yang (cf. p. 270) lies half-way between the Lo and the Pien. Above the Yellow River to the north the remains of the complicated Chhin-Wei navigations (see p. 316) are to be seen, with captions recalling that the water of Chhin from the Shanxi mountains found its way artificially to the Yellow Sea at Tientsin; this had been the northern part of the Sui Grand Canal. At the join of the two blocks comes the largest city shown, the Sung capital of Khaitung. In the right-hand half of the picture we see in the south the many almost parallel rivers that flow through Honan and Anhui to the Huai R., and noticeable is the fact that the Yellow River accompanies them, that is to say, it is flowing in its great southern stream on course ⑤, passing such towns as Yu-chiheng, Hsia-i, etc. Directed north-eastwards diagonally is the northern bed, course ⑥, smaller or almost dry when the map was made, and with an opening barred, or at least controlled, by six successive embankments; yet now again the main bed (see Table 60). As in Fig. 867 the Yellow River is seen almost throughout its length cribbed, cabined and confined within massive dykes, in some places as many as eight in parallel. These are denoted by thin black lines, joining occasionally with thin ladder-like thickenings along the river's edge; this difference in convention seems to indicate earthworks as opposed to masonry, judging by a caption just to the right of the junction with the north-easterly course. All cities are indicated by walls and gates, and a number of forts, passes, and places of historical (especially Confucian) interest, are shown. Photos. Alley, kindly communicated. Cf. pp. 220, 232 ff.
Fig. 871. Erosion in the loess country of North-west China. An air photograph of the north bank of the Yellow River east of Lanchow (photo. Fisher, 1).

Fig. 873. Typical rice-field terracing in Szechuan (Anon. 26).
Fig. 874. The oldest of three 'six-character teachings' at the temple of Li Erh-Lang at Kuanhsien (orig. photo., 1938). Placed in a commanding position on the monumental stairway, it reads: *Shen thao thun, it jiu yen*—'Dig the channel deep, and keep the dykes and spillways low'. See pp. 255-256.

Fig. 877. The genius for man-power organisation illustrated by a photograph of work at the Ming Tombs Reservoir Dam in June 1958 (orig. photo.). Although two belt conveyors can be seen in the middle of the picture, and a few bulldozers on and near the crest of the barrage, with cranes, and inclined planes for light railways, in the background, and although several lines of larger light railways were bringing up material hauled by steam locomotives outside the picture to the right; a large proportion of the total work was being done, in fully traditional style, by manual labour. The successful use of this necessarily involves a perfection of assembly control and spontaneous discipline. Cf. p. 144.
Fig. 878. The Ninghsia irrigation system, first begun in the Chhin period, shown in a scroll map of Chhing, possibly late Ming, date, formerly in the possession of Mr Rewi Alley. The view is taken from the east, and the Yellow River is flowing northwards, i.e. from left to right. The whole irrigated area, some 100 miles in length, is circled to the west and north by the Alashan Mountains and the Gobi Desert, to the east, this side of the river, by the Ordos Desert. Bounding it on the south, the Great Wall approaches from the east, as seen in the bottom of the picture, enclosing several small walled towns such as Hsüng-chheng; then on the right it continues beyond the river across the end of the area, guarding Hsüng-lo city and resting on the Alashan (off the picture at the top left it continues down to the Lanchow salient). Outside the wall to the right (north) of Hsüng-chheng encampments of Mongol yurts are seen. The river enters from the left, flowing past the towns of Chheng-wei and Kuang-woo into the defile called Chhing-thung Hsia (Green Bronze Gorge), here ornamented by many Buddhist stūpas. Immediately on emerging, it is made to give rise on the left bank to three main lateral derivative canals, the Thang-lai Chhth, the Hsien-ye Chhth and the Hui-nung Chhth, all of which rejoin the Yellow River about 100 miles downstream. Three much smaller and shorter ones take off from the right bank. Four important bridges cross the left canals soon after their origin, and about forty other named bridges are marked. Roads and paths are indicated by thin dotted lines. The most westerly canal, the Thang-lai, waters the capital city of Ninghsia itself. Many subsidiary channels are taken off from all of them, and six aqueducts convey some of the water of the Han-yen across the main course of the Hui-nung. Some half-a-dozen important sluice-gate sites are marked, and the four chief bridges already mentioned may well have been sluice-gates also. Between and among the canals a communicating system of 'lakes' is shown in darker colour; these presumably indicate low ground liable to flooding in seasons when the river is very high. One of the largest of these bears the name 'Thanks-to-the-Officials Lake' (Hsieh Kuan Hu). A large number of forts, villages, temples and pagodas are also marked. Each of the villages (paa) has a character inside it indicating to which city's jurisdiction it belongs. Near the derivations one can make out four Dragon-King Temples (Lung Wang Miao) dedicated to the god of the waters, so important for hydraulic projects; and beyond the wall, on the far right, where the river passes out between the Alashan mountains, there is appropriately a temple of the God of War (Kuan Ti Miao). Photos. Alley, kindly communicated. Cf. p. 272.
Fig. 880. A stretch of one of the trackers’ paths or half-tunnel towpaths cut in the rock-faces of the Yangtze gorges, here at the defile commonly known as Wind-box Gorge, above I-chiang (photo. Popper, RO/109/13). Those at Sun-mên Hsia on the Yellow River are closely similar. Cf. pp. 23, 277.

Fig. 885. The Min River and Kuanshien irrigation system head-works, a view looking upstream taken from the Jade Rampart hill (from Boerschmann (2), pl. 12, fig. 2 (3a), fig. 119). In the background, the heights of the Pa-lang Shan mountains. In the middle distance the Han-family island, and on the right the Thousand-foot Dyke; then the main division-head (the Tu-Chiang Fish Snout) and the suspension bridge. In the foreground the Diamond Dyke (Chin-Kang Thi) separating the Nei Chiang on the right from the Wai Chiang on the left, cut through by the “water-level adjusting spillway” (Phing-Shui Tshao). On the right the roofs of the temples of Li Erh-Lang and Lao Tzu can be seen among the trees. See pp. 288 ff.

Fig. 886. The Min River and Kuanshien irrigation system head-works, a view looking downstream taken from the hillside above the temple of Li Erh-Lang, the roofs of which can be seen nestling among the trees (orig. photo., 1958). The Nei Chiang is disappearing to the left round the Phoenix Nest Cliff of the Jade Rampart Hill into the Cornucopia Channel. Just beyond it there are the trees of the Li-Tui Hill hiding Li Ping's own temple. Below them the Jen-Tsiu Thi spillway is functioning, and nearer the spectator the broader expanse of the Fei-Shih Yen spillway, also in function, can be made out. Below him the upper part of the Nei Chiang is invisible because of the woods, but the Wai Chiang can be seen for a long stretch from right to left. See Fig. 884 on p. 290.
Fig. 887. The main division-head (Yü Tsui, or Tu-Chiang Yü Tsui) seen from the point where the suspension bridge crosses the artificial peninsula or island of the Diamond Dyke (orig. photo., 1958). Across the river, the Thousand-foot Dyke. See Fig. 884 on p. 290.

Fig. 888. Model of the Kuanhsien headworks in the exhibition-room of the Authority at the back of Li Ping’s temple on the Li-Tui hill (orig. photo., 1958). The Min river can be seen dividing near the suspension bridge into the Nei Chiang on the right and the Wai Chiang on the left. The Cornucopia Channel cutting is well shown between the old city walls to the right and the temple of Li Ping on the Li-Tui hill to the left. Li Erh-Lang’s temple appears to the right of the suspension bridge. On the extreme left the new intake of the Sha-Kou Ho and Hei-Shih Ho derivatory canals is indicated, while at the extreme right at the bottom we see the new sluice gates of the Tsou-Ma Ho derivatory canal. Cf. Fig. 884.

Fig. 889. Diagrammatic map of the Kuanhsien irrigation system painted on a wall of one of the buildings of the temple of Li Erh-Lang (photo. Richardson, 1942). The division of the Min River into the Nei Chiang and the Wai Chiang is shown at the top right-hand corner; the capital city of Chhengtu itself is seen within a U-shaped confluence of two canals about two-thirds of the way along the map to the left and about halfway up. The title reads: ‘Bird’s-eye view of the Tu-Chiang Yen Irrigation Area in Szechuan.’

Fig. 890. Cornucopia Channel, looking upstream from the terrace of Li Ping’s temple on the Li-Tui hill (orig. photo., 1958). The Phoenix Nest Cliff towers on the right; on the left the Flying Sands spillway is strongly overflowing.
Fig. 892. One of the temporary *ma chha* cofferdams used seasonally at Kuanhsien for clearing and dredging the beds of the Nei Chiang and the Wai Chiang; a model in the exhibition-room of the Authority (orig. photo., 1958).

Fig. 893. The set of three iron bars (wo thiêh) fixed in the bed of the Nei Chiang just opposite the Flying Sands spillway as a guide for the standard depth of excavation required (photo. Lowdermilk, 1943).

Fig. 894. The 'Trimetrical Classic of River Control', an inscription in the temple of Li Erh-Lang at Kuanhsien (orig. photo., 1958). The calligraphy is that of Wên Shen, Governor of Chhengtu in 1906, but the text may be as old as the 11th century. A translation is given on p. 295.

Fig. 895. An empty gabion of spheroidal shape beside one of the piers of the suspension bridge at Kuanhsien (orig. photo., 1958). Mr Li Chîn-Chu, one of the engineers-in-charge, stands beside it. Cf. pp. 293, 331 ff., 339 ff. and Figs. 913, 914.
Fig. 896. The image of Li Ping in his votive temple, the Fu-Lang Kuan, on the Li-Tui hill beside the Cornucopia Channel (photo, Boerschmann). The tablet reads: Kong Chiao Shu Tao ‘His achievement is the glory of the province of Szechuan’. See p. 296.

Fig. 897. The main courtyard of the temple of Li Erh-Lang at Kuansien (orig. photo. 1938). A picture of this place crowded with people on the occasion of the ceremonial opening of the Nei Chiang coffer-dam in 1943 is given in Lowdermilk (7).

Fig. 900. ‘The Imperial Equipage on a Visit of Inspection to the Pien Canal’, a work by an unknown Sung painter (from Anon. 36). The incident occurred in the time of the emperor Chen Tsung, in 1006, on the occasion of a flood when the canal nearly broke its banks. The imperial entourage is seen on the left, with punner gangs and a chantymen on the right, while other men are bringing fill materials from various directions. The people who worked all night to save the dikes, adding five inches to their height, were personally rewarded with presents of money by the emperor, and some who had been drowned were buried at the public expense. This picture is one of the same set as that in Fig. 4 of Needham, Wang & Price (1).
Fig. 901. General map of the Grand Canal in its final form (from Chêng Ch'ao-Ch'ing, 1). From north to south one may trace its course as follows: Peking, Tientsin, T'ê-chou, Lin-ch'ing, Crossing of the Yellow River near Tung-a, Ch'ih-ning, Hän-chuang (at the southern tip of the long Chao-yang Lake, and the crossing of the N-S Chin-phu Rly.), then T'ai-erh-chuang, followed by the crossing of the E-W Lung-hai Rly. near Phei-hsien, then Huai-yin and the crossing of the Huai R., then Yangchow, Crossing of the Yangtze at Kuachow, Chen-chiang, the crossing of the E-W Hu-ning Rly., Suchow and finally Hangchow. The less important extension to Shao-hsing and Ningpo, though certainly in part as old as the 17th century, is not shown. See pp. 306 ff.

Fig. 902. The crossing-point of the Grand Canal and the Yellow River, shown in a scroll map of late Chihung date formerly in the collection of Mr Rewi Alley. This chart adjoins the right-hand edge of the right-hand section given in Fig. 867. Again we are looking down on the river from the north-west so that it flows across the page from right to left. The square city at the bottom on the right is Shou-chang, the round one at the top on the left is Old Tung-a (today the name Tung-a is given also to a previously smaller place, Thung-chihng-tou, on the other bank). The Grand Canal enters from the bottom, splitting into three approaches; the right one, silted up, is marked 'old mouth', the left ones are stated to have lock-gates. Across the great river the canal starts again, also guarded with lock-gates, and passes off at the top into the Tung-phing Lake (not shown). To its right there is a depot of the Conservancy Authority and a few groynes. The canal is drawn tapering off at both ends, but this was the convention of the draughtsman, whose mind was set on the River. Opposite Old Tung-a there is a mariner's beacon drawn on the hill of Chiang-chuang. The dark bands, as in Fig. 867, indicate the course of the protective dykes. Photo. Alley, kindly communicated.
The wealth of further detail must pass without adequate comment. In the west, however, the tributaries of the Huai R. are well drawn, and the cities near them, some of which, such as Shoushao (Shoushao-lan), are referred to in the text (p. 287). In the east the bewildering maze of canals between the Shanyang Yen-Tao and the sea is striking, and it should be noted that most of these were artificially constructed, often as early as the Shun Hsiao period, partly for easing the ever-intractable problem of the drainage of the Huai valley, but principally for transporting inland the large quantities of salt which were always made along the coast. Thus the main E-W canal just north of the Yangtze was called the Shang Yen-Yen Ho; it met another, the Yen-Yen Ho itself (shown here as passing under three great arch bridges), beside the city of Tiusio. Another such canal, the Yen-Yen Haiao Ho, is marked on the map as running parallel with, and just south of, the Yellow River, all the way from the sea to the Grand Canal. More prominent than any of these, however, is the N-S salt artery which runs parallel with the Shanyang Yen-Tao, nearer the sea and inside an important dyke or sea-wall about 45 miles long (afterwards extended to just over 180 miles), the Fan Kung Thi, built by Fan Chung-Yen in 1427. This is the Yen-Yen Chhuan-Chiang Ho (Solent-Connecting Transport Canal), dominated at its northern end by Salt City (Yen-chhing), as the map shows, and able to discharge excess water into the sea through eighteen sluice-gates.

The city in the furthest south-east corner of the chart is Thungchow (new called Nan-thung), the birthplace, I add, as in private duty bound, of my collaborator Wang Ling. Just above and to the left of it some derrick-like structures are drawn in, and marked ‘the Eight Beacons’, while just below and to the right of it there is a mariner’s mark pagoda on the hill of Chiao-shan. Across the Yangtze, also by the mouth, near modern Kan-chhiao, a lighthouse or guard-post called Jiu-shan Tii is shown. Further upstream, beyond Chenching and the Grand Canal crossing, a hill on the south bank named Yen-Teu Chi (Swallow’s Nest Bluff) is to be seen; this is a well-known markpoint in navigation just north of the birthplace of my collaborator Lui Green. A prominent pagoda, the Chung Feng Tha, doubtless a mariner’s light or marker, is shown at this S-shaped bend. In addition to the lock-gates, this stretch of the Canal is equipped with eighteen named sluice-gates (cha) in its banks to relieve high water-levels, nineteen flying dykes (pa) for sudden release of heavy flood water, and several bridged outlets (diulas) normally open and flowing, probably with weirs.
Fig. 904. An engraving of the Grand Canal running along the edge of the Kao-Yu Lake but separated from it by an embankment to facilitate traffic in bad weather. From Nieuhoff (+ 1665), as his embassy saw it in +1656. 'In former times', he wrote (p. 148), 'all vessels coming from Nanking and the Yangtze, and bound for Peking, were obliged to wait below the walls of this city (Kao-yu) in stormy or foggy weather. But as these delays were very vexatious for trade, it was thought good to avoid the perils of the lake, to build along its eastern side a canal 60 stadia long; and this is done with square white dressed stone blocks of such a size that one cannot imagine where they were got from, seeing that in the neighbouring provinces there are no great stone hills or quarries.' Note the cross-sections of the dykes indicated by the artist in the foreground. Cf. p. 314.

Fig. 905. A modern analogue of the story of Pai Ying (+ 1411): engineering students of Chhinghua University learning from the experience of an old countryman skilled in irrigation, c. 1961 (photo. Anon. 68). The rapids of a mountain river can be seen on the left, and behind the group is a great noria of traditional type (cf. Vol. 4, pt. 2, pp. 356 ff.). The perennial Chinese way of paying attention to sagacious empirical experience independent of book-learning has been greatly extended and emphasised in contemporary life. Cf. p. 315.
Fig. 907. The Chhien-thang sea-wall near Hsin-ning (orig. photo., 1964). Near this spot stands a hexagonal six-storied pagoda dating from the Chhien-Lung reign-period, and a ‘platform for watching the tidal bore’ (cf. Vol. 3, pp. 483 ff.). In the foreground can be seen one of the remaining cast-iron geomantic bulls placed along the wall in +1730.

Fig. 913. A weir of gabions near Chhengtu in Szechuan (orig. photo., 1943). The plaited bamboo cylinders filled with stones can be built into any desired formation; in structures such as this the successive layers are covered with bamboo matting. Cf. pp. 295, 321 ff., 339 ff. and Figs. 895, 914.

Fig. 915. Hsia Yü Chih Shui Thu; a Ming painting by Ma Wen (Ma Wen-Pi) dated +1417, on the semi-legendary theme of Yü the Great organizing the control of the waters (cf. p. 247). The part shown gives a vivid impression of the Chinese people struggling with might and main to protect their country from flood and yet irrigate their crops. Yü of the Hsia appears with his retinue, giving instructions, off the scene to the right, but one of his foremen conveying them is just visible at the right-hand edge. On the right a gabion is being rushed to a danger-spot, and in the foreground on the left another is being sunk within the dyke. Carrying-poles, earth-baskets and mattocks are all busily in use. The upper part of the picture (not shown) depicts, besides mountains and water, Yü’s home (which according to the story, he never had time to go and stay in), some scenes of agriculture, and two very curious boats, perhaps dredgers.
Fig. 917. A great bale (sao) of kaoliang stalks being lowered into a dyke breach on the Yellow River near Liao-chheng and Tung-a (photo. Todd, 1935). The cordage and pegging of these veritably mobile haystacks gives life to the sketch in Fig. 916. When such a bale is set in place a foot or so of earth is deposited on top of it so that it settles down more firmly into the mud and silt of the bottom.

Fig. 918. Flash-lock gates on the Grand Canal in +1793 as seen by the Macartney Embassy (Staunton (1), pl. 33).
Fig. 2. Section of flash-lock, showing stop-logs and hoists.

Fig. 3. Transverse elevation, with gangway in position.

Fig. 4. Plan of double slipway, showing stone revetments of the inclines, and two capstans.

Fig. 5. Longitudinal elevation of double slipway or sluice, with boat ascending to the higher level, one capstan shown.
Fig. 923. River ships from the scroll painting Chhing-Ming Shang Ho Thu, by Chang T’se-Tuan (c. +1125). This gives some idea of the size and approximate tonnage of the craft for which pound-locks developed in the +10th and +11th centuries under the Sung dynasty. See p. 359.

Fig. 924. A *diolhus* (double slipway) on a canal in China c. 1800 (Davis, r). A boat is just coming over the top. There are capstans on each side, and a watchman’s booth on the left. Cf. pp. 363 ff.

Fig. 925. A *diolhus* still at work c. 1926, (photo. Fitch r). The usual pair of capstans is pulling over a small boat laden with produce near Hangchow.
were the answer Fang and Chang made their computations and collected financial resources. Then, says Hu Su:

for the outer gate they have piled up good masonry for the foundations, and made a strong dyke to take the force of the water, setting horizontal baulks (across the entrance), with two pillars (the crane arms) rising (one on each side). The lock basin is deep as the home of a sleeping black dragon, and like a dragon the water rises in the pool, so that the ships come and go continually, borne on waves like the tide flowing and ebbing. When the great gates are closed the water forms a whirlpool at the lock fills, and the white foam washes sides that never dry. Vessels pass through without any friction, and with very little expenditure of energy great advantage is received. At the north end there is the inner gate so that a basin is formed with well-built walls...When (either of the) wooden gates is opened, the boats go lightly through with ours propelled—not like the trouble of the slipways of old.

As Hu's inscription was dated +1027 the first part of the work, at Chen-chou, was probably accomplished in +1025. Perhaps the most significant part of Shen Kua's account is what he says about the increase of tonnage, an economic factor as important, no doubt, as the water-wastage question or the damage to the ships at slipway crossings.

We shall come back to this point.

After such clear descriptions we are certainly predisposed to recognise pound-locks in Chinese statements during the following three or four centuries even when less clear. The next evidence, however, is equally demonstrative. It comes from the travel diary of a Japanese monk, Jōjin,1 who journeyed northward on the Pien Canal in +1072 and back south again in the following year.2 The following entries occur in his book entitled San Tendai Gotaisan-Ki3 after the place of his pilgrimage. He is northbound on the Chiang Nan Ho section from Hangchow.

Hsi-Ning reign-period, 5th year, 25 Aug.

Weather fine. At the mao double-hour (about 5 a.m.) our boat cast off. By the wu double-hour (11 a.m.) we got to Yen-kuan hsien, arriving at the Chhang-an 3 double slipway (yen).c

About the wei double-hour (1 p.m.) the magistrate came, and we took tea at the Chhang-an rest-house. About the shen double-hour (3 p.m.) two of the lock-gates (shui men5) were opened (in succession), in order to let the boat through. When it had passed through, the stop-logs (hua mu6) were dragged back so as to close (the middle gate), and then the stop-logs of the third lock-gate (were lifted out) to open it, and the boat was let through. The surface of the succeeding part of the canal was a little more than five feet lower (than the upper part). After (each) gate was opened, the (water from the) upper section fell and the water level became equal, whereupon the boat proceeded through.

Here then we have a description of a two-stage pound-lock with three confining gates,d the gates being set so close together as to take Jōjin's barque alone, or with a few

a Tr. auct.
b We are much indebted to Professor E. Pulleyblank for communicating to us knowledge of Jojin's descriptions, and for elucidating the monk's mixture of Japanese with the colloquial Chinese of his time.
c This small place still exists with the same name. Cf. Sung Shih, ch. 97, pp. 9b ff.
d Either there was fear of too great a head of water at the gates, or some auxiliary supply fed one or both of the lock-basins. A similar triple-gate pound-lock was built at Gouda in +1423 by Jan van Rhijnsburch (Skempton (4), p. 442), and a staircase of eight gates with a total rise of 70 ft., built by P. P. Riquet c. +1675, can still be seen on the Aude-Garonne Canal (p. 377 below) at Béziers (ibid. p. 467).
others. In the entries for the following month he describes three pound-locks of the
more normal two-gate type, for example:

14 Sep.
Weather fine. At the mao double-hour (about 5 a.m.) we cast off, and by the chhen double-
hour (7 a.m.) our boat stopped at Shao-po village. Towards the nei double-hour (1 p.m.)
the two lock-gates were opened, and when the second was opened the boat passed right
through.

It is noteworthy that throughout his writing Jōjin reserves the term *tai men* ¹ for what
are clearly pound-locks, and speaks of *cha thou* ² when he means gates at the end of
very large lock-basins, or just *cha* ³ when he means flash-lock gates. Here is an instance
of the second case:

17 Sep.
About the six double-hour (9 a.m.) we started, the boat returning to Chhu-chou ⁴ (city),
and reached a lock-gate (*cha thou*). This is situated 9 li 300 paces from the city... After ten li
we got to the (next) lock-gate, but water was lacking so the gate was not opened... By the hai
double-hour (7 p.m.) there was enough water, so the lock-gate was opened. A hundred boats
were first let through, which took one double-hour, so that our boat did not get through until
the hai double-hour (9 p.m.). They did not open the second lock-gate (at this place) that same
evening, so we spent the night within (the lock-basin).

And for the third we may take an entry from his return journey:

6th year, 25 Apr. (+1073).
A letter came from the Transport Bureau to say that the gate-keepers must wait for a
hundred boats to collect, but if in three days' time that number had not been reached, then
they might open the gates (*cha*). For the needs of irrigation were not to be neglected. As this
was already the third day (we thought that) in the evening they must open the gate, but they
did not.

A few years after Jōjin's memoirs we can find another pound-lock in an official
Chinese source. The *Sung Shih* says: ⁵

In the 4th year of the Yuan-Yu reign-period (+1089) the Transport Bureau officials of the
Eastern Region said that the Chhing ¹ River (in the Huai valley) communicated (most usefully)
with many districts in Chiangsu, Chekiang and Huainan, but after two floods at Hai-chou,
Lü-liang and Pa'i-pu it had become shallow and infested with dangerous rapids so that many
ships had been wrecked. Consequently the sailors, the towing-oxen and ass drivers, and the
long-boremen, were doing everything in their power to prevent merchants going that way.
Now the government had already appointed the Prefectural Vice-Administrator of Chihchow,
Shēng Hsi-Chiang, and the Magistrate of Chhangchow, Chao Sung ² of Chin-lung, to survey
the place with a view to engineering operations. If therefore it should prove possible to repair
the stone-faced dam across the Yüeh ³ River, and to set up lock-gates (*cha* ⁴) alongside it
above and below, to be opened and closed at certain times so that ships should be able to go
through; that would be a long-term plan which would bring great benefits. They (the officials)
therefore begged that superintendents should be sent to make a start. The emperor agreed
and the suggestion was carried out.

Here then was a clear case of a pound-lock on a canalised river just after William the
Conqueror's time. ⁶ By the end of the century we are back at the pound-locks on the
Ling Chhúi (cf. p. 306 above). It is obviously unnecessary to prove the point further,
and we shall only add one more example, the building of the Thung Hui Ho section of the
Grand Canal between Peking and Thungchow by Kuo Shou-Ching in +1293. It will be remembered
from Table 70 that the rise over this stretch of country was some 30 ft. Describing Kuo's specification for the locks on the canal the *Yuan Shih* says: ⁷

(From Peking to) Thungchow let there be established a flash-lock gate (*cha* ¹) every ten li. ⁸
There will thus be in all seven *cha*. ⁹ At a distance of one li or more ¹⁰ from each *cha* ¹ let
there be set up double lock-gates (cha *tou men* ¹¹), so arranged as to open (lit. lift, *thi*) and
shut (⁴) interconnected in order that the boats may pass but the water be held back. ¹²

Thus the head of water at each pound-lock would have been of the order of 4 or 5 ft.
Unfortunately the canal silted up long ago, and no modern study of its remains
appears to have been published. ¹³ But we are now within a century of the datings of the
first evidence for pound-locks in Europe, so it is time to turn to what happened at the
other end of the Old World.

In the light of the facts so far described, it is clear that the conclusions of those who
have confined their enquiries to Europe will have to be much modified. A general
view, expressed in useful papers such as that of Wreden (¹), is that while sluices and

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¹ Further information on locks at this time will be found in the article of Nagase Mororu (I). It
is interesting to see again the social strains at work, as in the case of the original invention of Chihsu Wei-
Yo.
² Cf. Ch. 96, p. 128; tr. auct. with E. Pulleyblank. A parallel passage occurs in *Yuan Wei Lei*, ch. 50
(Kuo Shou-Ching's necrology).
³ It will be remembered (p. 312 above) that the distance between Peking and Thungchow was much
shorter than the length of the canal usually given, because that was reckoned from the water-sources in
the hills west of the capital. *Hsin Yuan Shih*, ch. 53, reads 'ten *cha* ¹ emplacements and a total of twenty
lock sites (¹²)'.
⁴ Upwards of 600 yards.
⁵ Another passage in the *Yuan Shih*, ch. 64, p. 3 a, b, recounts the whole list of lock-gates with their
names, starting from the west side of the capital and reaching some distance beyond Thungchow to the
junction with the next section of the Grand Canal. It mentions 8 double gates and implies two more. In
place of *cha* ¹ and *tou men* it speaks of *cha* ² and *cha* ³ respectively, internal evidence showing that the
first in each case applies to flash-lock gates and the second to double or pound-lock ones. Thus although
the terminology is confusing the meaning can be made out on careful study. Indeed, a kind of binomial
phrasing continually recurs in medieval texts on hydraulic engineering, though the components differ.
For instance, in +1118 Liu Chung-Chih ⁶ memorised that on the Shan-yang Yuan-Tou section of the
Pien Canal, between Hsuyin and Yangchow, there had been 79 *tou men* ⁷ and *cha* ¹ *tou* ⁸ and the like,
but most were out of repair, so he was authorised to restore them (*Sung Shih*, ch. 96, p. 95, cf. Chêng
Chao-Ching (¹), p. 210). Without further information one cannot identify which of these were the sluices
and flash-lock gates, and which the pound-locks, but at any rate the historian, one feels, did not mention
two things for nothing. We are indebted to Prof. E. Pulleyblank for friendly and helpful discussions on
the material concerning the Thung Hui Ho Canal and its locks.
⁶ In 1955 Dr Chstitial Han-Shing told us that he once made a special visit to Thungchow to see the
junction docks, much of which still exist.
simple gates may go back to the +13th century at least, the idea of the pound-lock is to be ascribed to Leonardo da Vinci. In the elaborate (but circumscribed) investigation of Parsons the problem resolved itself into deciding just who, among Leonardo's immediate predecessors, was responsible—the lock', he says,'the greatest single contribution to hydraulic construction ever made, is unquestionably of Italian origin'. a He overlooked the achievements of the Dutch, but now it is clear that neither can compete with those of the Chinese.

It is possible that the sluice-gate may have originated in the Fertile Crescent before the -1st millennium. A passage in the 'Epic of Gilgamesh' (c. -2000)b has been thought to mention the device, but the authorities do not agree about the meaning of the words.c Still, Mesopotamia might well be its home. There seems little reason to doubt the existence of sluice-gates in the impressive sweet-water canal system that Sennacherib gave to Nineveh in -690, but the case is not quite proved.d Evidence somewhat stronger for the — and millennia is provided by the Phoenician harbour-works still extant at Sidon, where rock-cut grooves (one only now remaining) indicate the former presence of four sluice-gates.e Guarding swell- and spray-filled basins cut in the rock of the reef, a natural enclosing pier, these would have been used, it is thought, for flushing out the haven and preventing silt-deposition. They could well go back to the—12th to—8th centuries, and later examples of the use of streams and sluice-gates for flushing harbours can probably be adduced, f but on this tidless shore the surmised system falls perhaps just short of conviction. Nevertheless the gate slot is there, amidst other Phoenician rock-cut work, even if its sluice retained a bath or fishpond only.g

Before going further, a word is necessary about the claim that there were ship locks on the ancient Egyptian canal which connected the Nile with the Red Sea. h This had

a (6), p. 372.

b It concerns something that the hero did before diving, like a pearler (cf. p. 688), to collect a submarine plant of immortality.


d The interpretation seems to be based on emendations of a neighbouring passage (I. 328) suggested by R. Campbell Thompson; see his (3), pp. 41, 55, 56: (a), pp. 52, 53. But all other translations either leave a blank or take the reference to be to other things, a channel, a girdle, sandals, etc. (Ungrad & Grémassi; Ranke; Contenau; Heidel; Lucas). Dr J. V. Künzler-Wilson (in private correspondence) believes 'sluices' almost certainly a mistranslation of the Akkadian.

e Near modern Moul; the water came from a tributary of the Great Zab R. (cf. p. 366). Jacobsen & Lloyd (1); Luckenbill (1); Thompson & Hutchinson (1, 2); cf. Droyer (1), p. 351; Forbes (10), vol. 1, pp. 135 ff.; Garbrecht, in Biews (1).

f See Frost (1), pp. 88 ff. and figs. 18, 19, 21, 23; Poideon, Laufluyr & Mouton (1), pp. 43, 70, 78, 88, pl. XIV; Renan (1), pls. LXVI, LXVII, LXVIII. In 1906 it was so fortunate as to be able to spend a day studying the Sidon harbour-works under the expert guidance of Mias Hoor Frost, and here record my warmest thanks.

g Bridgeport (West Bay) is apposite but late. Marseille (Vieux Port) had streams but no sluices (Bouchayer). Seleucia-in-Piæa, near Artecho, and the mouth of the Orontes, is claimed for both, but the remains are extremely complex and their reconstruction difficult (see Chesney; Chapot; Lehmann-Hartleben).

h Another report (Rao, 1) has mentioned sluice-gates in the overflow channel of a dock of the Harappa civilisation at Lothal north of Bombay (c. -1500), but the photographs so far published do not show the grooves claimed. As for the regulator sluices on the irrigation-canal in Egypt, where it spills into the Aswan Depression, often attributed to the -19th century, see p. 355 below.

i Herodotus, ii, 158; iv, 39; cf. Kees (1), pp. 113 ff.; Toussaint (1, 2).
length was just 100 ft. So far variations of water-level were alone concerned, but it was just at this time that the first successful attempt was made in Europe to overcome variations of the ground-level, that is to say, by the building of a true summit canal; and again this was executed not in Italy but in Germany, possibly because of Hanseatic connections with the Low Countries. The Stecknitz Canal, completed in +1398, bestrode a watershed elevation of some 56 ft., with the aid of two considerable pound-locks (Kammerschleuse). Only now came the upsurge of Italian civil engineering, destined to lead to such substantial improvements. A great builder of pound-locks was Bertola da Novate (c. +1410 to +1475); he constructed 18 on the Bereguardo Canal (part of the Milan system) between +1452 and +1458, and 5 more near Parma between +1456 and +1459. Possibly it was these which L. B. Alberti described in his famous De Re Aedificatoria, finished about +1460 but not printed till +1485. He suggested gates moving horizontally, not vertically, and this was taken up by Leonardo da Vinci, who certainly invented the mitre gate, and built several examples of it before +1497, when he had been Ducal Engineer of Milan for fifteen years. Leonardo also included a wicket door for admitting water with a valve balanced eccentrically like a Chinese rudder (cf. p. 655 below).

The installation of a series of locks for carrying a traffic canal over a watershed summit was proposed by Leonardo between +1497 and +1503 when he was working for the City of Florence on schemes for navigability and flood-control of the Arno. One proposal involved a cutting through hills which would have been 225 ft. deep, and a second suggested the series of locks on both sides of the summit. This, says Parsons, 'was the first suggestion for a double or reversed action by locks, something which was not consummated in practice until the Canal de Briare.' Yet we know that the Stecknitz Canal, built by artisans now unknown, had been a successful construction a hundred years earlier, as also that the Grand Canal of the Yuan had preceded Leonardo by more than three hundred years. The successive end-points of our titration of cultures in this particular field now begin to appear in some clarity. After the small sluices which were probably common in all the ancient civilisations of the Middle East came the traffic-carrying tide- or flood-gates of the Nile/Red Sea Canal in the - 3rd century; these bear comparison well enough with the fluvial entrance gates of the Pien Canal in Chou, Chhin and Han China, though there the partition principle is much more readily generalised by the erection of very numerous flash-lock gates. More than a millennium passes before these begin to multiply upon the canalised rivers of Europe, probably because of the fact that the Chinese built so great a mileage of purely artificial waterways before the end of the Han (c. + 200). Entry and exit gates were also fitted, quite probably, on the Ling Chü Canal of the - 3rd century, by far the oldest transport canal in any civilisation, and comparable only with the irrigation contour canals of Ceylon, not with any work in Europe. Pound-lock gates incorporated into this system somewhere about +1060 converted it into the earliest example of a summit canal. The two inventions are of course intimately related, but the times of appearance in East and West are each different, and so of much interest. The first recognisable pound-lock built in China dates from the decade following +980, the first in Europe from that following +1370; the former for a summit canal albeit the rise was fairly small (cf. Fig. 906), the latter for a tidal difference of water-level only. Leaving aside the conversion of the Ling Chü, the first summit canal in China was (senso stricto) the Pien Canal of antiquity and the Sui, but since the watershed was there so flat it is better to take the Grand Canal of the Yuan dating from the years following +1280; this must contrast with the first successful summit canal in Europe, the Stecknitzs, of the decade following +1390. Priority fails to China in all these achievements.

How paradoxical it is then that (as we have seen, p. 347) post-Renaissance European travellers on the great Chinese canals should have found only flash-lock gates and double slipways. The explanation is, I believe, already implicit in the quotation from Shen Kua on p. 352 above concerning the tonnages of tax-grain boats using the Pien Canal, and how they increased so rapidly when pound-locks were substituted for slipways. In the Sung Hui Yao Kao (Codex of Administrative Law of the Sung Dynasty) it is seen that the invention took so long in coming, but one must remember that the gradient of the land along the course of the North China plain was very gentle. Stop-log gates every three or four miles met the need, therefore, for many generations. Eventually, however, the Shan-yang Yín-Tao gradient, and its junctions with Huai and Yangtze, needed something more than tonnages rose; so also the Ling Chü approaches, and above all the direct route to Peking across the Shantung foothills. Quite large ships are indicated by the expressions la po' (in a speech of +1086, Sung Shih, ch. 64, p. 58), and lai in (speeches of +1088 and +1139, loc. cit., ch. 96, p. 13, ch. 97, p. 25). Cf. pp. 463, 467 below. To get a clear idea of the size of the cargo and passenger ships used on the inland waterways of the +14th and -15th centuries, nothing is better than the Chüang-Ming Shang Ho Thu, a scroll painted by Chang T'ai-Tuang just before +1125, and often elsewhere referred to; see Fig. 923 (pl.) and pp. 115, 165, 493, 568.

The great suggestion by two hundred years, and the conversion of the Ling Chü to a summit system by more than three hundred years.
28. CIVIL ENGINEERING

There is a passage which speaks of 'pairs of gates' (cha i chuang),\(^1\) saying that formerly only official convoys and heavy vessels were sent through these pound-locks, the others being hauled over the slipways, but now (i.e. in +1167) the local authorities, being eager to increase the revenue from taxation, were sending all craft through the locks whatever their flag or burden, and had abolished the use of the slipways.\(^2\) Pound-locks were in fact essentially the response to vessels of heavy burden on the canals, and if a time came when this stimulus should be withdrawn they might well not be renewed, junction points reverting to flash-lock gates and slipways. This is exactly what happened. When in the late +13th century the Yuan government fixed its capital at Peking, the canal system could not at first, and indeed throughout that dynasty never wholly, carry the weight of the northward traffic, so that a large part of it was shipped when at their highest pitch of efficiency, they often equalled the inland totals and quite often exceeded them. After +1450 Ming rule let drop the naval might that the Southern Sung and Yuan houses had laboured to build up,\(^3\) but during some three centuries the need for really heavy craft on the Grand Canal, like those which the Northern Sung had employed with such striking results, had been in abeyance. Hence it had become customary to use a multitude of smaller vessels, and as this tradition established itself, the pound-locks fell into decay one by one and were not replaced.\(^4\)

\(^1\) Shih Hwe section, ch. 8, p. 433 (T'uhao no. 125). This enactment was noticed, and kindly communicated to us, by Professor E. Pulleyblank.

\(^2\) At this time of course there was no control over the more northerly sections of the Pien Canal. As Jojin (cf. p. 352) negotiated slipways when southbound in +1073 and not when going north in the previous year, we might guess that his return was made in a smaller vessel than that of his previous journey.

\(^3\) Cf. pp. 312, 375, 478.

\(^4\) The question of whether there were pound-locks on the Grand Canal (or other Chinese waterways), and if so how many, between +1300 and +1700, is rather a difficult one. For this period travellers bear more witness than indigenous texts. Thus in +1487 a Korean official Chiho Pu,\(^5\) travelling in a small coasting vessel, was blown by a tempest to the Chinese coast near Ningpo, and so travelled home with his attendants from Hankow via Peking. In his Pihoko Rok, (Maritime Odyssey), the fascinating travel account which he wrote in the following year (cf. Mackill (1); cf. Makita Tarroyo), he gives a number of details about the Grand Canal which are helpful in the present context. He speaks, for example, of Ku-thou Lower Lock (gate, which implies an upper one, p. 106); he says of the Kuan-Yin temple at Lin-chhing that it stood on a promontory at the junction of two 'rivers' where 'to east and west four lock (-gates) had been built to hold water' (p. 113); and in a general summary he refers to 'the water in the locks' (p. 130) as they would hardly have done if they were miles apart. Besides this, Chiho Pu mentions various sluices and at least 16 flash-lock gates by name, gives a lucid account of the procedure at them (p. 153), and quotes in full an inscription of c. +1470 set up on a stele at Huang-chia Lock several stations south of the summit. From this we know that the distance between flash-lock gates varied from 5 to about 12 ft.

For the +16th century further evidence may be found in an itinerary from Hankow to Peking printed in +1531, the Ten Thu Shui *K", known only from the unique copy which the monk-artist Sakugen\(^6\) took back with him to Japan (cf. Moule, 16). Here one reads of slipways, sluices, 'opening and shutting passages' and 'level-water locks'. Such a term would clearly exclude the flash-lock gate with its rush of water from one level to the next. Of these 'level-water locks' the Grand Canal had at this time eleven from south to north. Further information is contained in Sakugen's travel account, the Nyus-Min *K", (Diary of Travels in the Ming Empire), reproduced and studied by Makita Tahyë (1). The +17th century we may note two pieces of evidence. The Chih Ho Pung Lien of +1668 has a description of long and as 24 ft. wide, the underwater approach at each end consisting of 85 steps of levelled stone-work; depths of water are not

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\(^5\) The decline and fall of the pound-lock in China notwithstanding, what influences could Chinese hydraulic engineering have exerted on Europe, given the datings just established? Ought the pound-lock and the summit canal to be inscribed among what we have already termed the ' +14th-century cluster' of technical transmissions westwards, and if so, how could the notions have come? It is always conceivable that the +12th-century Netherlanders and Italians knew by Crusader gosip of the Chinese flash-lock gates of Wang Ching, Li Pho and their innumerable colleagues going back at least to the +1st century, but the device was of such natural simplicity that they could surely have originated it themselves. Perhaps however the pound-lock is another matter. It may not be a mere coincidence that the beginnings of pound-locks and summit canals in the West occur in the +14th century, just after the time when the Pax Mongolica permitted the free travel and intercourse of merchants typified by Marco Polo. At a much earlier stage in this work we noted the statement of Yule\(^7\) that towards the latter part of the +13th century 'Chinese engineers were employed on the banks of the Tigris'. This has often been copied by sinologists;\(^8\) unfortunately, in spite of the grounds for suspecting westward transmission of hydraulic techniques just at this time, no one has yet been able to substantiate the statement from the sources which Yule quoted.\(^9\) That Chinese were first in the war of the Mongol conquest of Iran and Iraq is indeed well known—a Chinese general, Kuo Khan (Kuka-ila), was (with a Mongol brother officer Kiti-buka) first governor of Baghdad after its capture in +1258 by Hulagu Khan.\(^10\) That Chinese expert trebuchet artillerists and Chinese naphtha grenadiers formed part of Hulagu's armies is also well established.\(^11\) As the Mongols had a habit of destroying irrigation and water-conservancy works of all kinds to annoy their more agricultural enemies, it would have been most natural of them to turn to their Chinese technical colleagues for the rehabilitation of Mesopotamia as soon as government exploitation was ready to replace military operations. In another place we have mentioned a statement said to have been made by an Arabic writer of earlier date, al-Jâhiz (d. +869), that Chinese hydraulic engineers were brought to Iraq in his given. That there were two gates is suggested by the words chihien hou so khou,\(^12\) but there may have been only one. The lock is termed a cha,\(^13\) which may be significant (cf. p. 335 above). Additional evidence that pound-locks were still in use in the +17th century may be found in the travel narrative of Nieuhoff (1). Between Huai-an and Chi-ning, he says (p. 125): 'J'y ai constaté un grand nombre d'escluses basties de pierre carree; chacune d'elles a une porte par laquelle entrent les navires; on la ferme avec des six forts grands et epais; puis les ayant leves par le moyen d'une roue et d'une machine avec beaucoup de facilité, on donne passe a l'eau et aux navires, jusques a ce qu'on les ai fait passer par la seconde avec le meme ordre, et la meme methode, et ainsi en suite par toutes les autres... '. There is still something slightly ambiguous about this description, but it would be rather hard to maintain that what he saw at Nien-miao (Ning-niang-miao), also in the neighbourhood of Huai-an, was nothing but a flash-lock, for his words are (p. 154): '... apra avoir franchi une porte escuse, qui estoit defendue de deux rongs de portes... '. This was in +1656, some thirty years before the writing of Chin Fu's book.

\(^6\) Vol. 1, p. 217.

\(^7\) E. Pulleyblank (1), and ed., p. 169.

\(^8\) Notably d'Ohsson (1), vol. 2, p. 611, but he offers no contemporary evidence.

\(^9\) Cf. Yuen Shih, ch. 140, pp. 144 aften, and the Hsi Shih Chi (Notes of an Embassy to the West) already described in Vol. 3, p. 1234 aften; both translated in part, and discussed, by Bretschneider (a), vol. 1, pp. 109, 111, 120, 122 aften.


\(^12\) 1 HHH
time. This is in fact a mere typographical error; the text itself says that they were
Byzantine. Nevertheless there really were Chinese artisans in + 8th- and + 9th-
century Baghdad, notably the paper-makers, textile workers and others who settled
there after the Battle of the Talas River in + 751. ¹ There may well have been water
engineers among them. In general therefore, though little specific can be adduced,
there is good reason for thinking that the Middle East may have been a way-station for
ideas on how to make ships go up and down hill, between the time of Li Shih
and Chang-an, a lake intended for naval combat exercises.² The same term occurs again
later on, as at Hai-chow in + 1020, when Wang Kuan-Chih³ wanted to take water from
such a spillway dam for the Pien Canal.⁴ The commonest phrases, perhaps, are shih to ⁵
or shih to,⁶ mentioned many times in Sung texts, often in connection with the Pien,
which in certain stretches had rows of ten or thirteen spillovers one after another along
it.⁷ On a much smaller scale culvert spillovers (tung⁸), of stone, three or four feet square,
were often contrived at suitable heights in the embankments enclosing a canal; and of
course, as we have seen (Fig. 908), side sluice stop-log gates (cha?) were commonly in
use for rapid evacuation of flood water.⁹

For emergency clearance an unusual technique was developed. On several occasions
already¹⁰ we have met with the term pu,¹¹ defined in dictionaries simply as a dam,
dyke or embankment,¹² and no doubt sometimes loosely so used. More precisely,
evertheless, it meant a 'flying dyke', i.e. a very long shallow U-shaped spillway with a stone
revetment and masonry cheeks, running along the bund of a canal or lake. Normally
this was kept filled with reed bundles, fascines, earth, etc., forming part of the embank-
ment; but in time of emergency a small breach could be artificially made in the centre
of the fill, whereupon the force of the water would quickly wash all away, flood and
embankment being thus quickly dissolved,¹³¹⁴ through previously prepared channels. Eleven flying dykes

¹ Cf. Vol. 1, p. 236 above.
² We have already considered the role of the overflow constant-level device, doubtless the simplest
and oldest of all homoeostatic devices, in connection with the time-keeping clepsydrae; cf. Vol. 3, Fig. 138
and p. 344. It seems clear that the first application was in hydraulic engineering, and then in horological.
³ Cf. Dubs (a), vol. 2, p. 63.
⁴ Sung Shih, ch. 96, p. 240:
⁵ There are references for + 1020 (Chang Lun,¹² cf. p. 350), + 1058, + 1069, + 1137, + 1193 and
+ 1194, among others; cf. Sung Shih, ch. 96, p. 25, ch. 97, p. 28, and Ch'ing Chiao-Ching (a), pp. 288,
281, 213, etc.
⁶ Gaudard (1), p. 17, describes both.
⁷ Pp. 272, 318, 324, 344.
⁸ Its shorter form is not to be confused with chu,¹¹ which also means an embankment.
⁹ Of this kind, built between + 1680 and + 1757 in the defences of the Hung-Tsê Hu (lake) and the Grand Canal, measured an average length of 400 ft. and an average
height of 9 ft.¹² At some quite early time it must have been realised that if the ramp of a spillway
were made to slope at a reasonably gentle gradient it would be possible to drag
canal-boats up and over it to the higher level, wastage of water at the same time being
prevented. In this manner there arose the double slipway, a pair of inclined stonework
aprons over which boats were hauled, generally in China with the use of capstans, from
a waterway at one level to a waterway at another. The thing was partly also inspired,
no doubt, by the primitive rough portages which ancient peoples had undertaken to
avoid rapids on rivers, or to connect two arms of the sea across an isthmus. The Greeks called
this a diolkos (διόλκος). The commonest Chinese term for the double slipway was tai,¹³ but unfortunately it seems also to have been sometimes used (like pa) as a general
word for dams or dykes, so that its interpretation may give rise to difficulties. How-
ever, when in + 384 the philosophical Chin general Hsieh Hsian¹ built seven tai on
the Pien Canal at Lii-liang¹⁴ (near modern Thungshan), he did it at the suggestion of
Wênjen Shih¹⁵ to facilitate transportation', so that slipways are certainly meant.¹⁶
A contemporary writer refers to the use of capstans turned by oxen for drawing boats
over these slipways,¹⁷ which were therefore called ch'ien tai,¹⁸ a term often subse-
quently found, e.g. in the poems of Wang An-Shih. Sung people named the slipways
tai ch'eng¹⁹. They were so characteristic of Chinese communications that Rashid al-
Dîn mentioned them in his description of the Grand Canal in + 1307 (p. 313 above),
and Chhoe Pu gave a detailed account of them in + 1488.²⁰

Such slipways were still in widespread use when the European travellers began to
write their narratives of Chinese journeys. Thus Lecomte, for example, says in
+ 1696:²¹

I have observed in some Places in China, where the waters of two Canals or Channels have
no Communication together; yet for all that, they make the Boats to pass from the one to the
other, notwithstanding the Level may be different above fifteen Foot: And this is the way they
go to work. At the end of the Canal they have built a double Glacia, or sloping Bank of Free-
stone, which uniting at the point, extends itself on both sides down to the Surface of the
Water. When the Bark is in the lower Channel they hoist it up by the help of several Capstans
at the point, till being raised to the plane of the first Glacia, so far, till being raised to the Point, it falls back again by its
own Weight along the second Glacia, into the Water of the upper Channel, where it skids
away during a pretty while, like an Arrow out of a Bow; and they make it descend after the same manner proportionally. I cannot imagine how these Barks, being commonly very long and heavy laden, escape being split in the middle, when they are poised in the Air on this Acute Angle; for, considering that length, the Lever must needs make a strange effect upon it; yet I do not hear of any ill Accident happen thereupon. I've pass't a pretty many times that way, and all the Caution they take, when they have a mind to go ashore is, to tye ones self fast to some Cable for fear of being toss't from Prow to Poup.

These slipways have often been described and illustrated, e.g. by Davis, Altm. & Pelle; Staunton; Barrow; Dinwiddie and others (cf. Figs. 924, 925, pls.)

Similar arrangements go far back in European history. The classical instance is the slipway across the isthmus of Corinth, which, though perhaps not completed by the first designer of the work, the tyrant Periander (462-465), dates undoubtedly from the early 6th century. This was originally, and long remained, a masonry road across a large part of the isthmus terminating in a true slipway at each end. Recent excavations reported by Verdelis (1, 2) show that the road of stone blocks, 12 to 16 ft. wide and some 4 miles long, which passed at 130 ft. through a ridge some 260 ft. above sea-level, had two parallel grooves some 5 ft. 6 in. apart all along its length, so that the ships must have been carried on wheeled cradles running in veritable tramway tracks. There is even apparently a passing place on a curve, where there are traces of double tracking. This famous dióloia, connecting the Corinthian and the Saronic Gulf, remained in use at least until the 9th century. Soon afterwards the double slipway, now named 'overtoom', appears in Holland, where, in +1248 there were two examples in use on the Nieuwe Kijn Canal near Utrecht; probably another at Spaarnam in

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\[\text{Footnotes:}\]

1. Cf. Feldhaus (1), vol. 1, p. 138. We have already considered the alleged application of wind-power to these capstans with some scepticism (Vol. 4, pt. 2, pp. 250, 251). Altm. & Wright.
2. (1), fig. 34.
4. In Freundel (1), p. 72 and in Macartney (2), Crammer-Byng ed. p. 269. He considered the system 'preferable to English locks in every situation where the canal is nearly level, and constructed at a quarter of the expense, besides being cheaper they are much more expeditious'. Passages observed by him took 2-3 min. The device is still to be seen in England in parades, as those who pass back and forth across Coe Fen in Cambridge every day are well aware.
5. Audemard (4), p. 46, fs. to be avoided; he confused the stop-log flash-lock gates with the double slipways. It is true that the fulcrum of the latter was often equipped with a rounded wooden baulk, but not with stop-logs.

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+1220 and certainly at Ypres in +1298. A particularly well-known one was that on the Brenta Canal at Fusina near Venice erected in +1437, a remodelling of which was illustrated by Zonca in +1607. Here European continuity seems to exclude the possibility of Chinese influence, but whether Periander's work could have echoed in China might admit of a wide solution. The most grandiose successor of these designs was the ship railway proposed by J. B. Eads in 1884 for the isthmus of Tehuantepec in Mexico, where ocean-going ships were to be drawn across on cradles hauled by three double-ended 2 x 14 ft. 2 Mallet locomotives on parallel tracks. Owing to the Panama Canal this project came to nothing, but if it had ever been built it would have been indeed the apotheosis of the dióloia and the tei, delighting the hearts of Periander and Hsieh Hsian.

(10) COMPARISONS AND CONCLUSIONS

The comparisons of the preceding paragraphs invite a more extended survey or balance-sheet of the achievements of Chinese hydraulic engineering in relation to that of other times and places, ancient Mesopotamia and Egypt, Greece and Rome, the Renaissance, and so on, for which this book is hardly the place. The works of Willcocks; Mercel; de la Blanchere, and others, suggest that when allowance is made for the available technical means, only the systems of Babylonia and ancient Egypt, and in later times Ceylon and India, can be compared with what was accomplished in China. To confront the size of the works excavated in length, breadth and tonnage, with Chinese parallels, would require an elaborate research in itself.

Irrigation engineers distinguish between perennial and inundatory canals, the former drawing water for the fields at all times of the year, the latter filled only during the flood season. This distinction, as Willcocks (3) pointed out, differentiates also between the irrigation systems of ancient Mesopotamia and ancient Egypt, for the former watered the plain of the Tigris and Euphrates at all seasons, while the latter involved a vast chain of retention basins for silt deposition, and these were (and are) filled only during the flood season. The original plan of the 2nd millennium, which has always been retained, was to build a dyke along one side of the Nile and to constitute basins by tying this dyke by a series of transverse dykes to the hills at the edge of the valley. The average area of each basin is some 7,000 acres, and the average depth of water in them when the river is at its maximum of 30 ft. above its bed is about 3 ft; after the water has departed the land is sown and yields good crops. The Nile, says

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\[\text{Footnotes:}\]

1. Cf. Feldhaus (1), vol. 944; van Housten (1), p. 138; Forbes (11), (12); Skempston (4) and private communication to us May 1955. Some are still in use in Holland.
4. It is sometimes said that the greatest retention basin of all time was formed by the artificial construction of the Faiyum Depression into Lake Moeris (cf. Payne (1), pp. 14 ff.). Whoever thinks so has the authority of Herodotus (ii, 149, 150), but Herodotus was wrong; cf. Kees (1), pp. 215 ff. and R. H. Brown (1). On its northward course the Nile throws off a natural deltaic channel, 'Joseph's arm' (Baby Yafa), formerly from Asyut, now from Dairut; this runs parallel with the river on its left or western side.
Willcocks (1), is 'the most gentlemanly of all rivers', for it gives ample warning of its rise and fall, it makes no abrupt changes, it has enough silt to enrich the land annually but not enough to choke the canals, it is free from salt, and it flows between sandstone and limestone hills which furnish unlimited building-stone. The Tigris and the Euphrates, however, show a few of these qualities. With its silt content of about 0.75%, for example, may be compared the 0.75% of the Mesopotamian rivers and the 0.15% of the Nile. Now the Mesopotamian irrigation projects differed completely from the Egyptian, for apparently from the most ancient times they consisted of canals radiating from the main rivers and conveying away the water from derivations or division-heads. They were thus perennial, and in a sense aimed at converting the entire river valley into a delta. Archaeologists have succeeded in tracing the elaborate works of the 250-mile Nahrawan Canal, which sprang from the left bank of the Tigris some 125 miles above Baghdad and rejoined it some 125 miles below. This canal, of ancient origin, was perfected and adjusted to capture incoming left-hand tributaries under the Sassanians (+226 to +637); it has now long been for the most part in ruins. Running with a breadth of 400 ft. much of the way, it was the greatest work of the kind in Middle Eastern antiquity. Canals of similar type, however, near the edge of the desert for some 150 miles (cf. Budge (1), p. 6). Towards Illahun, near ancient Arsinoe (Medinet al-Faiyım), it leaves the Nile valley, however, and flows into the Depression north-westwards past two famous pyramids, splitting up into a great number of irrigation canals, which all go to form Lake Muwaḥhah (now called the Birket Ylisuf; cf. Vandier (1), p. 254). The surface of this lake is no less than 17,000 sq. ft., and though much smaller than of old, it still attains 90 sq. miles. It is certain that from the time of Sesostris II (+1906 to -1880) and Amenemḥāt III (+1832 to -1800) in the XIIth Dynasty, flood water was used to form the Lake Muwaḥhah (Budge (1), p. 250), and it is equaly certain that the use of its contents has been legal to get back again into the Nile; but by the time of Diodorus Siculus at least (+30; see ii, 53) and Strabo (+20 to +99; see xvi, i, 37) there was some sort of arrangement at Illahun (92 ft. above sea-level) by means of which the water could be routed either into the Depression or northwards through a 50-mile lateral canal to join the river near Cairo. Since Strabo speaks of 'artificial barriers' (kalethra, kaleispa), and Diodorus of a 'skilful and costly device' (katakeusma, katakeusma), translators have not hesitated to use the term 'lock-gates', and Egyptologists such as Drioton & Vander (1), p. 254, have freely attributed them to Sesostris himself; but Diodorus adds the significant information that it took the large sum of fifty talents (£10,000) to open or close the works. We should surely think therefore (with Hayes (1), p. 50) of some system of temporary dams (cf. p. 253), and not admit sluice-gates before Assyrian-Phoenician times if then. Probably what Sesostris and Amenemḥāt did was to cut the side-branch into the Depression, the northern lateral canal being the original course of the Baby Yfud, and the southern canal the result of a serious failure in the scheme due to overflowing of the former. It is certainly certain that many other similar irrigation canals, dates from the Palla dynasty in Bengal in the 9th century, by the Chandel dynasty (+850 to +1150) in Bundelkund, and in the south by the Pallava dynasty under Mahendravarman I, a Tamil contemporary of the Sui emperor in China (+610). One of the Pallava dams in Madras, 44 miles long and 40 ft. high, commands 6,500 acres. The +11th century saw the construction of the 250-sq. mile artificial Bholpur Lake by the Bhoja dynasty in the north, and the 16-mile dam near Jayamkonda-cholapuram by the Chola dynasty in the south. Under Islam there was at first a decline in hydraulic engineering operations, but later they revived, fostered by Firdūs Shāh Tughluq (+1320 to +1388), one of whose canals is still used, and the Bahrain sultans of the Deccan. Not to be outdone, the Hindu Vijayanagar dynasty in the south built the Bukka II in +1406.
of tributaries of the greater rivers, thus retaining the annual or inundatory flow, and is island, receive a rich precipitation and some perennial rainfall as well. Hence a those of their Chinese colleagues, though not to win the palm. Yet it was never in India that the fusion of the Egyptian and Babylonian patterns achieved its most complete and subtlest form.

This took place in Ceylon, the work of both cultures, Sinhalese and Tamil, but especially the former. Its interest is such that it merits description a little more at large. The invitation was set forth in the first place by the meteorological and geographical nature of that incomparable island. The central mountains of Ruhunu and Maya Ratta are surrounded almost on three sides by 'dry jungle', watered only seasonally by the south-west and north-east monsoons respectively, but the mountains themselves, together with the tract of country constituting the south-west quarter of the island, receive a rich precipitation and some perennial rainfall as well. Hence a challenge to devise irrigation works of such a nature as to take advantage of both these sources of water. The process of evolution which is thought to have occurred may be described as follows (Fig. 926): first the farmers made numerous small tanks in the hills and foothills near their fields or terraces to catch the run-off water, which they baled out at leisure. Then numbers of small dams (bunds, *bemma*) forming small reservoirs (tanks, *wewa*, (Tam.) *kulam*) were built, often in series, on the upper reaches of tributaries of the greater rivers, thus retaining the annual or inundatory flow, and discharging it as desired by small canals (anaka) along the valley sides. As time went on, larger dams were built, submerging or rendering unnecessary the smaller ones. The next step was revolutionary: a weir (anicut, (Tam.) *tekham*) was built much higher up the main river (ganga, oya, (Tam.) *ara*) to form the headwork for a long lateral trunk derivation-canal (yodi-ela), which thus brought perennial water to join the annual monsoon supplies in the great reservoir. This method, ambitious as well as scientific, had numerous advantages: (a) it harnessed a greater volume of water than any local}

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*a* During my stay in Ceylon in 1958 I had the valued privilege of personal discussions with the leading historians of Ceylonese civil engineering, Mr R. L. Brohier, and other members of the Survey and Irrigation Departments such as Mr W. Delay. The principal features of the story may be unravelled from the extensive technical publications which exist, notably Brohier (1, 2); Brohier & Abcaywardena (1); Brohier & Paulusat (1), etc., but nothing can substitute for the opportunity of inspecting the ancient works themselves, and of listening to those who have devoted to them a lifetime of study. In viewing the great achievements of their ancestors it was a great pleasure to be accompanied by my colleague Mr Mahinda Silva and the doyen of Ceylonese archaeologists Prof. Senarath Paranavitana.

*b* For most of the year the term 'dry' is fully deserved, but a precipitation of 36 in. (or occasionally double that) comes and goes within two or three weeks (cf. Sion (1), fig. 5).

*c* See the rainfall maps in Brohier (1), vol. 1, opp. p. 2; vol. 2, opp. p. iv. In the footnotes to the following paragraphs we shall dispense with this reference and give only volume and page numbers.


*e* When not identified as Tamil, or obviously English, the technical arms inserted in these paragraphs are Sinhalese.

*f* This was the point at which the Ceylonese went beyond what the terrain had generally rendered possible in South India. But it must be remembered that the Cauvery valley had the largest reservoir in the world for nearly a millennium, the Viratam-kulam near Jeyamkonda-cholapuram already mentioned, built by the Cholas, a command of 22,000 acres.

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catchment area could yield, (b) it put both monsoons as well as other rainfall to full use, (c) it secured a resource in drought periods as well as an even supply in normal years, and (d) it lessened the silt accumulation problem because the feeder canals could be cleared periodically much more easily than the tanks. Such yodi-ela canals, dropping very slowly along the contours, often passed across one or more watersheds en route. They were generally dyked only on one side (*kandiyaa*), sometimes spreading out into small lakes as they went, but in certain places a double embankment was needed (*depa-ela*). Smaller tributaries and gullies were crossed by means of spillway dams (*galawana*) with wing-walls, sufficiently ample to take care of the greatest freshets, but

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This had first been done in Assyria under Sennacherib for Nineveh's water-supply (~705 to ~690). A long aqueduct led the canal to a low cutting across the watershed; see Jacobsen & Lloyd (1); Garbrecht (in Biswas, 1).

These embankments could be as much as 90 ft. high, as at places on the Elaher-ela (vol. 1, p. 28).

There is reason to think that flume (aqueduct) bridges of wood may sometimes have been used, e.g. on the Yodiye-bendi-ela before its junction with the Amban Ganga.

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the Tungabhadra Dam, with its 15-mile aqueduct cut in solid rock most of the way. It will be evident even from this roughest of sketches that the achievements of Indian civil engineers in ancient and medieval times are quite worthy to be compared with those of their Chinese colleagues, though not to win the palm. Yet it was never in India that the fusion of the Egyptian and Babylonian patterns achieved its most complete and subtlest form.

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also so arranged as to deliver a constant supply from the canal in dry periods, thus converting the fitful tributary into a perennial stream, and saving labour by avoiding the construction of purely artificial distribution canals. Elsewhere the yodi-ela ran (and run) for many miles over apparently flat country. For all these works can be traced today after many centuries, and many still function.

The type-specimen of this double tank-and-canal arrangement is perhaps the Walawa Ganga catchment in the south above Hambantota, where a river helps to feed a large reservoir with over 4,400-acre reservoir, not far from one of the two classical capitals in the northern plains, Polonnaruwa. The next step was the extension of the feeder canal so that it linked a chain of those elegant man-made lakes which embrace the western side of the total distance of 54 miles, replenishing two other tanks, Kaudulla-wewa and Kantalai-wewa. But before it had reached this length it was outstripped by the artificial 54-mile-long Jaya-ganga, originating from the running northward to connect with the Tissa-wewa and the Abhaya-wewa one after the other, those with almost perpendicular falls. The outstanding example of this is the +5th-century Minipe-ela, which parallels the Mahaveli Ganga (Ceylon's greatest river) for some 50 miles and then almost certainly ran into the Amban Ganga above the take-off for the +4th-century Toppa-wewa (and the later Parakrama Samudra), thus greatly augmenting its perennial supplies. Another system was to lead off two canals from the same weir; this was done at the Kalinga anicut on the Mahaveli Ganga, a work of the +5th century, probably due to Dhatusena. All kinds of combinations can be found. Thus the Wahalkada-wewa in the Yan Oya basin far out in the northern plain was fed partly by a yodi-ela poaching across the watershed from the neighbouring Ma Oya valley, but as

Elahera-ela date from rather earlier, in the time of Mahāsiṃha (r. +277 to +304), but the latter did not reach its full length till the end of the +6th century. The Walawe valley system may go back earlier than Mahāsiṃha, to the +2nd and +3rd century. Among the latest of the works is the Parakrama Samudra (Sea of Parakrama) reservoir, built by Parakrama Bahu I, adjoining Polonnaruwa, between +1153 and +1186; it submerged the old Topa-wewa of Upatissa II (+368) and other earlier tanks. Parakrama's most grandiose conception, however, the culmination of Ceylonese hydraulic engineering, was that of the Giant's Tank near Mannar in the north-west, an artificial lake with a 64-mile embankment on three sides of a square, because sited on a sloping plain and not in a river-valley at all. A very fine anicut diverted the waters of the Malwatu Oya, but the 17-mile feeder canal, falling only 12 ft. in 114 miles, was apparently never completed, doubtless owing to the king's death. Though little new was built after the +12th century, the dams and tanks of the ancients were so excellently planned that many, if not most, of them have been restored in our own time, and are again in use today. The designs so far mentioned were far from exhausting the inventiveness of the Sinhalese engineers of old. Some trunk canals (yodi-ela) do not end in reservoirs directly, but convey water from a high division-head along a lateral course above a river, providing irrigation water on the way. It is believed that some of these eventually discharged into a large tributary at a point above an anicut on it serving a great tank still lower down. The outstanding example of this is the +5th-century Minipe-ela, which parallels the Mahaveli Ganga (Ceylon's greatest river) for some 50 miles and then almost certainly ran into the Amban Ganga above the take-off for the +4th-century Toppa-wewa (and the later Parakrama Samudra), thus greatly augmenting its perennial supplies. Another system was to lead off two canals from the same weir; this was done at the Kalinga anicut on the Mahaveli Ganga, a work of the +5th century, probably due to Dhatusena. All kinds of combinations can be found. Thus the Wahalkada-wewa in the Yan Oya basin far out in the northern plain was fed partly by a yodi-ela poaching across the watershed from the neighbouring Ma Oya valley, but as
The layout of the land did not favour direct irrigation of rice-fields from the tank it mainly
anicuts, three on the right bank and one on the left.\textsuperscript{a} The Ma Oya is notable for its
Padawya-wewa, built by Dutthu Gāmāni in the -2nd century and enlarged by Parākrama Bāhu in the +12th, an exceptionally large tank, some 10,000 acres in extent.\textsuperscript{b} Lastly, resort was had on occasion to tunnelling. The Buhu-ēla at Pattipola in the mountains originates from an anicut on the Kotmale Oya, traverses a couple of tributaries with the usual spillway crossings, and then plunges through a ridge by means of a 220-yard tunnel (buhu-kotta), dug through compacted quartz gravel, with five shafts) to irrigate terraced rice-fields in a quite different valley, that of the Uma Oya.\textsuperscript{c}

It remains only to mention some of the more interesting special devices of the Sinhalese engineers.\textsuperscript{d} Already in the +1st century they understood the principle of the oblique weir, and had their anicuts traversing the stream at angles never more than 45\textdegree{} to the line of current flow, thus guarding against shocks that might dislocate the masonry.\textsuperscript{e} Only later, when better stonework with hydraulic cement on rock foundations could be used, did they transgress this rule. The outer layers of anicut stones also had raised lips or mouldings so that each course was retained in position not only by its own weight but by the difficulty of forcing it forward by pressure from behind. Wootz steel tools were used in the dressing. The heights of dam spillways (gal-pennuma) were adjusted by removable pillars (kalingula) which would hold up with building an extra depth of water if larger retention was desired.\textsuperscript{f} Sluices were well understood, as grooved stone abutments remain to testify. The inside surfaces of reservoir embankments were faced with ripple-bands, i.e. stone revetments (relapana) of pitched work to prevent wave-erosion, and some of the greater tanks had submerged bunds which acted as wave-breaker groynes.\textsuperscript{g} But perhaps the most striking invention was the intake-towers or valve-towers (bisi-kottuwa) which were fitted in the reservoirs, perhaps from the -2nd century onwards, certainly from the +2nd.\textsuperscript{h} These were built of close-fitting cyclopean masonry half in and half out of the bund, so that the water spilled down within their walls and left the tank by double horizontal sluice-tunnels or culverts (horowa, sorowa) contrived at the base of the embankment. In this way silt- and scum-free water could be obtained, and at the same time the pressure-head was so reduced as to render the out-flow controllable.\textsuperscript{i} How the heights of the sluice-towers were anciently adjusted is not exactly known, but the larger reservoirs seem to have had three or four of different heights, while other traces suggest that the tops could be raised or lowered by detachable woodwork or fireclay rings.\textsuperscript{j} Finally, the Sinhalese engineers were not without their charts, though hardly any have survived. We possess however a rare map of the Elahera anicut and canal leaving the Amban Ganga, with a contribution from the Kalu Ganga by way of the Yodiye-bendi-ēla (one of those canals planned to arrive at anicuts), and making its way across a number of tributaries in the usual manner towards the great Minneriya-wewa.\textsuperscript{k}

Such were the highest developments of South Asian hydraulic engineering in ancient and medieval times. When we turn to the East Asian theatre, and look back upon all the Chinese achievements which have been described in this Section, we are struck at once by a marked difference of emphasis. Irrigation, though important, is no longer supreme, and to share its prominence with an unceasing struggle for river-control and a constant preoccupation with inland water transport.\textsuperscript{2} The tank simple, as we might call it, begins, analogously, with Ceylon and India, though earlier,\textsuperscript{3} in the -8th century or so, as the early Chou Shih Ching bears witness (p. 269),\textsuperscript{4} and reaches substantial development by the early -6th in the Anfêng dam of Sunshu Ao (p. 271).\textsuperscript{5} Though similar projects continued to be built down to the +13th century and beyond (p. 297),\textsuperscript{6} the great reservoir was not destined to be the most characteristic form of Chinese hydraulic technique. The urgent need for a conservancy of rivers greater than almost any in the Indian culture-area made itself felt equally early, if we may accept the -7th-century dating for the first dykes of the Yellow River (p. 232).\textsuperscript{7} From that
time onwards incredible efforts had to be devoted to the embanking and training of the
Ho and the Chiang and their tributaries—a work the consummation of which is not yet
even now complete. In the course of it there arose quite naturally (if indeed it was not an
importation from the Fertile Crescent) the conception of lateral derivatve irrigation
canals with many branches, and these indeed we find from the 8th century onwards;
associated with the names of Hsi men Pao (d. 387) who diverted the Chang River
north-eastwards to irrigate the left lower Huang Ho basin (p. 271), and Li Khuei
(d. 380), both of the State of Wei. By the 2nd century such works had attained, as we
have seen, an astonishing level of sophistication, as in the Ch'engkuo project (p. 285),
the Kuanhsien system (p. 298) and the Ninghsia desert reclamation (p. 272). In the
6th century we have noticed a system of "amicuts" and canals very similar to those of
Ceylon (p. 281). Thus was the Babylonian pattern transplanted to Chinese soil.

But now a part of the orchestra unknown in South Asia, and almost unknown in the
Middle East, took up the theme, for surprisingly soon the Chinese were building their
wonderful transport canals. Here we need not enlarge upon the social motivations of
this, already sufficiently evident (p. 225), but seemingly far stronger than in any other
ancient and medieval civilisation. For nearly twenty centuries the Chinese alone
appreciated the great mechanical advantage which artificial navigable waterways could
offer for the systematic transportation of heavy goods, anticipating long in this the
industrial revolution of the 18th century and dazzling all foreign observers who visited
their works prior to that time. The Hung Kou (p. 269), even if of the 7th rather than the
6th century (and there are arguments for the earlier dating), has good claims to be the
first important practical inland artificial waterway in human history, and the

a To gain some idea of what floods have meant in Chinese life, even in our own time, with all its
resources, see Wan Nung (1); Yang Wei-Chun (2) and Alley (2).
b Cf. p. 354 above, on hints of close connections with Iranian culture in ancient times. But where the
technological 'elements' of water, earth and wood are concerned, people in very different parts of the
world may well have developed their own traditions fairly independently—for metal I would not like to
say much.

We have seen the connection clearly enough in the famous speech of Chi a Jang on his three
altitudinal missions and the remarkable river control (p. 285 above).

By this time 'Ta Yu, Yü the Great, originally a god who had made the earth rise above the surface of
the waters, was turning into a human culture-hero of hydraulic engineering (cf. Vol. I, pp. 87 ff.), and
soon after became honoured as the founder of the Hsia kingdom. Perhaps he was part of the southern

The Egyptian one found no home there exactly (except in the form of the river-valley dams) until the
retention-basins of the great rivers which our own contemporaries have built (p. 238).

Note how Seuma Chihen places the emphasis in his words on canals quoted on p. 296 above.

The primary duty was of course the transport of taxes in kind (grain, textiles, etc.) from the
periphery to the centre. At the same time water communications were important for the movements of
officials and personnel, especially after the decay of the Ch'in and Han road system (p. 30). But also one
must not forget a considerable military element (cf. pp. 265 and 299 above). This took at least four
forms. The diversion of natural waterways to sap city-walls, the weapon of floods caused by deliberate
dike-breaking, the defensive use of artificial canal networks against cavalry, and lastly the
construction of important canals chiefly for the transport of army supplies but also for the passage of
warships. The first two of these had Babylonian antecedents, but the other two, not at all developed in
South Asia, are rather characteristicly Chinese.

c Cf. p. 276 above.

The Nile/Red Sea Canal has been taken into consideration on p. 356 above and we shall hear more of it
below (pp. 465, 609). Although said to have been begun in the time of Sunshu Ao (c. -600) and con-

Han Kou's early 5th-century date is in no doubt at all (p. 271). These works, helped by the
lakes and flat country, were the ancestors of the Pien Canal (p. 307) and ultimately of the more
daring Grand Canal, oldest summit canal in any civilisation (+13th century, p. 312). In the 3rd century Shih Lu
had scored another triumph with the oldest contour transport canal in any culture, the Ling Chhü (p. 299),
taking the First Emperor's barges and warships across a mountain range, just as some centuries
carefully the Assyrians had led their irrigation water poaching from valley to valley. In the 2nd century again,
Ch'eng Tang-Shih and Hsü Po of the Han set a pattern for later ages in the West when they designed and built a transport canal
parallel to a navigable river but more suitable for heavy traffic (p. 273). This history affords plenty of laurels—if the Chinese ever felt inclined to rest upon them.

A couple of basic questions remain. If one asks where the works first arose one has to
visualise initially, in early Chou times, a wide area from the lower Yangtze basin northward to the lower Yellow River, i.e. the North-east and the East-central key
economic areas (cf. p. 226 above, and Fig. 35); then in the Warring States time the
addition of the North-west (Kuan-chung, the Wei valley) and Western (Szechuan)
areas. Already in the Ch'in dynasty (3rd century) all parts of China, except perhaps Fukien and Yunnan, were open to operations. If one asks what the earliest works were, it
would seem that the impounding of run-off water from hill valleys in tanks by dams,
with small derivatory canals, came first, quickly followed by the river-controlling
dykes; then after no long time the cross-country navigation canal, perhaps even preceding
the river-derived lateral irrigation canal system. It is quite clear therefore that the
Chinese achievements, though conditioned of course by physiographical and social
features, were deeply original, a symphony on benefit of water by a different composer.

If lastly one asks how the Chinese picture fits in to the framework of the annual-
perennial concept, the answer is not very easy. Nowhere in China were two highly
contrasting hydrographic zones in that proximity which pertained in Ceylon. With a
climate essentially monsoon in character all China's rivers had a marked rise and fall,
e.g. the 100 ft. excursion of the Yangtze at Chungking. They were therefore annual in
this sense, but perennial in that the low-water levels were themselves formidable—the

great seventeenth-century canals of France, the last of which was not finished till as late as +1775. None of these was longer than 150 miles. There were only 630 miles of canals in all France by the end of the eighteenth century, and even by 1893 the total mileage in that country was only three times that of the Grand Canal in +1342. The canals of all Europe probably still fall short of the Chinese artificial navigable waterways in mileage. Similarly the dimensions of the early nineteenth-century canals in England (about 5 ft. deep and 45 ft. broad) were less than that of the Yuan Grand Canal (from 10 to 30 ft. deep and often 100 ft. broad). Again, the locks on the Caldonian Canal in the same period were of just about the same dimensions as those on the Ling Chi-hui and Pien Canals in the +11th, i.e. 170 ft. long and 40 ft. wide.

It is tempting to make a comparison between the canals of Lombardy, among the first artificial navigable routes in Europe, and the waterways of the Ch'eng-tu plain (p. 289 above), since both cover an area about 50 miles square. The Naviglio Grande originated in the irrigation needs of the Duchy of Milan. Water was brought to the city from a point on the Ticino River 31 miles away by a canal with a +110-ft. fall which was finished in +1209. Sixty years later its cross-section was enlarged and flash-locks built to allow of the traffic with Lake Maggiore from which the canal then took its name. In +1359 it was extended, for irrigation purposes only, down the Ticino valley half-way to Pavia. After the cathedral of Milan was begun in +1387 marble was brought south by way of the Naviglio Grande, and at an early date in the +15th century this was put into communication with the city's old moat, which thus acquired the name of the Naviglio Interno. But as the moat was fed from a different source it stood normally at a different level, so that there were long waits at the single staic while the levels equalised. In +1458 the first pound-lock in Italy was installed there as the solution of this problem. After +1452 much expansion took place under the house of Sforza, when Bertola da Novate (cf. p. 358 above) was Ducal Engineer. A new extension of the Naviglio Grande to another point halfway to Pavia, for traffic this time, was built with the use of 18 pound-locks (+1458). A decade later Bertola built the Martesana Canal, connecting Milan with the Adda River; for crossing two tributaries at right angles he adopted not the Sinhalése and Chinese spillway technique, but a 3-arch aqueduct in one case (the first of its kind) and a large culvert in the other. The Martesana was intended to link Milan with Lake Como, but the Adda needed a by-pass at Paderno, and this though well planned was never completed. All these waterways were supplemented by a considerable number of subsidiary irrigation canals and

* These were (a) the Aude-Garonne, planned +1516 by Francis I and the lord of the manors of Clas Lucé (Leonardo da Vinci), surveyed +1539 and +1559, completed +1681; (b) the Loire-Saône-Rhône, planned +1536, completed +1765; (c) the Seine-Saône-Rhône, planned +1564, completed +1775; (d) the Seine-Vienne-Loing-Loire, planned +1603, completed +1742. Details in Mord (1); Parsons (2); Skempton (4); Esplan (1); Pinseau (1); Andreossy (1). (The Canal de Briare (d) was not, as others besides Espinas have claimed, the first summit canal in the world.

+ 144 miles, 72 miles, (c) Vol. 4, pt. 2, p. 129.


Unfortunately we have not been able to find even an approximate figure for this.

Vernon-Harcourt (1), p. 331. Cf. Rott (3); Hadfield (1, 2, 3); de Mare (1).


Detailed accounts of these will be found in B. B. Smith (1); Parsons (2), pp. 367, 399; Skempton (4), pp. 444 ff. and fig. 280; see also Calvert (1); Hadfield (4).
conduits. Nothing could have been more different than the problems, aims and operations in the Szechuanese and Lombard areas, yet the same basic devices were needed, division-heads, weirs, dams, excavations, bridges, and the like. We may thus accept some parallelism between them—the only thing one can hardly avoid noticing is that the European works were carried out with various deficiencies, false starts and failures, more than a millennium and a half after the successful inauguration of the former.

All our comparisons can be as yet only preliminary and tentative. But it is evident that a comparative world survey on quantitative as well as qualitative lines would set the Chinese achievements in a highly favourable light. Thus we face once again a paradox. The lack of developed Euclidean deductive geometry did not prevent the successes of a cumulative empirical tradition from which the intuitive and the rational conduits. Nothing could have been more different than the problems, aims and operations in the Szechuanese and Lombard areas, yet the same basic devices were needed, division-heads, weirs, dams, excavations, bridges, and the like. We may thus accept some parallelism between them—the only thing one can hardly avoid noticing is that the European works were carried out with various deficiencies, false starts and failures, more than a millennium and a half after the successful inauguration of the former.

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Our aim must now be to place the junks and sampans of China in their proper relationship, with the ships and boats developed in other parts of the world. The history of Chinese nautical technology can mean little if it is not set in a comparative way, so that the distinctive contributions of the civilization can be seen. Distinctive characteristics there certainly were: indeed Chinese shipping has generally been thought to stand very much apart from all other water-borne creations. Whether priorities in time also imply transmissions, even if only of ideas, to other peoples, is a problem which will again arise acutely, and a final answer may well be impossible. Ethnologists and historians of technology studying diffusion and convergence should pay more attention to ships and ship gear, since the material, though highly complex, is often strangely precise, and its very complexity may help to lessen the plausibility of double or simultaneous invention.

The Chinese texts which give us information about shipping will speak for themselves as we go on, but we have been able to choose only a few from a wide literature which has never yet been fully explored. The sources from which they have to be collected are in fact many and various, for unlike some other technical subjects such as agriculture or pharmacy, systematic nautical treatises did not arise in Chinese culture, or at least did not get into print. Let us glance briefly then at the varieties of Chinese

The word 'junk' applied to the Chinese ship is, according to Yule & Burrell, one of the oldest in the English language. It occurs in the travels of Odoric of Pordenone (c. + 1320) and of Ibn Battutah (+ 1354), and appears as 'Tzuch' on the Catalan Atlas (+ 1375, see below, p. 471). It undoubtedly derives either from Chinese ch'huang, a ship (Cantonese sham, shn), or from the cognate Javanese and Malay words jung and joeng. It cannot come from trung, which means a fleet or squadron (Pao Tung-Pheng, I), cf. p. 491.

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A thousand years later the Thang-Yu Lin, or in the private memoirs of individual scholars. An outstanding example of the latter is the Phing-Chou Kho Than (Phöngchö TáblTd-Talk) written in + 1119 by a man whose father had been Port Superintendent and later Governor of Canton, and dealing with the maritime life of the coast during the last decades of the + 15 th century. Naturally enough, there is much about shipping in the literature which dealt with foreign countries and took it in hand to describe the way thither. Thus the + 15 th-century books Nam Chou I Hu Chih (Strange Things of the South) and Wu Shih Wei Kao Chuan (Records of Foreign Countries in the time of the State of Wu) both preserve important information. So also does the record of the embassy to Korea in + 1124 by Hsi Ching. Perhaps the best of all classical depictions of a
Chinese sea-going ship is contained, not in any of the encyclopedias already mentioned, but in the *Liu-Chin Hau Chih Lueh*, Chou Huang’s eighteenth-century ethnological account of a visit to those islands (Fig. 939).

For navigation and shipbuilding we are unusually dependent on manuscript material. At an earlier stage we saw how runters and sailing-directions were beginning to be preserved in late Sung, Yuan and Ming, after the use of the mariner’s compass had become universal on Chinese ships. By the +17th century substantial books on navigation were printed both in China and Japan—the same year, +1618, saw the appearance of the *Tung Hsi Yang Kho*, (Studies on the Oceans East and West) by Chang Hsieh, and the *Genna Kokaiko* (Navigation Manual of the Genna reign-period) by Ikeda Kōun. Of course the books of earlier date are still more interesting; one such is preserved in MS. at Oxford, the anonymous *Shun Fung Hsiang Sung* (Fair Winds for Escort) which dates probably from the first half of the +15th century, the time of the great voyages commanded by Chêng Ho. We shall give an analysis of it later on.

For ship-building we are again beholden to a remarkable manuscript (now at Marburg), but it is a very late one, the anonymous *Min Shêng*... *Chun Shao Chhuan*... *Thu Shuo*, or Fukien Shipbuilding Manual, which belongs to the end of the +18th century. Other useful material is contained in the *Thien Kung Khai Wu* (+1637) by China’s Diderot, Sung Ying-Hsing; and there is a +16th-century record of the yards near Nanking which had built many of the ships of Chêng Ho’s fleets a hundred or more years earlier, but it has not yet been properly studied. How regrettable it is that Chinese naval architecture never found its Li Chieh, its systematising scholar! At any rate one would not be far wrong in believing that the shipwrights of the Ming were probably the most accomplished artisans of any age in any civilisation who were at the same time illiterate and unable to record all their skill.

So much for the texts. As we shall find, archaeological evidence comes often to our aid, in the form both of models and pictures. This we shall discuss as it arises.

Though Chinese literature itself is thus not rich in works dealing specifically with the construction of ships, there is abundant material in the works of sailors and scholars of an even more maritime civilisation. General accounts and histories of navigation, such as those of Charnock (1), Jal (1), Moll (1) or la Roerie & Vivielle; of scholars of an even more maritime civilisation. General accounts and histories of navigation, such as that of Marguet (1) or Hewson (1); and of shipbuilding, such as those of Abel (1) and van Konijnenburg (1), can all be brought under contribution. About a hundred years ago a French admiral, F. E. Paris (+1809), laid the foundations of a comparative morphology and evolution of sailing craft.

What is the fundamental relationship of the Chinese junk to all other types of craft which have used? This can best be understood by means of a summary such as that embodied in the accompanying chart (Table 71), which is based upon the survey of Hornell (1). In the first place, following this scheme, we must be concerned with hull structure, reserving methods of propulsion for a later sub-section.

At the outset it is necessary to dispose briefly of a number of primitive types of craft which had no great future before them, but some of which played their modest role in history. As will be evident, the chart is arranged according to the various natural or artificial objects which ancient people must have seen floating on the water, and upon which they conceived the idea of launching forth themselves. Thus floating baskets gave rise to a number of small boats some of which are still used at the present day. They could be simply caulked, either with bitumen if this was available, as in the *paffa*

(b) COMPARATIVE MORPHOLOGY AND EVOLUTION OF SAILING CRAFT

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and *hibiya* of Iraq,* a or otherwise with a kind of mud, as in Tongking in Indo-China.*

No evidence of the use of this simple form in China proper remains, but it is probably

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* Hornell (1), pp. 57, 102; Nishimura (1).

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* Hornell (1), p. 100; Nishimura (1); Dumouzant (2), p. 152; Poujade (1), p. 183. The strange *ghe-

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29. NAUTICAL TECHNOLOGY

the _manashi-hatama_ of Japanese legend. When the basket was covered with skin or hide, the familiar coracle or curragh came into existence. The distribution of this craft, both in time and space, is much wider than has often been realised. It appears on a number of well-known Assyrian bas-reliefs, from which a Mesopotamian origin seems indisputable, and it is the characteristic vessel found near Batang, on the Yalungchiang, the upper Yangtze and the upper Mekong. Thus probably a coracle. Not long after Ko Hung's time cowhide coracles were used both in time and space, is much wider than has often been realised. Chuang for feint attacks during military operations along the Yellow River about +386. Three coracles are depicted on the walls of a Sui cave at Chihien-fu-tung. And there is much evidence that boats of this type were abundantly used by the Mongols in their +13th-century conquests. But in the Chinese culture-area such craft never developed into the elongated skin-covered and decked boats of the Eskimos and northern Siberian peoples, with all the curious arts pertaining thereunto. Bark canoes are also remote from our sphere, yet interesting in that Hornell found reason for regarding them as possible ancestors of dugout canoes since in some localities the latter show vestigial rib-like internal ridges running in relief transversely across the bottom and up the sides.

Other basket-shaped objects may also float. The pottery bowl, if large enough, may be used to carry a man, as in Bengal, but its place is taken in China by the wooden 

**tub**, which many writers have described. It is often called the _hu chhuan_ or kettle-boat, and is much used for collecting aquatic food plants; Japanese legend knew it as the basin-boat (_tarai-bune_).

Buoyant objects, more or less spherical, formed the beginning of another line of descent. Swimmers supporting themselves upon gourds or inflated skins are frequently seen on Assyrian reliefs of the 9th century, and the method survived for centuries in many parts of the world, especially for campaigning purposes, as in the Mongol armies, when it entered Chinese military books from the +11th-century _Wu Ching T'ung Yao_ onwards, and was perpetuated in later encyclopaedias (_fou nang fa_). People are shown using them in the reliefs at Sanchi in India, and four centuries earlier Chuang Chou had referred to them. The logician Hui Ta,t who had received a present of large gourds (_ta hu_*) from the Prince of Wei, did not know quite what to do with them, and the more practical Chuang T'ai suggested to him that he should use them for crossing rivers. Gourds (_hsiagou_?), inflated deer-skins (_kako-no-kawes_?) and closed clay vessels (_kani-bune_?) all occur in Japanese legend (Nishimura, 1). In +12th-century China such aids were known as waist-boats ( _yao chou_?). They are used to this day in Japan by women fishers and divers.

The transition to what might be called craft in the strict sense came when a number of buoyant objects were attached to a framework of wood to form a buoyed raft, Lagercrantz (1), who has studied the present distribution of these rafts, concludes that their original focus was the region of fast-flowing rivers rising in Central Asia. The _phi fa t'ou_ (skin raft), composed of thirteen goatskins, is indeed common in North-west China, on the Yellow River and all its tributaries; I myself have journeyed often on them in the province of Kansu (Fig. 927, pl.). Still today one sees them being carried on men's backs beneath the walls of Lanchow. I have not, however, viewed the greater rafts of which Nishimura speaks, borne upon as many as 700 sheepskins, each of which is (or was) stuffed with a cargo of camel-hair or wool. Closed pottery vessels as boats seem not now to be used in China, but they certainly were in antiquity, for the Han general Han Hsin achieved a famous crossing of the Yellow River with his army by the aid of such rafts (_mu yang_?). The device is described in the _Wu Ching T'ung Yao_ of +1044, and late encyclopaedias also illustrate it.

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29. SHIPPING
The real key-point in the origin of most ships is thought by many to have been the observation of the floating single log, and its conversion to a convenient vehicle by hollowing out to form the dugout canoe. A it would then be a natural notion to increase its freeboard by adding first a wash-strake, and later gradually building upwards a succession of strakes which became the sides of the ship. Thus in most kinds of ships the ghost of the dugout canoe still lives on in the shape of the keel, not indeed vestigially however, since the keel gives necessary longitudinal strength, and if projecting much below the hull, has importance for the sailing properties of the craft. An early invention was the fanning of the sides of the dugout underbody by steaming the wood, after which they were retained in place by the insertion of U-shaped frames. Finally the keel became purely a beam. From the forward end there grew out of it the stempost, and aft the sternpost by a like extension. Boat-building then diverged into two recognisably different traditions, in one of which the strakes were laid overlapping each other, while in the second they were abutted edge to edge so as to form comparatively smooth external and internal surfaces. For these two methods the terms clinker-built and carvel-built are used respectively.

This particular classification is one into which all vessels in the world will fit, but it is far from being the whole story. Broadly speaking, the clinker-build is characteristic of northern Europe alone, while the ships of all other regions (the Mediterranean, the Persian-Arab culture area, India, Oceania, and China) are carvel-built. Further distinctions then arise; the strakes may be sewn together with vegetable fibres or they may be nailed or secured by wooden pins (trelains). Frames and ribs, thwarts and longitudinal stretchers, may be constructed first and the strakes attached to them, or on the other hand the planking may be fitted together first and the frames inserted afterwards. This second method was that of the ancient peoples of northern Europe throughout- out the Viking period. From the Als boat of the 4th century to the Oseberg and Gokstad ships of the 9th, the overlapping strakes were lashed to transverse framing girders of the fore and aft the sternpost by a like extension. Boat-building then diverged into two recognisably different traditions, in one of which the strakes were laid overlapping each other, while in the second they were abutted edge to edge so as to form comparatively smooth external and internal surfaces. For these two methods the terms clinker-built and carvel-built are used respectively.

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Compared with the distinction we now have to make, all these details are relatively unimportant. It is clear that the ships of East Asia cannot be genetically explained on the theory of the simple floating hollow log. Bamboo is their ancestral material, not wood at all, for as we shall see, the Chinese hull (however its sides are built) is an elongated structure as full of transverse bulkheads as the stern of the bamboo is of those partitions which botanists call septa. These, they would say, are the transverse solid partitions which botanists call septa. This construction is thus seen to be provided by the sub-family Bambuseae. And this construction it is which sets the Chinese ship apart from the ships of the rest of the world.

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9. Nautical Technology

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It must have occurred very early to primitive men that instead of hollowing out a single log to make a canoe, they could bind a number of logs together and obtain a 'ship' of considerable size. Rafts made of bundles of reeds or rushes need not much concern us; they were important for the development of sailing-craft in Egypt and the New World, but not in China, though not unknown there (phai fa). Rafts of logs joined together in various ways achieved wide distribution and were of great use to many peoples, especially in the form of the sailing catamaran, so common on the coasts of India and the East Indies. In China they are seldom used at sea, but very great rafts of wood still descend the Yangtze and many of its tributaries. We have exact descriptions of the shan-mu fa tsou of pine wood which comes down to Chungking, the raft of the Min River which has to negotiate the works at Kuanhsien, the huge mu phai of the Lower Yangtze, and the small rafts of the Miao tribesmen in Kwetschow. Their prototypes must have been in use in the Chou period; at any rate we hear of them in the Han, for in +47 the prince of the Ai-Iao barbarians, Hsien Li, ordered his forces to sail downstream upon rafts (phai chhuan) to make an attack on the Lu-to tribe. Nishimura (1) plausibly finds mentions of wood rafts in Japanese legend, under the terms ame-no-ukihashi and uki-tahara. But Chinese wooden rafts were not of genetic importance; bamboo rafts assuredly were, and to them we shall shortly return.

The moment has now come to describe the basic characteristics of the Chinese junk and sampan. In doing this it is necessary to put aside, as it were, much that we have learnt in the last few pages, for everything which was done in shipbuilding in the rest of the world failed to exhaust the ways in which the men of old found it possible to make ships. In Europe and southern Asia the basal beam, the keel, was scarfed at each end to another stout beam which turned upwards to form the stempost and sternpost respectively. The strokes of the hull, which connected them, were held apart in the traditional way by wooden pegs. All this has been revealed by the systematic study of submerged Mediterranean wrecks; see Frost (1), pp. 223 ff.; Benoit (4, 5), Casson (3), p. 193, 6, 7); Bass (1); Hassloff (1, 2, 3).

1 Hornell (1), pp. 41, 43, 53; Poujade (1), p. 190; Reiner (1); Brootx (1).
2 Cf. Wu Ching Tung Yao (Chhien chih), ch. 11, pp. 12b, 14b.
3 Hornell (1), p. 61 ff.
4 In +1656 Kniehoff sketched a 'floating village', i.e. a great bamboo raft, on the Yellow River near Hu-han, and afterwards gave a copper-plate of it, (1), p. 154 ff.; Reprod. Rudolfsky (1), p. 2.
5 Worcester (1), p. 70.
9 Hou Han Shu, ch. 19, p. 172; ch. 116, p. 175. Another example, a military crossing in a campaign against the Chhiang people (+88), occurs in Hou Han Shu, ch. 46, p. 16b. In this case the rafts seem to have had bulwarks made of leather. A text of about the same time, the Yeh Chiao Shu, tells (ch. 8, p. 46b) of the building of a great fleet of rafts by 2,800 sailors of Koo Chien, King of Yucht (cf. Vol. 2, pp. 275, 555 above) in +472. These may well have been sailing-rafts (cf. p. 393).
10 The precise statement of the principles of junk construction owes much to Hornell's classical paper (2). (Ch. 8 and 1), p. 86 ff. Of course, many Chinese statements exist, and some of them we shall note hereafter (p. 428), but Chinese writers never knew enough about the ship-building of the rest of the world to realise the true originality of their own people.

29. SHIPPING

desired profile by an internal skeleton of bent timbers. But junk design, exemplified in the oldest and least modified types, has a carvel-built hull wanting in all the three components which elsewhere were regarded as essential—keel, stempost and sternpost. The bottom may be flat or slightly rounded, and the planking does not close in towards the stern, but ends abruptly, giving a space which would remain open if it were not filled by a solid transom of straight planks. In the most classical types there is no stem either, but a rectangular transom bow. The hull may be compared to the half of a hollow cylinder or parallelepiped, bent upwards towards each end, and there terminated by final partitions—like nothing so much as a longitudinally split bamboo. Moreover, frames or ribs are replaced by solid transverse bulkheads (analogous to the nodal septa) of which the stern and stern transoms may be regarded as the outward units. This is clearly a much firmer method of construction than found in other civilisations. Fewer bulkheads were required than frames or ribs to give the same degree of strength and rigidity. It was obviously also possible for these bulkheads to be made watertight, and so to give compartments which would preserve most of the buoyancy of a vessel if a leak should occur, or damage below the waterline. In other ways, also, the bulkhead structure involved corollaries of great importance, for example in providing the essential vertical components necessary for the appearance of the hinged axial rudder. These, together with cognate inventions in the domain of propulsion by sail (of surprisingly early date), will be examined in due course. Here we need only stop to remark the striking similarity between the bulkhead structure of the Chinese ship and the prominence of the transverse partitions or frameworks so fundamental in Chinese architecture (cf. p. 102 above). If the latter prevented a longitudinal vista and permitted the classical curve of the roof, the former provided distinct holds, rendered the vessel extremely strong, and gave it the typical bluff bow and stern of large Chinese craft. One cannot but feel that both systems were inspired by the bamboo, that plant so familiar to every Chinese from a thousand uses, with its transverse nodal septa. The sampan (shan) is reminiscent of the bamboo stem just as much as the junk. It is an open punt-like skiff, wedge-shaped in plan, shallow, keelless, and very broad in the beam aft, where the gunwale rail and side strakes are often continued beyond the stern as an upwardly curved projection, endowing the craft with checks or wings facing...
astern. It was the roofing of the space between these projections that led to the overhanging stern-gallery of the junk.

There have been several theories about the origin of the junk and sampan. One suggests that the design derives from a double canoe system, in which twin hulls were placed parallel a short distance apart, and connected by planking to form a new bottom with square ends. Craft of this kind, however, have not been found anywhere. Nor is there any evidence of the longitudinal bulkheads to which it would have given rise. On the other hand, a double-canoe build, as such, has existed, and still does, in various parts of the world. It is curious, too, that the Chinese language contains a number of old words (fong, tang, hang) and perhaps originally hang, which came to mean sailing in general, all indicating two boats lashed or secured together with cross-timbers side by side. Moreover, such devices are in current use in China, notably for transporting reed-stacks downstream, and for fishing (the Ichang river). There are, however, no evidence for the use of such a method in China at any time. Moreover, it is not possible to say that dugout canoes occur nowhere in the Chinese culture-area; they are in occurrence and distribution exceedingly sparse. Generally speaking, too, they seem to have disappeared during or before the Han.¹

¹ Examples in Worcester (3), p. 316, 373. That this is an ancient feature is proved by many old paintings—for the Thang, the boats on the Tunlung tang frescoes (see on, p. 455), and a painting by Wang Wei reproduced by Siren (6), vol. 1, pl. 58; for the Sung, the painting by Hua Ku reproduced by Waley (19), pl. 43; for the Yuan, the paintings of Ma Yuan (Waley (10), pl. 42; Siren (6), vol. 2, pl. 59; Binyon (1), pl. 17) and Wu Chen (Siren (6), vol. 2, pl. 123). This is favoured, e.g., by Gibson (2), p. 16, 32.

² Hornell (1), pp. 44 (Peru), 78 (Fiji), 151, 248 (India), 262 (Polynesia). Double-hulled vessels have been used for various purposes all through nautical history (cf. the invention of Sir William Petty in + 1684) and they are even employed for fast-sailing pleasure-boats (Brown, 1). The Times has published a photograph of such a craft (Jan. 1958), tending it, however, a catamaran. This is a 'common and deplorable error' (Hornell), for the word is properly applied not to double-canoe or outrigger-canoe, but only to log rafts.

³ Definitions in Shuo Wen, Erh Ya, Fang Yen, etc. Locus classicus (Phi-She-Ki, 6), p. 59. (French), 39, 1225 Chao Ju-Kua, speaking of the people of Southern Formosa (Phi-Shé-Yeh¹), wrote that 'they do not sail in junks or rowed (boats) but lash bamboo into rafts, which can be folded up like screens, so that when hard pressed, a number of them can lift up (the component parts) and escape by swimming off with them.' Another reference to such events is in the Sung Shih (which describes the sailing-rafts used by the Liu-Chhiu islanders in piratical raids on the Chinese coast between +1174 and +1189. But our oldest picture of these vessels¹ was drawn by a Japanese sailor, Hata Sadanori, as late as 1825.

If an evolution of the junk from the bamboo raft form is envisaged, it is only necessary to suppose a conversion of the wooden thwart-beams into bulkheads, the
substitution of wood planks for bamboo in bottom and sides, and the addition of decking. Such a process can actually be seen at work in the catamaran log rafts of Madras, some of which have plank strakes pegged on along each side.a In many Chinese vessels, notably the Liu-phêng chhuan: of Kuangtung, the lines of the sailing-raft are preserved or exaggerated.b The conception of transverse bulkheads would have grown naturally out of the septa of the bamboo stem itself. Indeed, a length of bamboo cut in half longitudinally and floated on water gives a striking model of the constructional principle of all Chinese craft (see inset on p. 391).

It is not necessary to insist upon the sea-going bamboo sailing-raft of Thâiwan as the only ancestor of all junks, for many other forms of bamboo raft are regularly using Chinese rivers at this day.d One of the most interesting is the Ya River raft of Szechuan, which moves both up and down 100 miles of intractable waterway between Yachow and Chiating, carrying Tibetan trade.e This Chu-fa chhuan must be one of the lightest-draught general cargo-carriers in the world, for its depth below the waterline when loaded (with a cargo of 7 tons) is often as little as 3 inches and never exceeds 6, owing to the buoyancy of the bamboos. In length the rafts, which are quite unsinkable, vary between 20 and 110 ft., and are built throughout of the culms of the giant bamboo (nan cha; Dendrocalamus giganteus) which grows as high as 80 ft. with a diameter of as much as a foot. The bow is narrowed, and bent upwards in a curve by heating, so that the raft can slide over rocks which may be almost level with the water surface (Fig. 930, pl.). In other provinces there are also interesting bamboo rafts (chu phài), some of which have the upturned bow (Fig. 931, pl.). Moreover, certain boats, such as the 'fan-tail' (Shen-po-tzu) of western Szechuan, seem to have transferred this ancient device to the stern as a protection against shipping water when descending rapids.

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- Hornell (8).
- Extremely similar craft are in use, as we have seen, on the coast of Indo-China. All these closely parallel the famous balas-wood or log sailing-rafts of the Amerindian culture-area, especially the Inca coast of Peru and Ecuador, and the northern coast of Brazil (cf. Lethrop (1); Hornell (1), pp. 81 ff., (2a); Heyerdahl (2), pp. 513 ff.; Clissold (1), etc.). In their traditional form, however, the Amerindian sailing-rafts were manoeuvred by the use of the centre-boards only, and knew no steering-oar or rudder. Ling Shun-Sheng (1) attacks the thorny problem of the relations between East Asian, Polynesian and Amerindian sailing-rafts, pointing out the remarkable similarity between the Formosan and Ecuadorian-Pervian forms. He goes so far as to suggest that even the names of such craft in the southern and western Pacific areas derive from Chinese roots, but this is linguistically unconvincing. Moreover, part of his argument for a basically Chinese origin rests on an apparent acceptance of the traditional — 3rd and — 4th millennium datings for the legendary emperors and culture-heroes of China. Nevertheless it seems to us much more probable for many reasons that the sailing-raft with centre-boards did traverse the Pacific from Asia to America rather than in the opposite direction. This opinion was also held by F. Paris, cf. (3), pp. 34, 64, 67, and by Hornell (2a). Bowen (1), p. 108, supports it too.
- And long have done so. Cf. Fig. 929 from TSCC, Khaung hien, ch. 178, p. 126, originally from STTH.
- A very similar illustration of rafts on a river in Kuangtung is given by Eigner, Alley et al. (1).
were boats, people crossed rivers by means of rafts. Since the term fa means the same thing as fa, these rafts must have been known before Huang Ti's time. Nowadays people call any raft (phai) consisting of bamboo or timber a fa. Bamboo rafts are probably meant by the classical word wei; the Shih Ching has a verse 'I can cross the river on a (bundle of) reeds' (i wei hang chih).b The view that the junk developed from the bamboo raft is not contradicted by the famous passage (phai 3) measuring between 35 and 110 ft. Formerly they were built as large as 150 ft. As will be seen from the elevation, there are no less than 14 bulkheads (liang chou), forming so many separate holds (tshang). In the oldest and most characteristic build, there is no basic longitudinal strengthening member (i.e. keel) at all, the structure depending for lengthwise rigidity only on the planking nailed to the bulkheads, and on very solid wales (chhsuan pien chia ta chin), lit. 'grasper sinews') upon the sides. These are still fitted, taking their place among the strakes (chia chin), but modernisation has now sometimes induced a 'keel' (liang ku), see p. 429 even in remote river types of build. Or there may be a kelson and two side kelsons at the turn of the bilges, inside their planking (tsan chiou pan).

Between the bulkheads, there may be some frames, half-frames, or ribs (35 yu) though it is doubtful if these are of ancient origin. Floor-boards (ti yu) in the holds can lie on these above the structural bottom planking (chhsuan ti pan). The bulkheads themselves nearly always include vertical members or stiffening bars (liang chou pan). Many types of Chinese craft have a considerable tumblehome like European ships of the + 18th century, in other words they may be said to be turret-built, and this is the case with the Ma-yang-tzu. The deck (chih mien pan) does not, therefore, occupy by any means the whole beam breadth. As is almost invariably the case on Chinese ships, superstructures are aft of the main mast (chhiang)z), their topside planking (han phi) continuing into rails or bulwarks (han phi mien chih chin), though these are seen more on sea-going ships, and indeed generally absent forward of the mast on river junks, thus giving uninterrupted space for handling oars, yulohs, c tracking gear, and so on. The deck is carried on transverse beams (chi hsiang) placed at intervals along the top of the hull; some of these project outboard and serve for the fullcr of different kinds of oars, so that they may clear the guard deck or whaleback (i.e. the sloping upper boarding of the hull; chhsuan wai chiou pan). The square bow ends in a massive projecting cross-beam (jun) useful for all kinds of purposes. Hatch coaming (tshang khou pien pan) is fitted from the bow to the deckhouses, and the deck planks run athwartships above it.

(c) CONSTRUCTIONAL FEATURES OF THE JUNK AND SAMPAN

The best way to proceed from the point we have now reached will be to examine more closely a few typical examples of marine architecture. At the same time we shall be able to gain an idea of some of the most important technical terms which were, and are, used by the shipwrights and sailors.

- Hsin-Yuen was one of the names of the legendary emperor Huang Ti.

- Hsiao no. 61, tr. Kardgren (14), p. 242; Legge (8), p. 104.

- Lu Yu, vi. The part about the barbarians was added by later scholars, as e.g. in Shuo Wen, s.v. The great Legge, in his translation (2), p. 28, made out that Confucius intended to get on a raft and drift aimlessly at sea. Doubtless he did not know of the existence of excellent sailing-rafts, but it was a pity to generate yet one more unnecessarily fatuous occidental conception of China. In fact, the picture of the sage's tall lug-sail breasting the waves of a stormy sea to bring the message of rational social order to men still slaves of superstition has a real sublimity. Well might such a vessel have merited the epithet of 'Starry Raft' (hing e Ma) applied long afterwards in Chinese usage to the ships of ambassadors. And this is convenient, but I do it also as in private duty bound, since the square bow of Szechuan. Description in Worcester (1), p. 357.

- Chih mien pan (3). The bulkheads, superstructures are aft of the main mast (chhiang) does not, therefore, occupy by any means the whole beam breadth. As is almost invariably the case on Chinese ships, superstructures are aft of the main mast (chhiang)z), their topside planking (han phi) continuing into rails or bulwarks (han phi mien chih chin), though these are seen more on sea-going ships, and indeed generally absent forward of the mast on river junks, thus giving uninterrupted space for handling oars, yulohs, c tracking gear, and so on. The deck is carried on transverse beams (chi hsiang) placed at intervals along the top of the hull; some of these project outboard and serve for the fullcr of different kinds of oars, so that they may clear the guard deck or whaleback (i.e. the sloping upper boarding of the hull; chhsuan wai chiou pan). The square bow ends in a massive projecting cross-beam (jun) useful for all kinds of purposes. Hatch coaming (tshang khou pien pan) is fitted from the bow to the deckhouses, and the deck planks run athwartships above it.

- This is convenient, but I do it also as in private duty bound, since in former days I made a number of journeys on this type of vessel. What understanding I have of Chinese river steamship I owe to Captain Wu of Szechuan. Description in Worcester (1), p. 357. Claudel & Hopenot have published (1) pl. 31, a striking photograph of models of Ma-yang-tzu and their makers.

- See p. 62a below.

- On Chinese hull construction in general see Audemard (1), pp. 10 ff. He has also an excellent general statement on masts and tabernacles, pp. 31 ff.
The pinewood mast, some 80 ft. in height, is stepped in tall tabernacles which rise as high as 6 ft. above deck level. A tenon on the heel of the mast fits into a socket in a movable timber of considerable strength, bearing on half-frames below and fitting snugly against the sides of the bulkheads, thus distributing the thrust (Fig. 934). On modern versions of the build, coffer-dams or small compartments kept free of cargo are introduced between bulkheads, into which bilge-water can drain for removal by bamboo pumps. It will be seen that the rudder (\( \text{tho} \)) is a balanced one (that is to say, part of its blade is forward of its axis), and carries a tiller 25 ft. long, which may require as many as three men to handle in a difficult rapid. There may also be a bow-sweep. The mast will carry a single lofty lug-sail. While the permanent crew of a large river-junk of this kind may be only eight, fifty or sixty more men will be engaged from time to time; and for towing upstream in certain places, as many as 400 trackers may be necessary.

Of this kind of vessel there are many variations, such as the Tho-lung-tzu \(^1\) and the Nan-ho chhuang \(^2\) which ply west of Chungking. \(^3\) Some of them, such as the latter, supplement their rudders with a very massive bow-sweep.

As our type-specimen of the sea-going junk we may take the Chiangsu freighter \(^4\) or Sha-chhuang \(^5\) (sand-ship). \(^6\) Formerly these reached in size a length of as much as 170 ft. The pinewood hull (chhuang kho) \(^7\) is flat-bottomed (see Fig. 935), the central longitudinal timber being somewhat larger than the others and substituting for a keel. As many bulkheads are present as in the up-river boat just described, and the sides of the hull are strengthened by wales. Since the curves of the turret-built hull converge at bow and stern, the foremost and after compartments are masterpieces of construction, \(^d\) and the curved deck beams are rabbeted with great ingenuity into the curved frames of the hull. \(^e\) Certain of the stem and stern ribs (longitudinal members) are actually grown to shape. \(^f\) Both bow and stern are bluff and capable of withstanding the worst weather, but abait the stern a kind of \( ' \text{false stern} \) (\( \text{tho-lou} \)) is built on by extending the sides of the hull in a rising curve beyond the final transom, to terminate in a shorter false transom about 7 ft. above the water-line. The decked surface of this structure prolongs the deckhouses and carries a windlass for hoisting or lowering the rudder, which is slung within this enclosed space. Such an arrangement has been for centuries particularly characteristic of Chinese ships. The rudder-post works in three open-jawed wooden gudgeons, and the tiller is handled either on the roof of the deckhouse or from within it. Still aft of the false stern is a long stern-galley, 

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\(^{1a}\) Worcester (I), pp. 61 and 78. 
\(^{1b}\) Sometimes called the Pechili freighter. 
\(^{1c}\) Worcester (3), vol. I, p. 114; Waters (a). 
\(^{1d}\) See, for example, Fig. 956 (pl.), which shows the bow of a Fuchow pole-junk; cf. Worcester (3), vol. I, p. 130; Donnelly (5). And Fig. 937 (pl.), those of a Hangchow Bay freighter; cf. Worcester (3), vol. I, p. 137. 
\(^{1e}\) What Smyth said of Dutch vessels is applicable here: \( ' \text{As with the case of the Chinese junk, however bluff or unwieldy the upper works appear, the underwater lines are generally very sweet, and Neptune, to his credit be it said, has ever a soft heart for a full sweet curve' } \) (p. 84a). 
\(^{1f}\) A remarkably "Twist" practice. But it was also used by European shipwrights.

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Fig. 934. Tabernacle of typical Chinese mast (from Worcester, I).
Attention should be given to the masts, of which there are five, for (as we shall see) this system was surprising for the Europeans of the +13th century, and seems to have exerted a great effect upon their subsequent ship design. Generally speaking, all sea-going junks of any size were, and are, provided with multiple masts, river craft rarely having more than two. A feature, however, which did not spread outside the Chinese culture-area was the system of staggering the masts in port and starboard positions. Thus in the present case, the foremost (thou wei) is placed off centre to port, while the second foremost (erh wei) is amidships; both are raked forward. The main-mast (chung ta wei) is also amidships but raked slightly aft, then come the mizen mast (su wei), on the port side with a marked forward rake, and lastly the bonaventure mast (wei wei), considerably taller than the mizen and stepped with no rake at all. The raking is not the same on all ships, but the general tendency is to have the masts radiating like the sticks of a fan. There is also individual variation in the construction of the tabernacles. As in nearly all traditional Chinese sea-going ships, the masts are completely devoid of stays, but in some types the heavy primary masts are provided with single or Y-shaped struts about deck level which transfer part of the thrust of the sail to the junctions of hull and

Key to Fig. 935 (continued)

19 fore-and-aft stern timbers grown to shape
20 bluff and rounded transom stern
21 false stern, consisting of an 8-ft. extension of the sides of the hull beyond the transom, ending in a shorter false transom
22 windlass for hoisting the rudder (cf. p. 632)
23 rudder, iron-bound and non-balanced
24 16-ft. tiller
25 10-ft. stern gallery
26 31-ft. port foremost (forward rake)
27 28-ft. port mizen mast (forward rake)
28 48-ft. aft mizen mast (vertical), slightly to port of amidships
29 port foremost tabernacle (inside bulwarks)
30, 31 fore-and-aft baulk securing midship foremost heel
32 hounds of mizzenmast
33 light topmast of mainmast
34 sheave pins passing through both masts and securing double halyard sheaves
35 light topmast of aft mizen mast
36 navigation light
37 galley
38, 39 cabins with bunks and sliding doors
40 rice bin and stores
41 shrine to Kuan Yin
42 cooking-stoves
43 below-deck living quarters
44 Scale 10 20 30 40 feet

Fig. 935. The Sha-chhuan or Chiangsu freighter, a sea-going junk which was probably the parent type for many kinds of Chinese ships (from Worcester (3), vol. I). It was often nearly 200 ft. in length, approaching the size of the great wooden ships of the Ming navy (cf. pp. 479 ff. below), but the example here drawn is of 85 ft.

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bulkheads forward (Fig. 938, pl.). All the masts carry balanced lug-sails, and some of them have top-masts on which, today as in the Middle Ages, topsails are set under suitable sailing conditions. Such junks as these, today carry a crew of about twenty, must resemble fairly closely the prototypes which journeyed to the Indian Ocean in the Sung period. Their beauty when in full sail has fascinated many observers.

(2) Technical Terms

As we have already pointed out, the elucidation of Chinese shipbuilding and nautical nomenclature has its difficulties. So far as we know there is nothing in Chinese literature which does for this subject what the great Ying Tsoo Fa Shih* did in the field of building technology. Again the trouble is that the practical men never committed anything to writing, and the literary men had little or no knowledge of the building and handling of ships; they could only make commentaries on technical terms which even their predecessors had perhaps only half understood. So although Chinese encyclopaedias, from the Erh Ya onwards, generally contain sections devoted to shipping terms, it is noticeable that the majority of these concern types of boats and ships long obsolete (or not very easily identifiable), such as mend, tien, thang, tang, and so on. The number of technical terms for distinct parts of the ship and its gear is smaller.

Even then, much space is devoted to the identification of dialect phrases or local usages, so that the task of selecting out items of information which really prove the existence of any given technique at a given time in history will require prolonged research.

Although the field is so inviting, we have naturally not been able to attempt this here. For example, in +1126 Jen Kuang produced his Shu Hsi Chih Nan (Literary South-Pointer), the 19th chapter of which is partly devoted to explanations of terms concerning ships, but this has never been studied. An investigation of the sort we need would

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* Sometimes the heavy masts are compound, i.e., built up of several separate longitudinal spars bound together with iron straps. In 1848 British naval officers were astonished at the size of the main-masts of Shanghai junks. The circumference of one, taken a little above the deck, was 11 ft. 6 in., its height 29 ft. 5 in., and its main yard 111 ft. 6 in. long. Very strong spars were necessary for the enormous sail, and there were no shrouds or stays. See Bernard (1), vol. 2, p. 365.

** Cf. below, pp. 595 ff. Those of the main- and fore-masts are always stiffened with barrels; the others may be.

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6 A word of caution should be spoken here regarding the reconstruction of a sea-going junk in Cloves & Trew (1), p. 81, just because it occurs in a collection of drawings otherwise so excellent. I suspect that it was taken from Adm. Paris (2), pt. IV. But the rudder "ail" is too narrow, the side-galleries too long and prominent, the multiple sheets wrongly drawn, and the hull also out of drawing.

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* E.g. STTH, CHM yung sect., ch. 4, pp. 94 ff.

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* Contains in Chiao Shih Ko Wen Chia I Chi 3 (part of his collected works), ch. 2.

* The same deficiency was noted (Vol. 4, pt. 2, p. 30 above) regarding the otherwise excellent book of Hommel on Chinese tools and technical processes. The same explanations apply, but Hommel is more open to criticism in that he gave no Chinese characters at all. It may be added here that reliance is not always to be placed on the sinological-historical discussions in Worcester's monographs; lacking, unfortunately, the collaboration of a Chinese historian, he allowed the incorporation of a certain amount of legendary and semi-legendary material. But it was hard to interest academically trained scholars in anything so low and tarry as ships. Dr Chhen Chen-Han told me in 1944 that he intended to write a history of Chinese shipping, and we must hope that he will. On English shipwrights' tools see Salaman (1).

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* I can confirm this from personal experience, especially among the dialects of the north-west. Now that interest in, and respect for, indigenous crafts has so greatly increased in China, we may expect that a multitude of new characters will be coined in technical dictionaries so that old craft terms can be written down.

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* Such, at least, was the thirty-year experience of Worcester himself (personal communication). Why did this difference exist between Chinese and European sailors? Perhaps the European attention to detail in nomenclature was a direct result of the dominance of the scientific view of the world during the past three centuries. Elsewhere, Needham (3), p. 71 (47), instances were given of the way in which failure to develop adequate scientific terminology was characteristic of medieval European science, and this was one of the limiting factors which the upsurge of the Renaissance swept to one side. Above (Vol. 4, pp. 43, 260) we saw the same thing with regard to the Taoists. If this is true, then the "main spacer outboard" is as much a sign of analysed complexity as the "imaginary augmentative fail".

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* Publications of the first-hand work of Miss Barbara Ward upon the shipping of Hongkong, embodying much traditional and living technical information, will be awaited with interest. In the meantime, see Ward (1). Similar studies of Chinese sailors' ways from the life are contained in Worcester (14).

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* But one should not confuse the two. A history of Chinese shipping cannot be written from the models of junks in the Science Museum, as the title of Worcester (15) seems to imply.
on the Yangtze shipyards, the Lung Chiang Chhsuan Chheng Chih, written by Li Chao-Hsiang in + 1553. Discussion of this will be postponed to a more convenient place (p. 48a below). The work is illustrated by a number of drawings of ships and boats, but only one or two of them help to explain technical terms and the rest are rather roughly sketched.8 The best picture of a Chinese ship which we have been able to find in a Chinese work is that contained in the Liu-Chhii Kuo Chhii Liih (Account of the Liu-Chhii Islands) written by Chou Huang in + 1757.9 This is pictured in Fig. 939. The drawing is particularly valuable because the artist added a number of technical terms (see the accompanying key). The transom stern and stern are clearly shown, as also the longitudinal strengthening member (lung hua, 'dragon spine', cf. p. 429) of the hull. Four masts are stepped, and the characteristic mat-and-batten sails are well drawn, with the topping lifts on both fore- and main-sail, and the multiple sheets on the foresail.10 Additional sails, and masts or spars for setting them, as in Marco Polo’s time (cf. p. 467), are carried—bowsprit-sail, spinnaker, topsail, and a notably bellying mizen-sail, all of these being cotton, reinforced with vertical roping. One cannot help recalling the combination, in modern racing-yacht practice, of a taut battened fore-and-aft mainsail with a bellying spinnaker; and of observing too the contrast with the ‘full-rigged ship’ of Renaissance Europe, where the square-sails were dominant and the fore-and-aft sail only on the mizen (cf. p. 609). Our junk is obviously running merrily before the wind. The use of the deck winches (tiao) for hoisting sail will be appreciated from Fig. 940 (pl.). Then the slung rudder, partially raised to reduce water-resistance, should be noted, and the housing-to tackle which runs from the foot of the rudder under the bottom of the vessel to a windlass in the forecastle and holds the rudder against the transom, where it rotates in wooden jaws (cf. p. 632). This was mentioned by Lecomte in the tradition which culminated in the picture of Fig. 939. Aru the rudder against the transom, where it rotates in wooden jaws (cf. p. 632). This was mentioned by Lecomte in the tradition which culminated in the picture of Fig. 939. A

8 The best study of them so far is that of Pao Tsun-Pheng (1, 1). With a colleague, he had been an official envoy to the islands in the previous year.

9 Thu hai sect. (preceding ch. 1), pp. 233, 234.

10 Cf. pp. 535b. below.

11 See below, pp. 591, 602.

12 Interesting, for this also had been one of the surprises for Europeans in the + 15th century.

13 There are of course occasional diagrams of ships in Chinese books. For example, rather rough ones exist in the Chuch-Shun Chhiaoj Hieh Lih (Travel Diary of an Embassy to the Liu-Chhii Islands), written by Hu Pao-Kuang in + 1721. These seem indeed to be earlier specimens of an iconographic tradition which culminated in the picture of Fig. 939. A Shaih Shih Chi Yao (Essentials of Sea Affairs) was partly translated into Russian a century ago by K. A. Skachkov (1), but we have not been able to find any information on it in Chinese sources, and the paper itself has been inaccessible to us. Cf. p. 442.

14 No. 5 in the Hirth Collection, formerly at the Royal Library in Berlin. We are much indebted to Dr. W. Seubersch for providing a microfilm for our use.

While there exists no great published work on Chinese shipbuilding,8 some MS. material is available, and there must be a good deal more still dormant in Chinese provincial archives. In Europe, the Library at Marburg now possesses a most interesting manuscript9 which appears to have been a manual for Fukienese officials concerned with the building of junks.10 We are much indebted to Dr. W. Seubersch for providing a microfilm for our use.

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with building and maintaining government ships. This has been described, very inadequately, by Moll & Laughton, who dated it at about 1850. Having had the opportunity of a re-examination of the document in microfilm form, we would be inclined rather to place it more than fifty years earlier. In any case, it fully merits publication by editors competent both sinologically and technically. Including as it does about sixty drawings of the component timbers of five classes of ships, it constitutes the nearest approach in the domain of shipbuilding to the standard set long before in architecture by Li Chieh. The dry descriptions, too, are reminiscent of his style.\footnote{Pronunciation here is surmised.}

The MS. is entitled Min Shêng Shâi-Shih, Ko Piao Chen Hsiêh Ying, Chan Shao Chhuan Chhih Thu Shao\footnote{The latest date mentioned in the MS. is +1730, and decisions taken in +1688 are referred to as if they were still authoritative.} (Illustrated Explanation of the (Construction of the Vessels of the) Coastal Defence Fleet (Units) of the Province of Fukien stationed at each of the Headquarters of the several Grades). It opens with diagrams of the five classes of small corvettes (as they might be called), then proceeding in turn to details of their mustering (chhuan chhih hao shu\footnote{At the same time, we do not feel sure that the official who wrote the text always fully understood what the shipwrights were trying to explain to him.}), the itemisation of their parts (hau chhian ming mu\footnote{The drawings of the ships and their parts are ill reproduced, so Chinese characters are given, and in their stead only unintelligible romanisations, many of the pieces of woodwork and their functions are not identified, and what appears to be a translation is only an abbreviated paraphrase, often erroneous.}), and the methods and dimensions in construction (tso fa chhih tshun\footnote{The drawings of the ships and their parts are ill reproduced, so Chinese characters are given, and in their stead only unintelligible romanisations, many of the pieces of woodwork and their functions are not identified, and what appears to be a translation is only an abbreviated paraphrase, often erroneous.}). The five classes referred to are the following:

1. 'Arrow Pursuit Vessel' (Kan-tieng chhuan\footnote{Inadequately, by Moll \& Laughton.} 34 ft. x 12 ft. to 43 ft. x 21 2 ft.
2. 'Two-Master' (Shuang-pheng chhuan\footnote{The latest date mentioned in the MS. is +1730, and decisions taken in +1688 are referred to as if they were still authoritative.}) 34 ft. x 9 ft. to 61 6 ft. x 16 6 ft. These two types were first fixed in +1688.
3. 'Flat-Bottomed Ship' (Phing-ti chhuan\footnote{The latest date mentioned in the MS. is +1730, and decisions taken in +1688 are referred to as if they were still authoritative.}) 42 ft. x 11 ft. to 48 ft. x 14 8 ft. Said to be steadier, and good with yulohs, but not sea-going. Design fixed about +1730.
4. 'Official Boat' (Hua-tso chhuan\footnote{The latest date mentioned in the MS. is +1730, and decisions taken in +1688 are referred to as if they were still authoritative.}) 32 ft. x 9 ft. to 40 ft. x 12 ft. Design of both these fixed in +1728.
5. 'Eight-Oared Boat' (Pa-chiang chhuan\footnote{The latest date mentioned in the MS. is +1730, and decisions taken in +1688 are referred to as if they were still authoritative.}) 32 9 ft. x 9 ft. to 40 ft. x 12 ft. Design of both these fixed in +1728.

In spite of the variation of these names and dimensions, all five have a forecast and mainmast, with a small mizen lacking a sail and stepped on the port side of the poop. All have lang lu\footnote{The latest date mentioned in the MS. is +1730, and decisions taken in +1688 are referred to as if they were still authoritative.} or stout longitudinal hull bottom members, except the third, here reproduced as Fig. 941. Since the component parts are labelled rather clearly, it is possible to confirm a number of important words, e.g. sheets (pheng so\footnote{At the same time, we do not feel sure that the official who wrote the text always fully understood what the shipwrights were trying to explain to him.}), yard and boom (shang and kia pheng tan\footnote{Inadequately, by Moll \& Laughton.}), halyards winches (ta hiaoo lao nui\footnote{Inadequately, by Moll \& Laughton.}), tabernacle (ta erk\footnote{Inadequately, by Moll \& Laughton.}), crownest (wei li\footnote{Inadequately, by Moll \& Laughton.}). The bottom of the transom bow is called the 'wave-lifting board' (tho lang pan\footnote{Inadequately, by Moll \& Laughton.}). But some of the characters are peculiar, not to be found even in the Kiang-Hsi dictionary, for example chhuan, apparently the bow-sweep; and since the transom bow is inclined rather to place it more than fifty years earlier;\footnote{The latest date mentioned in the MS. is +1730, and decisions taken in +1688 are referred to as if they were still authoritative.} the Chin Chih (pheng chhuan) bears considerable resemblance to that in Fig. 939. For explanations of some of the Chinese technical terms, see text; but not all those in the MS. are either legible or identifiable in the best dictionaries. However, the many diagrams of component parts often tell their own story, and permit the identification of sea-terms which the lexicographers ignored.

Also noteworthy in this picture are the 'weather-vane pennants' (lung mu), the oculus (hau chhi), the standard of (the goddess) Ma-Tsu\footnote{The latest date mentioned in the MS. is +1730, and decisions taken in +1688 are referred to as if they were still authoritative.} (cf. p. 620), the rudder (hau), and the bulkwark gate (sha hieun mui).
which are marked (khan niu). From left to right one sees, first the emplacement and tabernacle of the forecast (sha tou teo), then that of the mainmast (sha tou eliu), a succession of holds and hatches amidships, and two water-tanks (sha lou) to port and starboard. All of these there is a section marked 'combat deckhouse' (chan peng), presumably a place of comparative safety, and still further aft (showing that this is not the same ship as that in Fig. 941) the halyard winches (lan mia). At the stern an entrance leads into the quarter-deck and chapel (pau peng), where the compass was kept.

**po-mo,** vertical supporting timbers for the bulwarks which sheltered the guns on the deck,* with their loopholes (tshao yen)*. All of these vessels were built with bulkheads (khan niu) forming fifteen compartments in each (Fig. 942). Among the component pieces mentioned are those (lu tu le*) which hold fast at the bows the tackle retaining in place the rudder aft. The transverse gantry on the afterdeck in Fig. 941 is one of several frames (pheng chin) on which the sails were stowed. The value of this manuscript for further research on these questions will be obvious.

* We have in our collection a photograph of a traditional war-junk's topsides, taken in 1929 on one of the Cantonese rivers. It might however be a launch-towed passenger-boat, for these were also armed (G. R. G. Worcester, unpublished material, no. 299). Probably the best photographs ever taken aboard such war-junks are to be found in the book of Lilius (1), a Finnish journalist who investigated the people of the Bissay region in the twenties of the present century. There is a vivid account of a woman bandit chief (tu tu), and unfortunately Lilius was not interested in the nautical technology which she and her colleagues understood so well.

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29. **NAUTICAL TECHNOLOGY**

Chinese literature contains several interesting accounts of the building of model ships for instructional purposes.* About +1138 Chang Chung-Yen was in the service of the Jurchen Chin. Of him we read:*

> When they began to build ships, the artisans did not know how. So (Chang) Chung-Yen made with his own hands a small boat several tens of inches long. Without the use of glue or lacquer he fastened together perfectly from bow to stern. He called it his 'demonstration model'. Then the astonished artisans showed him the greatest respect. Such was his intelligence and skill.

After the large ships had been built and were ready to be launched, people were to come from all the surrounding districts to drag them to the water, but Chung-Yen ordered several tens of his craftsmen to build sloping runways leading down to the river. Fresh millet stalks were collected and spread thickly on these slipways, which were supported on each side by large beams. Early in the morning, when there was a frost, he led the men to the launching, and because of the slipperiness the work was accomplished with very little effort.

A contemporary in the service of the Sung south was Chang Haieh.* When he was prefect of Chhuchow he wished to construct a large ship, but his advisers were not able to estimate the cost. (Chang) Haieh therefore showed them how to make a small model vessel, and then when its dimensions were multiplied by ten (the cost of the full-size ship) was successfully estimated.

The text goes on to tell how his artisans estimated a cost of 80,000 strings of cash for the walls of a temple park, but he had them build an experimental 10 ft. length, which proved it could be done for 20,000. Evidently a man not to be trifled with.

One of the few serious literary descriptions of nautical technology is to be found in the relevant chapter of the Thien Kang Khat Wu (Exploitation of the Works of Nature), written by Sung Ying-Haing in +1637. It is so informative that sample quotations could hardly be omitted. Sung Ying-Haing describes first a typical grain-carrying ship* (Tshao fang) of the Grand Canal towards the end of the Ming (Fig. 943), and then goes on to refer more briefly to sea-going junks similar to that which we have already examined in Worcester's modern drawings (Fig. 935).*
The general construction of a canal ship [Sung continues] is as follows: a bottom (t'ii) of stout planking serves as the foundation, there are (thwart and fore-and-aft) timbers (fang') like the walls (chhoang') of a building, and there is bamboo tiling (yu yang ehu') (to cover the hold) as if it were a roof. (The compartments) forward of the mast framework (fu shih'), i.e. its tabernacle and associated structures are like the main gates, and (the compartments) aft of it are like the sleeping quarters. The mast (tei') is like (the stock of) a crossbow, and the halyards (kua') and sails (pheng') are like wings. Oars (lu') (may also be motive power) as the horse is to the cart; hauling cables (thian chhein') are as the shoe is to the walker. The cordage (yu so') adds strength like the bones and sinews of a hawk. The bow-sweep (chao') goes before like a spearhead, the rudder (tho') (at the stern guides the direction of the vessel) like a commander, and the anchors (mao') call a halt like an army encamping for the night.

On the original specification, the grain-ship is built 52 ft. long with planks 2 in. thick. The choicest timber for it is large baubles of man-suu', but chestnut (fu') is also used as second best. The bow and stern are each 9.5 ft. long, while the breadth of the bow is 9.5 ft. at the middle, 6 ft. at the bow, and 5 ft. at the stern. The breadth of beam at the foremost tabernacle is 8 ft., and that at the mainmost tabernacle is 7 ft. Fourteen bulkheads (liang hou liang) are built across the ship (that forward of the main hatch) the 'dragon's mouth' bulkhead (liang hou liang i) is 10 x 4 ft.; (that beside the main-mast) the 'wind-using' bulkhead (shih feng liang i) is 14 x 3.8 ft.; and that towards the stern, the 'cut-water' bulkhead (tsun shui liang i) is 9.5 x 4.5 ft. The width of two granary holds (ch'ao) is 7.6 ft.

* Tr. suct. adjov. Ting & Donnelly (1); Sun & Sun (1).
* Sung Ying-Hsing explains in landman's terms. If we had not studied building technology (cf. p. 92 above) we should not know that fang means tie-beams, both along a structure and from side to side of it. Most Western dictionaries fail to give this most important meaning of the word.
* So called because made of inlaid half-bamboo sections.
* Lit. 'lion-tamer', a good name for a weather-withstander.
* This word means of course a bow-string or the string of a musical instrument, hence the chord of an acute angle in the triangle (cf. Vol. 3, pp. 22, 96, 194, 109 and passim). Here it fits the halyards very well, the other two sides of the triangle being the mast and the distance along the deck between the mast and the halyard winch. Sung Ying-Hsing himself makes just this analogy elsewhere, see below, p. 604.
* For tracking and towing; cf. pp. 62a ff. below.
* An unusual term—but the thing is clearly depicted in the Ming illustration though not in the Chhing one.
* Cuscuta vulgaris, as in Europe (Bri, 494). The classical passage in Europe about timber for ship-building is Theophrastus, V, vii, 1-3.
* Presumably from the furthest forward point to the bow water-line or to what corresponded to the fore-foot griepe, and the same reckoning maat sunzut on the stern.
* There may be room for a suspicion that the text has inverted the beam dimensions as between bow and stern.
* As we shall see later (p. 415) it was obligatory to have more than one mast on ships over 100 ft. long, but these of half that length also had two, as the illustrations show. They are better differentiated as to height in the Ming than in the Chhing one.
* Note that in the Ming the number of bulkheads was about the same as on the modern-built ships described above (p. 308).
* These dimensions may imply some degree of turret-build. Donnelly however (in Ting & Donnelly) made a reconstruction according to them, without this; the resulting lines look quite like a modern river- junk, perhaps rather broader in the beam, and lower, amidships.

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Sung Ying-Hsing says that the design of his standard inland navigation ship or sailing barge dated back to the beginning of the 13th century, when in the Yung-Lo reign-period, on account of the grain-transport losses on the sea route, it was decided to revert once more to the use of the Grand Canal. Accordingly, the present shallow-draught canal boats were introduced by a certain Mr Chhen, lord of nearly fifty locks as well as protective dykes for the Grand Canal. In peoples, but later worked mainly as a hydraulic engineer, especially in the Huai region, where he built ennobled, taking his title from his predecessor.

This was Chhen Hsian (cf. p. 315, and Ta Ming Hui Tien, 29). NAUTICAL TECHNOLOGY
The general plan is thus uncompromisingly flat-bottomed and keel-less, with numerous transverse bulkheads each specifically named. Such a ship could take a cargo of nearly 2,000 piculs of rice, though in practice only 500 piculs were delivered to each boat, but another type designed independently later on by the army transport service was 20 ft. longer and more 2 ft. wider both at bow and stern, so that it could carry 3,000 piculs. As the flash-lock gates ('cha hou') in the (Grand) Canal are only 12 ft. wide, these craft are just slim enough to negotiate them. The boats used nowadays for travelling officials (Kuan-tao chih-tuan) are of just the same type (as the freighters), but their windows, doors and passageways are made somewhat wider, and besides they are more elegantly painted and finished; that is all.

It is interesting to compare these figures with others for the nineteenth century. A burden of 2,000 piculs (tun) is about 140 tons. According to Playfair (1), 670 grain junks in 1874 transported to the capital 136 million piculs of grain (96,000 tons), so that the lading of each was about 143 tons. The average size of the ships thus remained at that time just about what it had been at the beginning of the +17th century, and indeed the beginning of the +15th. From evidence given above (p. 332) in connection with the invention of the pound-lock, it can be seen that this tonnage had already been attained very nearly by the middle of the +11th century. But it had probably dropped greatly during the three centuries when the sea route was predominant. Indeed, just after mentioning his figure of 2,000 piculs, Sung Ying-Hsing adds, in one of his commenting 'footnotes', that upon comparing his specification with actual practice, he found that the burden was generally not more than 500 tun (25 tons).

Sung Ying-Hsing next tells us what he saw on his visits to the shipyards. The construction of a boat begins with the deck (chii). Bulkheads (liang) are set at intervals to divide the vessel (into separate compartments), and (the holds have) sheer vertical sides which are (also) called chhiang. The hull is covered at the top (or, surmounted) by great longitudinal members (ching fang). The winches (for the) halyards (hsien) are fixed above these. The position of the mast just forward of the drift. 1, 2

1. Or of course other tax goods such as silk.

2. Sung Ying-Hsing's own 'footnotes'.

The joints ('ning') between the planks are caulked (niem) by first forcing in raffled floss jute fibre (pai ma) with a blunt chisel. Then a (putty-like) composition of fine sifted lime and nails (shen) is placed symmetrically to divide the vessel (into separate compartments). The pieces' are connected by components called 'lion-tamers' (fu shih), which grasp the tenon at the base of the mast in its socket or mortice. These are all parts of the structure in which the mast is stepped, and which distributes its thrust. Perhaps means bamboo matting as well as a sail. The part where the stern slopes upwards is called the 'flying-lap' or poop deck-house, often only a framework, is confusing, but these are connected by components called 'lion-tamers' (fu shih). Under the 'lion-tamers' are the 'closure pieces' ('feng shih') otherwise known as the 'triple tie-bars' (lien sian fang). On the deck towards the bow there is a square hatchway ('tung chih') (in which ropes, cables and miscellaneous gear are kept). At the forward quarter (lit. the eyebrows) on each side, two (strong) posts are placed symmetrically to serve as bollards (for making cables fast, etc.); these are called the 'two generals' (chih-kung 2), while underneath them is the 'grass-sandal bottom' (tshao hsieh 3). It is composed of the short transverse timbers (tuan fang) which close the top of the stern, under which is the transom stern itself, or 'sandal-strap bulkhead' (tun chih fang). The deck at the stern is the place where the helmman stands to manage the rudder, having above him a bamboo platform (yeh chih ching) on which, when sail is hoisted high, someone sits to manipulate the sheets (pheng so) according to the wind.

We have a number of eye-witness accounts of Chinese shipbuilding in the present century, all confirming and elaborating what Sung Ying-Hsing had to say. Many observers have been struck by the fact that the Chinese traditional shipwrights used no templates or blueprints, depending rather upon the skill and sureness of eye of the oldest and most experienced craftsmen. Although, as we have seen, some technical manuals have existed, the greater part of the industry must always have been based upon the personally transmitted 'know-how' of the masters. Elsewhere in the yards Sung Ying-Hsing sees the finishers at work:

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The timber for the mast is usually fir (chan-mu)4 which must be straight and sound. If the natural size of the spar is not long enough for the mast, two pieces can be coupled together by means of a series of iron bands placed around the joint a few inches apart. An open space is left in the deck for the mast. For the stepping of the main-mast, its upper part is laid across several large boats brought alongside, and the top hoisted up (into position) with a long rope. Hull timbers and bulkheads are made of nan-mu,9 camphor wood (chun-mu), elm (yu-mu),3 or sorghora wood (kau-mu).9 [Camphor wood, if taken from a tree felled in spring or summer, is liable to be attacked by boring insects or worms.]9 Deck planks can be made of any wood. The rudder-post is made of elm, or else of lang-mu or of chu-mu.4 The tiller should be of chu-mu or of lang-mu.4 The oars should be of fir (chan-mu)9 or juniper (hui-mu)9 or catalpa wood (chu-mu).4 These are the main points.

Sheets and halyards (pheng so)9 carried are made of retted hemp fibres (huo mu)9 (in other words ta mu)9 twisted roughly together until they reach a diameter of more than an inch;
chhien chuan), another the ‘boring-into-the-wind ship’ (Tausan-feng chhiuan) [or the ‘sea-eel’ or ‘sea-serpent’ (Hai-chhiu) ship]. Their voyages did not exceed 10,000 li along the coasts, across the Deep Sea and past the Shu-men islands. No great danger was encountered in the voyage. As compared with the junks which sailed to Japan, the Liu-Chhiu islands, Java and Borneo for trade, these (coastal transports) were not one-tenth as large or expensive.

The build of the first type of sea-going junk is similar to that of the canal junk, save that it is some 16 ft. longer, and 2'5 ft. broader in the beam. All else is the same except that the rudder-post must be made of iron-wood (chieh-lu-i-mu) b .

The bearings of all the different islands can be found by the magnetic compass, which is in this connection it is interesting that a European ship with three masts (and a lateen sail on the mizen, cf. below, p. 512) is depicted in TSSC, Kiao hung tiem, ch. 178, hai hou, p. 24b. But we agree with Sun & Sun (1) that Sung Ying-Hsiing did not mean foreign ships here. The analogy is with ‘China clippers’, which were not Chinese.

The ship of approximately rectangular cross-section, with rounded corners, which was already apparent to Charnock’s contemporaries a century and a half ago that such a form was already apparent to Charnock’s contemporaries a century and a half ago that such a form of the iron and steel steamships of our own time. It

...
ancients. A Charnock gives a diagram to illustrate his ideas. Hull with its master-couple well forwards. The text sets forth an argument in favour of quarter-rudders.

One boats and small ships in any European harbour, or the models in any great naval museum, to see how widespread was the conviction that the greatest fullness should be towards the bow. One of the drawings in the Baker MS. of +1586 compares the underwater body of a ship with the form of a fish, according to the famous maxim 'a cod's head and a mackerel tail' (Fig. 946, pl.).

A fit prora, B quipps. Aquae itaque motu navis concentra & concentrica ad proram A prima quidem insignis declinat ad utrunque navis latus CC, defectu vero ipso augent leiratatem, donec perveniant ad DD, ubi intensiusdem effit aquarium lapius. Inde repulsus occurrat aquarum pede relabentur declinat ad EE, ubi demum nullum & locum dant aqua a tergo & utroque latere ventebant. Sed vero conflar guberaculis non ab inquinibus, sed ab affluentibus a prori regi undis, unde planum fit aptius collocari ad DD, quam ad B, quo vix attingent subterlabentes undae, cum ad DD maxima fiat percussio & sufficiens ad regendam totam navem, quod quanto longior est tanto facilius regiur, & quanto velocius procedit tanto magis oblique guberaculis, & hinc effit quod longae naves facilius & citius convertantur & circumagantur, quam minus longe, & quod minus ista cymba, majori egebant guberaculis, quam quibus maxima naves, cum enim non alte aquae sustineant, nec multas propellant undas, utique etiam imbicillis eft aquarium relabentum affluens, quia proper regi vix possunt, nifi enorme habeant gubernaculum.

Fig. 945. A diagram and paragraph of text from the Variarum Observationum Liber of Isaac Vossius (+1685). In the section entitled De Triremium et Librariorum Constructions he gave this drawing of a hull with its master-couple well forwards. The text sets forth an argument in favour of quarter-rudders.

Nautical Technology

Some peoples have made the keel follow a convex curve, others have made it concave; some make the hull float lower forward than aft, or they place the broadest beam forward, amidships, or aft. For our best hulls we have taken the fishes as models, always larger at the cephalic end, but the Chinese, who also copied Nature, imitated the palmpeds, which float with the greatest breadth behind, for somewhat obscure reasons. In this they were acute, for aquatic birds, like boats, float between the two media of air and water, while fish swim only in the latter. These strange people seem to have done everything in the opposite way to which it is done at the other end of the continent, and they copied Nature still further in seeking to exert the greatest possible propulsion on the stern, instead of applying, as it were, a tractive force to the prow. This led them to the use of those strong paddles (the yuloha) which imitate in position the web-feats of the palmpeds—a position which must have been very important for swimming, since it deprived such birds of the facility of walking easily on land, and, even, in the case of the best swimmers, prevented this altogether. These very simple observations (which the Chinese have utilised) will find one day, perhaps, a happy application to the steam-boat, which, set in motion as it is by an internal force not coming like the wind from without, finds itself in exactly the same situation as the swimming bird, and might gain from a closer approximation to the latter's form.

These prophetical words of Paris were justified within a couple of decades by the coming of the screw propeller; indeed in the year before they were written, F. P. Smith's 45 h.p. screw steamer 'Archimedes' had made her trial run. As for the hull shape, the pioneer water-tank experiments of Gore in +1797 had seemed to prove the superiority of shapes with the fullness forward, but his trial objects were totally immersed. That precisely the opposite is true we now know; the largest master-couple of a good sailing-ship should be located between 3 and 8% aft of the middle of the flotation line. The racing yacht 'America' demonstrated this in the last years of the nineteenth century.

That the lines of Chinese vessels do show their greatest fullness aft has been confirmed by Worcester in a range of accurate drawings far beyond the data which Admiral Paris had at his disposal. A cursory examination reveals about thirty-five forms which are built in this way. Some merely continue the master-couple for varying distances aft of the mid-line," but others show distinctly the master-couple itself well aft. All the Ma-yang-tzu varieties are so built, and the name itself means 'hemp sprout', something more pointed at one end than the other. Several of the familiar names for the river junk types allude to the form bulging aft—the 'hempseed oil bottle' (Ma-yyu

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9. NAUTICAL TECHNOLOGY

Lo junks with the significant name of Hai-pheng. The reference was to the gigantic bird which could take off from the water and fly to the south, so famous in Chuang Tzu. No more definite statement could be imagined.

Lo Lung alludes to a famous shipbuilder of the Yuan dynasty. 20

As these vessels are not to be laden with goods, their holds may without inconvenience be divided into separate apartments after the Chinese manner, and each of these apartments caulked tight so as to keep out water. In which case a leak should happen in one apartment...This being known would be a great encouragement to passengers.

In 1845 Guppy read a paper to the Institution of Civil Engineers in London describing the trial voyages of the iron steamship 'Great Britain', and in the ensuing discussion a communication was read from Lady Bentham about the improvements in naval architecture which had been introduced by Sir Samuel Bentham (+ 1877 to 1881). The merit of the first introduction of that great improvement of fixed water-tight bulkheads was, it appeared, his. In the year +1795 he had been entrusted by the Lords Commissioners of the Admiralty to design and construct six vessels of entirely new type, and he adopted from China, namely the water-tight compartment. From all that has gone before it will have become evident that bulkhead construction was the most fundamental principle of Chinese naval architecture (cf. Fig. 947, pl.), and water-tight compartments were its corollary. This is one of those cases where it is also possible to be fairly precise as to the date when the device was adopted. It was 'in the air' during the closing decades of the +18th century, and nearly every reference of the period recalls its use in Chinese ships. In +1789 Benjamin Franklin wrote a letter concerning mail packets projected between the United States and France, in which he said:

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(4) WATER-TIGHT COMPARTMENTS

It is possible to discern another valuable shipbuilding technique which Europeans adopted from China, namely the water-tight compartment. From all that has gone before it will have become evident that bulkhead construction was the most fundamental principle of Chinese naval architecture (cf. Fig. 947, pl.), and water-tight compartments were its corollary. This is one of those cases where it is also possible to be fairly precise as to the date when the device was adopted. It was 'in the air' during the closing decades of the +18th century, and nearly every reference of the period recalls its use in Chinese ships. In +1789 Benjamin Franklin wrote a letter concerning mail packets projected between the United States and France, in which he said:

As these vessels are not to be laden with goods, their holds may without inconvenience be divided into separate apartments after the Chinese manner, and each of these apartments caulked tight so as to keep out water. In which case a leak should happen in one apartment...This being known would be a great encouragement to passengers.

In +1845 Guppy read a paper to the Institution of Civil Engineers in London describing the trial voyages of the iron steamship 'Great Britain', and in the ensuing discussion a communication was read from Lady Bentham about the improvements in naval architecture which had been introduced by Sir Samuel Bentham (+ 1877 to 1881). The merit of the first introduction of that great improvement of fixed water-tight bulkheads was, it appeared, his. In the year +1795 he had been entrusted by the Lords Commissioners of the Admiralty to design and construct six vessels of entirely new type, and he

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after such a sorte, that if one of them should breake, the others may goe and finish the
Voyage.

Cressey (1) is quite right, therefore, in remarking that this practical safety
device was not adopted until five hundred years after knowledge of it first reached
Europe.

Less well known is the interesting fact that in some types of Chinese craft the fore-
most (and less frequently also the aftermost) compartment is made free-flooding.
Holes are purposely contrived in the planking. This is the case with the salt-boats
which shoot the rapids down from Tzuliuching in Szechuan, the gondola-shaped boats
of the Poyang Lake, and many sea-going junks. The Szechuanese boatmen say that
this reduces resistance to the water to a minimum, and the device must certainly
acquires and discharges water ballast rapidly just at the time when it is most desirable
cushion the shocks of pounding when the boat pitches heavily in the rapids, for she
to counteract buffeting at stem and stern. The sailors say that it stops junks flying up
into the wind. This, however, would seem to have involved openings which could be controlled, and
may well be that the Chinese bulkhead principle was introduced twice, first for small
coastal fishing-boats at the end of the seventeenth century, and then for large ships a
century later.

The master of the ship then played a trick on them. He made (as it were) a way for the water to enter the bottom of the boat, which seemed to be about sunk, and remained stationary, moving neither forward nor backward.

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coastal fishing-boats at the end of the seventeenth century, and then for large ships a
century later.

water ballast under control was, of course, one of the cardinal inventions accompanying the
European development of the submarine (Bushnell, +1775; Fulton, 1809). Mayers (5) reported the
types described had 'keels'. As deeply, (1), p. 399. William Bourne tells us, in his
Regiment

One reason for using water-tight compartments with a free-flooding portion is
to bring the catch to port and market in live condition. This was easily effected in China, but the practice was known also in England, where the compartment was called a 'wet-well', and the boat in which it was built, a 'well-boat'. The sailors say that it stops junks flying up into the wind. This, however, would seem to have involved openings which could be controlled, and
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Tr. Pelliot (29), eng. auct.

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European development of the submarine (Bushnell, +1775; Fulton, 1809); cf. de Lorete & Hauffer, pp. 261 ff.

Fishing-boats so equipped are common there especially in the estuaries of Kwangtung (G. R. G. Worcester, unpublished material, no. 100), and at Hongkong (B. Ward, private communication).

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1 聂致敏 2 吴龙

(d) A NATURAL HISTORY OF CHINESE SHIPS

There are those who affirm', said Domingo de Navarrete in +1669, 'that there are
more Vessels in China than in all the rest of the known World. This will seem incredible
to many Europeans, but I, who have not seen the eighth part of the Vessels in China,
and have travel'd a great part of the World, do look upon it as most certain. All the
early travellers to China remarked upon the abundance of shipping, from Marco Polo
and Ibn Batuta onwards (cf. Fig. 948, pl. J). It was natural, therefore, that a great
variety of types should have developed, and modern research has done a good
deal towards their analysis and classification. Our frame of reference will not allow us
to embark upon an extended review of its achievements, but a few pointers to the
literature may be given, and some of the more remarkable vessels mentioned.

Systematic lists of shipping types occur on several occasions in Chinese literature
throughout the ages, and we mention some of them elsewhere in this Section. One of the
oldest descriptions of classes of warships which has survived dates from +759, the
work of a Taoist military and naval encyclopedist in the Thang; we shall translate it
fully later on in the context of the history of ship armour. Sung descriptions of types
also exist (cf. pp. 381, 602). For the Ming period, there is the Shui Chan I Hsiang Lun
(Advisory Discourse on Naval Warfare) of Wang Ho-Ming1 written late in the +16th
century, before +1586, which describes nine warship types in detail. At the same
time Wang Chih1 wrote a classification of the suitability of the different types for the
defence of the different parts of the coast. Sung Ying-Haing, in +1637, at the conclusion of the passage above quoted
(pp. 411 ff.), went on to describe nine other types of ship; in the course of which he
mentioned the yuloh (self-feathering propulsion sail), the cloth sails of the Chien-
thang River, and the bipod masts (shuang chu) of the river-boats of Kwangtung province.
These occur only in the south. Two Chinese MSS in the British Museum,1
dating from about +1700, give, according to Donnelly (4), drawings and paintings of
some eighty-four vessels; these documents have not yet received scholarly

1 Tratados... de la Monarquia de China, Cummins ed., vol. 2, p. 237. Worcester (3) quotes this from the
New History of China (+1688) of Gabriel de Magalhens, but we could not find it there. The statement is
akin to one of Ricci's, in Triginti (Gallagher tr., pp. 12, 13) and in d'Elia (1), vol. 1, pp. 26, 27. Cf.
Ybarns Ideas, p. 163. Other quotations will be found in Audomard (2), pp. 19 ff. Perhaps the first
statement of a modern type was that of Cristovao Vieira, writing from Canton in +1554, 'ships and
boats without number' he said he had seen (D. Ferguson (1), p. 29). Barrow in 1604 was impressed just
deply, (1), p. 399. William Bourne tells us, in his Regiment for the Sea (+1580), how Master John
Dee encouraged him to plan navigations to Cathay by showing him passages from Marco Polo describing
the vast number of ships which flew the flag of the Great Khan (see Taylor (13), p. 313).

Hsiu Wen Hsiung Thung Khao, ch. 122 (pp. 3972-72 ff.). By this time
occidental influence was perhaps manifesting itself, as two of the types described had 'keels'. Some were
also armed with culverins in Portuguese style. Cf. pp. 481 ff.

Hsiu Wen Hsiung Thung Khao, ch. 123 (pp. 3972-72 ff.). Cf. pp. 462 ff.

Cf. pp. 435 below.

Landau, no. 1242 and Egerton no. 1095.
of craft nearly a century ago. He had been preceded by K. A. Skachkov (1) who in a little-known paper discussed a MS. or printed book in the Rumiantzov Museum entitled Shui Shih Chi Yao¹ (Essentials of Sea Affairs), seemingly on warships of a traditional kind but sinologically so far unidentifiable. In recent years a number of types have been given detailed descriptions, the greatest collection of which, that of Worcester (1-3), has analysed no less than 243 vessels, ranging from the smallest sampans to the largest sea-going junks. The catalogue of the Maze Collection of Chinese ship models in the Science Museum at South Kensington (Anon. 17), together with the fine photographs issued by the Museum, affords further aid.²

Paintings of Chinese vessels by Westerners began only in the early years of the last century, when in 1801 William Alexander’s excellent coloured pictures, made upon the occasion of Lord Macartney’s embassy (+ 1793), appeared. Afterwards came the hsiuen edition of from about the same time.³

Here the centrepiece is, as we have said, the descriptions, those of the Lou chhuan. ⁴ The artist was so enamoured of the warlike aspect of his task that he omitted the masts and sails altogether, and drew the balanced rudder very poorly, but did not fail to show a counterweighted trebuchet on the top deck.⁵

From the beginning of the + 17th century encyclopaedias both military and civil continued to copy all this ancient material while at the same time enlarging it by many new descriptions and accounts of ship types. Wang Chhi’s³ Sun Tshai Thu Hui⁶ of + 1609 gave some thirty of these, including nine civil vessels and one with a bipod or sheerleg mast (the ‘ship of the immortals’, Hsien chhuann).⁷ In spite of its romantic name, this craft was said to ply upon the southern rivers and lakes as a transport for high officials. About twenty of Wang Chhi’s items were incorporated by Mao Yuan-I ⁸ into the thirty-four of his Wu Pei Chia² (Treatise on Armament Technology) of + 1628. This was concerned entirely with war vessels, but in most editions the drawings are somewhat crude, and the artists do not seem to have been sufficiently interested in sea matters to differentiate much between the ships which they were supposed to be depicting. Some however bear reproduction, such as the ‘sand-boat’ (Shu chhuan)⁹ of the Chiangsu coast, with its lug-sails set (Fig. 950). Other pictures show craft with what seem to be rudders at the bow as well as at the stern (the ‘eagle-ship’, Ying chhuann ¹⁰ and the ‘double-headed ship’, Liang-thou chhuan ¹¹). There may have been

- ‘Tower-Ships’ (battleships with fortified upper-works), Lou chhuann.¹²
- ‘Combat-Junks’ (less protected), Chan hsien ² or Tou hsien.¹³
- ‘Sea-Hawk Ships’ (converted merchantmen), Hai-hu (or -ku).¹⁴

¹ E.g. Audemard (1), (5, 6, 7); Farrère & Fouquey (1); Carmona (1) on craft typical of the regions near Macao; Waters (1-5) especially on the Antung, Pechili, and Hangchow traders of the north; Sir William Alexander (1) on the Ta-tung; Donnelly (1, 3-5) on ships of the Yangtze and of Fukien; Lovegrove (1) on those of the Canton and West River systems in the south. See also the catalogue of Nootseboom (2).
² Cf. Worcester (10) on the late Sir Frederick Mace, and (16) on the junks of Chao-chou.
³ These have been reproduced in accessible form (Anon. 19). Those of Capt. Drummond may date from about the same time. On George Chinnery (+ 1774 to 1852) see Berry-Hill & Bi-er-Hill (1).
⁴ In vol. 1, fig. 14 and vol. 2, fig. 46.
⁵ See pp. 471-472 below.
⁶ Chhuan Chhi, ch. 11, pp. 48 ff.
⁷ Ch. 106, p. 168 (pp. 848.3, 849.1).
⁸ See pp. 471-472 below.
⁹ See pp. 109 ff., tr. p. 685 below.
¹⁰ Ch. 110, p. 168 (pp. 843.8, 849.1).
¹¹ The order of enumeration varies in the different sources. In the WCTY the description of the patrol boat (Yu thun)¹² was conflated with that of quite another type of ship, the ‘five-flaged cruiser’ (Wu-ya hsien ¹³), equipped with ‘grappling-irons’ (cf. p. 689 below), which Yang Su¹⁴ had built for Sai Kao Tchou about + 1795. This came in from a source other than TFCY. The picture in the San Khu Chhiun Shih edition of WCTY shows the five-flaged cruiser wrongly labelled as the patrol-boat. STTH put this confusion right, but TSCC, in its usual garbling way, brought it back again.
¹² Presently we shall see that this term is much older still.
¹³ Shih Chun-Sheng ch. 97, p. 259. The text concerning this in TSCC, jung chhuan tien, ch. 97, p. 259, is translated by Shih Chun-Sheng et al. in Audemard (1), p. 33 ff., with translation of the TSCC text by Shih Chun-Sheng et al.
¹⁴ Collected Edition of Armament Technology of + 1628. This was concerned entirely with war vessels, but in most editions the drawings are somewhat crude, and the artists do not seem to have been sufficiently interested in sea matters to differentiate much between the ships which they were supposed to be depicting. Some however bear reproduction, such as the ‘sand-boat’ (Shu chhuan) of the Chiangsu coast, with its lug-sails set (Fig. 950). Other pictures show craft with what seem to be rudders at the bow as well as at the stern (the ‘eagle-ship’, Ying chhuan ² and the ‘double-headed ship’, Liang-thou chhuan ¹¹). There may have been
a confusion here with the bow-sweep, which has certainly existed on river ships for many centuries; but it seems rather more likely that the reference was to types of craft far forward or even sliding on the stempost. Another illustration shows two barges made fast alongside supporting a turret or turrets above (the 'mandarin-duck rowed (now mainly Indo-Chinese) which have a rudder at the stern and a centre-board very explosively placed). The designers (Chhi's drawings and two of Mao Yuan-I's were incorporated into the Thang Tien). Our translation of the basic source, the Thai Pai Yiu Ching, will be found on p. 685 below, reserved thereto because it fits in better with the story of ship armour, and projectile (as opposed to close-quarter) tactics, in Chinese naval history. The work of Krause seems to have been unknown to Worcest er (4), who essayed a study of the Chinese war-junk, and still more regrettably to Audemard, in whose posthumously published work (2) we have a full translation of the relevant passages of the Thu Shu Chi Chheng made by Shih Chun-Sheng. Audemard was wisely cautious about attributing any date to the texts and drawings which he and Shih studied, but the futility of attempting a 'history of the junk' on the basis of a corpus c. +1760, without knowing that some of the most important go back to just before +760, will readily be apparent. Such a proceeding (especially in view of the inability or unwillingness of Chinese book-illustrators in olden days to depict machinery accurately) could hardly fail to give Western readers yet one more crass misconception of Chinese technology; for what may be laudable in the +8th century becomes scandalous in the +18th—in 'unchanging' China quite as much as everywhere else. Moreover, the use of the word 'encyclopaedia' for translating the title of the Thu Shu Chi Chheng, though traditional, is very unsatisfactory, since it invites comparison with modern works such as the Encyclopaedia Britannica. The compilers of the Thu Shu Chi Chheng did not set out to produce a work of reference giving the most up-to-date information on all subjects, but rather to compile a vast anthology or

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Fig. 949. The battleship (Lou chhuan) in the +1510 edition of the Wu Ching Tuang Yao (+1044). Comments in text. For a translation of the passage on the left, see p. 685.

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\[6b\] The analysis of these valuable materials (and they are far from exhausting the available Chinese literature) has not been particularly happy. Long ago Krause (1) translated the brief descriptions in the Thang Tien. The compilers of this cf. Vol. 4, pt. 2, pp. I, 373.

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Westerners still further historically unwarranted grounds for their customary self-satisfaction. In fact, an ocean of further research stretches out before us.

Geographical factors have had considerable influence in differentiating the craft found along the coasts of China. This was clearly seen already in the +17th and +18th centuries by acute observers of local customs.

A scholar of that time, Hsieh Chan-Jen, commenting on a passage in the Jih Chih Lu (Daily Additions to Knowledge) of Ku Yen-Wu, itself finished in +1673, wrote as follows:¹

The sea-going vessels of Chiang-nan are named 'sand-ships' (Sha chhuan) for as their bottoms are flat and broad they can sail over shoals and moor near sandbanks, frequenting sandy (or muddy) creeks and havens without getting stuck. Chekiang ships (are built in the same way) and can also sail among sandbanks, but they avoid shallow waters as they are heavier than the sand-ships. But the sea-going vessels of Fukien and Kuangtung have round bottoms and high decks. At the base of their hulls there are large beams of wood in three sections called 'dragon-spines' (lung ku). If (these ships) should encounter shallow sandy (water) the dragon-spine may get stuck in the sand, and if wind and tide are not favourable there may be danger in pulling it out. But in sailing to the South Seas (Nan-Yang) where there are many islands and rocks in the water, ships with dragon-spines can turn more easily to avoid them.

Here the reference to the better sailing qualities of ships with deep hulls and centre-boards is rather clear. With this passage in mind we may look again at Fig. 939, where the lung ku is the central strengthening member of the hull of a Fukienese or Cantonese sea-going junk, with rounded bottom and high decks. Such a timber is still called lung ku by Chinese shipwrights, but it should not be regarded as a keel in the European sense (to which they sometimes apply the same term), for it is not the main longitudinal component of the vessel, this function devolving rather on three or more enormous hardwood wales which are built into the hull at or below the water-line.² The real value of the passage is that it points up the differences in hull shape induced historically by the geographical differences between the northern and southern parts of the Chinese culture-area. North of Hangchow Bay (Lat. 30° N., cf. Fig. 711) the coastal and sea-going craft are flat-bottomed and hard-chined with relatively large, heavy and square rudders which can be lowered well below the ship’s bottom or raised up high. They are thus fitted for frequent beaching in the shallow harbours or muddy estuaries of the north, where the tidal effects are most noticeable, while at sea the rudder acts as an efficient drop-keel. South of Hangchow Bay the coastal waters are deeper, the inlets fjord-like, and the islands more numerous. Here the under-water lines of the vessels become progressively more curvaceous, with a sharper entry, softer chine and rounder stern; at the same time the rudders, often supplemented by centre-boards, become sometimes narrower and deeper, sometimes fenestrated and rhomboidal. All this is implicit in the words of Hsieh Chan-Jen.

¹ Ch. 29 (p. 89), tr. auct., adv. Lo Jung-Pung, p.c.
As for the flat bottom and the rectangular cross-section, it is certainly interesting that this build became generally adopted throughout the world for iron steamships in modern times. Among medieval shipbuilders in wood, the Chinese alone had had it. But Chinese ships, as we have said, were not always flat-bottomed; though lacking any true keel, their sides sometimes rose up in a quite rounded way from the lowest main longitudinal timbers. This we see from texts of a much earlier date, e.g. the Kao-Li Thu Ching (Illustrated Record of an Embassy to Korea) of +1124. Speaking of the Fukui-built Kho chou of Retainer Ships, which carried the ambassador's staff, and were somewhat smaller than his own 'Sacred Ship' (Shen chou), Haü Ching says:

The upper parts of the ship (the deck) are level and horizontal, while the lower parts shear obliquely like the blade of a knife; this is valued because it can break through the waves in sailing (kuei chi hko i pko lang eh liang yeh) . . . When the ship is at sea the sailors are not afraid of the great depth of water, but rather of shoals, for since the bottom of the vessel is not flat, she would heel over if she went aground on an ebb tide. For this reason they always use a lead weight on a long rope to take soundings.

Such a shape of hull could be seen in modern times in certain types of Chinese construction, e.g. the fishing-boats of Chusan called 'pairers' (Tui chhuan) and the smaller naval junks used towards the end of the Chhing dynasty (Khuai tu). But all the sea-going junks of the south exemplify it.

Among the most extraordinary of all Chinese craft are the crooked-bow and crooked-stern boats of the upper Yangtze region, to which a special monograph has been devoted (Worcester, 2). The crooked-stern junks (Wai-phi-ku) centre upon Fouchow, east of Chungking, at the mouth of the Kungthan River; but the crooked-bow boats are used west, for bringing the salt down along an almost un-navigable river from Tzu-liu-ching. In both these cases the 'rectangular' bows or sterns are slewed round in such a way as to bring one of their corners more or less in line with the main axis of the vessel. This is done at Fouchow by bending the bottom planks under heat and steam along a line making an angle of some 60° with their long axis, not at right angles. The terminal bulkheads, moreover, are not quite vertical. The final result is as shown in Figs. 951 and 952. In the Lu chhuan of Tzuliuching, the bow only is slewed; in the Fouchow Hou-pa or Huang-shan the process affects only the stern. In all these types of boat, very large stern-sweeps (hou shao) are carried, and in the latter region two, which owing to the construction do not interfere with one another (Fig. 953, pl.). Whether the balance of the whole vessel is so affected by the unsymmetrical lines as to confer real advantages in the negotiation of rapids has not been scientifically investigated, but the boatmen maintain this, and there is at any rate no reason for denying antiquity to this strange build. The most obvious explanation would be that at some time unknown, it was desired, in these parts of China, to obtain a fulcrum for the stern-sweep firmer and more intimately linked with the whole structure of the boat, than could be obtained by mounting it centrally on the usual transom stern. Such a view would not be in contradiction with an invention of the axial 'stem-post' rudder even earlier, since this would not necessarily have penetrated to these western provinces. In order to appreciate the rapids which these boats have to ascend and descend, it is necessary to read the graphic descriptions of Worcester.

Another remarkable vessel is the Liang-chieh-thou or articulated junk, which works on the Grand Canal. This is a very long and narrow barge of shallow draught, built in two separate component sections which are detachable. Coupling and uncoupling of the bow and stern portions is simply done, by the aid of a wire becket and handspikes. A collapsible mast and leeboards are fitted. The invention of the articulation doubtless took place as the Canal became silted up, for the two halves can separately negotiate shallow channels where larger boats would be forced to await a rising water level. The two halves also bank in alongside each other. Although this

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*a* See below, pp. 60a, 61a.
*b* Ch. 34, pp. 465, 59, tr. auct.
*a* Paik (1) translated this as 'their ability to sail against the wind'. Although they certainly could and did do this (see p. 60b below), it cannot be the meaning of this particular sentence.  
*Similar procedures are described for Korean shipyards by Underwood (1), p. 22. Slightly twisted or crooked bows and sterns are also known in that country (ibid. pp. 7, 11). The bamboos of the Formosan sailing-raft are also steam-bent (Ling Thu, fr. 1).
*a* As long as the boats themselves.
*b* Experiments with models indicate this (personal communication from Mr G. R. G. Worcester).
*1* 鐵桅 *2* 木節 *3* 亂纏 *4* 黃漆 *5* 黃銅可以破風行驶也 *6* 對舵 *7* 極流 *8* 白流 *9* 坚船 *10* 厚板 *11* 端航
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invention may not be very old, it was perhaps the first instance of the use of the articulation principle which in the railway age became so important. In any case, it certainly goes back beyond the early 18th century, for we see it depicted in the Thu

* All trains of carriages exemplify it, but especially the articulated locomotive, first introduced by the Swiss engineer Anatole Mallet in 1888.

29. SHIPPING

Shu Chi Chêng encyclopedia* adapted for war purposes; the forward section is filled with bombs and other explosives, while the crew and marines occupy the aft section. Presumably the idea was to work the vessel (here called Lien-huan chou) up some creek on a dark night to a point beside some city-wall or under a bridge, then uncouple and silently withdraw, having set a time fuse. Since the boat is described and figured under the same name in the Wu Pei Chih, the late 16th century would seem to be a likely time for the origin of this device. Fig. 954 is taken from a MS. of a related work by the same author, Wu Pei Chih Shêng, in the Cambridge University Library.

(1) AFFINITIES AND HYBRIDS

It may be that those who have denied any connection between Chinese and ancient Egyptian shipping have been rather too hasty. The most typical and characteristic Egyptian ship was that familiar type which has an extremely long bow and stern sloping and tapering in each direction above the water-line. The flotation length may be not much more than half the total length. But this was not the only kind of hull known in ancient Egypt. Especially during the VIth dynasty (c. -2550), a quite different type was prevalent, and it presents some extraordinary similarities with certain river-junks still in use in China today. Egyptologists (e.g. Boreux; Reisner and Klebs) know these two types as the Naqadian and the Horian respectively, for the former can be traced back to the pre-dynastic pottery designs of Naqada, and the latter are associated with a conquering people who came from further east and worshipped the god Horus (Fig. 955). Both types of ship are sometimes seen in one and the same carving, for example at the Deir al-Gebrawi necropolis, where two funerary reed-bundle Naqadian boats are being towed by a Horian ship with square-sail set. One has only to compare the latter type, with its high stern, stern gallery, low bow, relatively truncated ends, and mast set forward of the mid-line, with existing Chinese vessels, to see the

* Jung chung tien, ch. 97, shui chun pu, hui khoa 1, p. 334; cf. Audemard (a), pp. 84 ff.

† Ch. 117.

‡ Not long after writing this paragraph, we were interested to see an articulated set of pontoon-barges in three sections used by the contractors engaged in the repair of the river-wall of Magdalen College. Such barges were much used by army engineers during the second world war. We have already referred (p. 423) to the introduction of the device to Europe by Samuel Bendor and at the end of the 18th century, and we have shown that he had had prior Chinese contacts. According to Touzoue et al. (1), p. 333, the same suggestion was made by Robert Fulton in 1803, and they illustrate his proposal. So also James White in 1773 patented a scheme for a 'serpentine' canal boat, i.e. a string of barges articulated in such a way as to reduce tractive effort, and apparently he carried out some successful experiments (see Dickinson, 5). Thus the idea was very much in the air at that time.

§ F. H. Wells (1), who devoted a paper to alleged similarities between Chinese and ancient Egyptian nautical techniques, concluded that there was very little in common, but his level of analysis was somewhat superficial.

Boreux (1), p. 17. They have some resemblance to the boats on the Indo-Chinese bronze drums (cf. p. 446 below), and with the bows of extant Siamese dugout canoes. Occupying an important intermediary position, and much older than these, are the rare remaining representations of Mohenjodaro ships, one of which is clearly 'Naqadian' and the other not unlike it (see Bowen, 8).

Boreux (1), p. 153. More Horian ships escorting, p. 158; discussion on this, p. 491. Another Horian ship is seen in Klebs (1), fig. 86, p. 105; and again in Klebs (2), fig. 102, p. 138. The latter is early Middle Kingdom, c. -2350. Cf. also Whibody (3).

Fig. 954. An articulated barge of the late 16th century in use for military purposes; from the Wu Pei Chih Shêng (MS. in the Cambridge University Library, copied in 1843). Such vessels (Liang-chieh-chou or Lien-huan chou) were used as minelayers, the forward portion being left beside the target with a time fuse while the aft portion silently withdrew.
all the Ma-yang-tzu varieties answer to it, especially the Nan-ho chhuan, but a number of others are also relevant.

Poujade (3). The latter immediately emphasised one point of fundamental importance, have been examined from the point of view of naval archaeology by Reisner (1) and blocks), the use of the bulkhead was unknown; at any rate when the model is hollow Chinese ships. However, so far as can be ascertained (for many of the models are solid there are only a number of arched flat thwart timbers. The foremost of these is likely supporting the steering-oars (see cut). The stern gallery is as characteristically Chinese as the transom stem and stern. Boreux himself did not see these striking similarities between the Horian and Chinese build, but believed that the Horian people had come from Mesopotamia; in this case certain elements of Chinese shipbuilding might join with other proto-scientific material which elsewhere we have seen reason to believe were diffused from Mesopotamia to the beginnings of Chinese civilisation. According to Boreux and Reisner, the Horian type of ship died out before — 2000, but perhaps it would be safer to say that after that time it appeared no more in carvings or tomb-models.

Fortunately, a number of tomb-models of both kinds of boats have survived, and have been examined from the point of view of naval archaeology by Reisner (1) and Poujade (3). The latter immediately emphasised one point of fundamental importance, namely that some of the Horian boats are square-ended (Fig. 956, pl.), like all true Chinese ships. However, so far as can be ascertained (for many of the models are solid blocks), the use of the bulkhead was unknown; at any rate when the model is hollow there are only a number of arched flat thwart timbers. The foremost of these is likely to carry the bipod mast, and the aftermost has also two sockets for the two posts supporting the steering-oars (see cut). The stern gallery is as characteristically Chinese as the transom stem and stern. Boreux himself did not see these striking similarities between the Horian and Chinese build, but believed that the Horian people had come from Mesopotamia; in this case certain elements of Chinese shipbuilding might join with other proto-scientific material which elsewhere we have seen reason to believe were diffused from Mesopotamia to the beginnings of Chinese civilisation. According to Boreux and Reisner, the Horian type of ship died out before — 2000, but perhaps it would be safer to say that after that time it appeared no more in carvings or tomb-models.

Poujade, inspired by a beautiful terra-cotta lamp in the form of an Athenian galley, with bifid rostrum, stolos, and forward-curving stern, found examples all over southeastern Asia of builds which might have derived from these Mediterranean conceptions. The only Chinese vessel affected is the so-called fan-tail junk of the Ta-Ning 1 River in Szechuan, the 'lighter of the gods' (Shen-po-tzu 2), which has a forward-curving stern. But this might equally well be a relic of Egypt.

The bipod masts of southern Chinese shipbuilding (see Fig. 957, pl.) have already been mentioned (p. 425). Hornell (18) drew attention to the fact that such masts were quite characteristic of ancient Egyptian ships; a resemblance which had not escaped the eagle eye of the prince of diffusionists. There really seems no reason for rejecting this trait as a possible transmission eastwards in ancient times, but if so, it is curious that it did not spread or survive further north in the Chinese culture-area. The bipod mast is, of course, far from being a mere historical curiosity; from the engineering point of view it was excellent, and it has come back in the days of metal tubing. Moreover, a bipod mast is recommended by modern yacht designers as avoiding interference with the mast.

E.g. astrological doctrines (Vol. 2, pp. 353 ff.), equatorial astronomy (Vol. 3, pp. 254 ff.), and the fundamentals of acoustics (Vol. 4, p. 1, pp. 176 ff.), not to mention such things as bronze technology, the wheel and the chariot. One wonders whether Hornell's theory of an origin from the bamboo raft would apply also to the Horian ships? Bamboo of an inferior kind was known and used in Africa and Assyria (cf. R. C. Thompson, 2).

The local shipwrights preserve the memory of a priest, presumably Taoist, Wang Yeh’ (Grandfather Wang), who taught them how to build these boats, in the Thang period or before.

E.g. Burmese royal barges, the doubly bifid canoes of Madura Island, those of Baweian Island; and certainly remarkably Greek-looking, those of Talaud Island; all these are in the Javanese area (pp. 283, 284). Cf. p. 389 above.

If. The only Chinese vessel affected is the so-called fan-tail junk of the Ta-Ning 1 River in Szechuan, the 'lighter of the gods' (Shen-po-tzu 2), which has a forward-curving stern. But this might equally well be a relic of Egypt.

If. The local shipwrights preserve the memory of a priest, presumably Taoist, Wang Yeh’ (Grandfather Wang), who taught them how to build these boats, in the Thang period or before.

If. Here we illustrate (Fig. 957, pl.) from the Li River near Kweilin (Goff & Lau, 1). Another good photograph from Yangshuo further down will be found in Forman & Forman (1), pl. 179. Cf. Schultheiss (1), pl. 165.

If. See Boreux (1); Reisner (1). There is a hint of the bipod mast in the Mohenjodaro culture (c. -1500); see Bowen (8).

If. Elliott-Smith (2). But he missed the resemblance of the Horian ships to Chinese river-junks. Many of his views are of course quite unacceptable today, e.g. that Red Sea shipping reached the Chinese coast in the 7th century. He also maintained that East Asian craft in ancient times succeeded in crossing the Pacific to the American continent—this too was unacceptable in the pre-Heyerdahl era, but whether it still is we shall discuss later (pp. 540 ff.).

2. 航海 3. 航海 4. 航海 5. 航海
airflow over the leading edge of the sail. And two lesser spars could substitute for a more massive one if that was not available. Of course it may be said that the greater the practical value of a simple invention the more likely it was to have been made independently—but just how simple are any inventions? Diffusion may perhaps be thought more probable when a practice is magical rather than practical, as in the case of the oculus, i.e., the painting of an eye on each bow quarter of the hull. This certainly has certainly have spread outwards in all directions from ancient Egypt or Mesopotamia. When it reached China we do not know, but the fact that it is confined there to the southern and central regions suggests that it came relatively late, perhaps not before the Han.

Several general questions may now be asked. Were there any exceptions in the Chinese culture-area to the basic principle of boats without keel, stem or stern posts? There is one, and it is of great interest. The dragon-boats (Lung chuan), used for those races (Fig. 958, pl.) which form such an important feature of the Fifth Month festival (tuan su chieh), synonymous to commemorate the poet Chhi Yuan (d. -288), are (in many cases at least) built with a true keel or a kelson. This takes the form of a shan-mu (fir) pole the length of the boat, which may be as much as 115 ft. and resembles an English 'eight', though longer and narrower. There may be thirty-six or more paddlers. Although bulkheads slotted to the kelson are built in, we are here clearly in presence of an archaic element of one of the constituent cultures which fused to give Chinese civilisation. This is well seen in the ethnological study of Bishop (7) on a lake beside a Thang imperial palace (see Sickman vol. 1, pp. 220, pl. 20). These were also called lung chiau.

Another possible exception is constituted by the boats of the Erh Hai Lake in south-western Yunnan, described by Fitzgerald (6). These seem to have frames without bulkheads, but the presence of keels needs further investigation. The area is a very isolated one, and could well have been influenced from India.

To what extent did the rectangular construction spread from China to other lands? Information here is scanty, yet so far as may be ascertained all Japanese hulls before the seventeenth century followed approximately the build of the Chinese shipwrights (cf. Fig. 1038, pl.). Clowes & Trew give a reconstruction of a medieval Japanese ship, based upon the drawings of Admiral Paris. An English shipwright, Will Adams, worked in Japan during the first two decades of the century, however, and later vessels were often copies of occidential models, notably Russian schooners.

A somewhat more interesting, though much more obscure, problem concerns the origin of the punt, as we know it today in Western countries. This familiar rectangular craft is extremely similar to the Chinese sampan, and it is curious that no one has investigated its origin. The word itself is, of course, related to the Latin root significas signifying a bridge. There were 'pontones' in Roman times, but apparently they were merchant-ships, if we may judge from the remarkable +2nd-century mosaic at Althiburus in

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* Curl (1), p. 81.
* The oculus is considered in Hornell (1), pp. 285 ff., cf. also (33), and its diffusion was of course noted by Elliott-Smith (2). It has recently been the subject of an epic controversy between Bowen (2) and Quigley (1); the former maintaining that it passed from Mesopotamia to China, the latter that it passed from Mesop0t.=na or Egypt to India by way of the +1st-century Roman (actually Graeco-Syrian and Graeco-Egyptian) trade, the latter that it has spread outwards in all directions from ancient Egypt or Mesopotamia.

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* Dropping of bow and stern portions of a boat. See, e.g., Boreux (1), p. 471; Neuhuber (1), p. 479; Keble (1), fig. 83, p. 103; Winlock (2); Chatterton (1), p. 20.
* Poujole (1), pp. 277 ff., thought he could recognise traces of the anti-hogging truss in the ornamentation of the stems and sterns of a number of Asian boats, and in the stem-embracing mast-stay used on certain Chinese river-junks when tracking. Dr J. S. Morrison tells us that a truss was part of the normal gear of the standard -+th-century trireme in ancient Greece. What is perhaps most astonishing is to find that a form of it survived in the construction of Mississippi stern-wheeler steamboats where the boilers were right forward and the engines right aft (King-Webster, l). And we may see a form of it every time we go to a railway station if we look at the inverted trapezoidal trusses underneath the frames of bogie goods trucks and wagons.

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* An internal keel, i.e. one which does not come in contact with the water.
* Average beam about 4 ft. In one case studied, the bottom of the boat was markedly concave below, like a modern racing motor-boat, but apparently this feature was not general (C. G. R. Worcester, unpublished material, no. 131).
Tunis, which incorporates the names, as well as the pictures, of a number of different craft. Caesar mentions a Gaulish transport boat under the name of "pontonium," and "pointebots" begin to appear in East Anglian records about + 1500. A punt is mentioned in a London law case report of + 1371. The oldest illustrations of punts which we have found are in the pictures of the MS. Fischereibuch of the Emperor Maximilian I (+ 1459 to + 1519) conserved at Vienna. Yet Isidore of Seville (c. + 650) described the 'ponto' as a simple rowed boat of rectangular shape, with sloping sides and flat bottom; and the Pandects (+ 533) refer to it as being used for ferry services.

The problems of affinity and transmission are thus rather obscure. Cloves, commenting in the discussion on Brindle (+), alluded to the widespread use of punts in Kashmir and the Upper Indus valley. If the Chinese build found its way overland already in Buddhist times, punts in our sense may well have existed in Roman Europe. On the other hand if Roman boats with the same name were not what we should call punts, those of St Isidore may have been introduced through Byzantine contacts. Or perhaps Chinese technicians following the Mongol armies constructed rectangular keel-less boats for military purposes in + 13th-century Eastern Europe—and indeed the punt, like the crossbow, may have been introduced several times. Or lastly the European punt may always have existed as a descendant of the square-ended boats of ancient Egypt just described.

Did hybrid types develop in south-eastern Asia in the regions where Chinese mingled with Indian and indigenous influences? Abundantly, as we know from the exhaustive account given by P. Paris (3) of the ships of Indo-China. Individual types have been carefully described too, by Poti (2); Pietri (1); and others. A keel was perhaps the first feature to be adopted, then bulkheads were abandoned for rib frames (wan chhau), as in the teago of Singapore (Waters, 4). Cases are known, such as the Malayan tongkang (Waters, 3), in which the ships are designed, built, owned and worked by Chinese, yet the structure and rig is entirely European. The Chinese sails, however, on account of their great efficiency, are among the last components to disappear, and indeed, as in the famous Portuguese 'iorchas' (lua thang') of Macao and Hongkong, have co-existed since the + 16th century with a slender hull of normal European type.

(c) The Chinese ship in Philology and Archaeology

If it is not putting too much weight on what might have been only an arbitrary convention of scribes, the Shang and Chou forms of words for boats indicate that already in remote antiquity the characteristic build of the Chinese vessel had developed. They seem to give a remarkable pictorial statement of the basically rectangular shape, though a design with pointed ends would hardly have been too difficult to draw. The earliest form of the word chou (Rad. no. 137; K1084), as seen on the oracle-bones, shows the transom and bulkhead construction, without any sharp stern or stern—or, at the least, a rectangular slightly concave raft with thwartwise members. The original significance of the other component in chhuang, a ship (K2496; f), is not known, but the mouth probably represented the crew, and the two lines river-banks. The word pan (K182a, b, c), which eventually acquired many meanings (to transport, change place, turn round in general), distinctly shows an oar and a hand beside a boat; it is, indeed, as Edkins (12) knew, an old steersman's word, now often written with the hand radical. Pan shao means to pull the stern-sweep or steering-oar to oneself (i.e. to port), thui shao to push it away (i.e. to starboard). The word chem (K893; f) is, as apparent, in the three-masted fishing-boats of Amoy (Worcester, 7), and in the sea-going junks of Hainan island and many other parts of Kuangtung (Worcester, 8). The Maze Collection embodies a fine model of a 106-ft. Kuangtung freighter of this kind (Anon. (17), no. 3) which we illustrate in another connection at Fig. 1440 (p. 429 above).

References to this attractive type of vessel are found as early as + 1509 (Peri (1), p. 107). It is a remarkable illustration of the rule enunciated by Poujade (1), p. 170, 177, that hulls tend to change more easily than rig. He gives good sociological reasons for this—the shipwright and the sail-maker are quite different people. Hulls, he says, are sensitive to commercial contact; riggs, more closely associated with the traditions and life of the sea-faring folk, change only under political dominance. But there is much contrary evidence, and all 'rules' in this field are probably premature.

Attention has been drawn to the interest of the ancient forms by Gibson (4) and Worcester (3), vol. 1, p. 6, but strangely they failed to see the significance of the shape. How old these expressions are we do not know. While they seem to appear but rarely in written records, they may well belong to ancient oral tradition.
formerly written chên and now meaning a seam, originally meant to caulk the seams of a boat, since we see indeed a boat accompanied by two hands holding something, presumably the caulkling chisel. So common a word as chou, to receive, was also once written in such a way as to depict a boat-like object and two hands (K 1085), but this was more probably a weaving shuttle; if so, the pictogram does not indicate, as some have thought, the loading and unloading of boats. People of the Chinese culture-area were always surprised when they saw the sharp-ended boats and ships of other civilisations. For example, the Ch'in Tartar Wuksun Chung-Tuan, who had been on diplomatic missions for his country, wrote in his travel notes about +1220 of the Islamic lands of the West (Yin-T'u Hui-Ho): 'Their boats resemble a shuttle. And in +1259, when Chhang Tê crossed the Syr Daria River on his embassy from Mangu Khan to Hêliêgu Khan, he was much surprised to find that the boat 'resembled a Chinese woman's pointed and crescent-shaped shoe'.

(1) From Antiquity to the Thang

There seems to be nothing very revealing among the mentions of boats in the Shih Ching or other classics, and the Tao Ch'uan's accounts of naval battles do not help much. Nevertheless, there is no reason to doubt the historicity of the fleet which was sent northwards by the State of Wu, under the admiral Hâi Chêng, to attack the State of Chhi in +486. What he probably commanded was a number of large padded canoes, some perhaps large enough to carry deck-castles for archers, and they certainly kept close in-shore. We have already had occasion to mention the great fleet of sailing-rafts

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a useful glimpse of a particular kind of seamanship important at the time.\(^a\) In the following year another substantial river and coastal fleet was organised, and sent under Han Yüeh\(^b\) and others to suppress a rebellion in eastern Yüeh.\(^b\) Then in -108 Yang Phu led a sea force against Korea.\(^b\) Thus naval operations were conducted on a considerable scale in the reign of Han Wu Ti.\(^d\)

At the beginning of the Later Han period, Kungsun Shu\(^4\) tried to set up an independent kingdom in Szechuan. Three of his military engineers built a remarkable fortified floating bridge and boom in Hupeh, but this was destroyed by a Han fleet of thousands of vessels including many 'castled ships'.\(^e\) We shall describe this action more closely on p. 679 below, on account of the interest of the types of craft involved. This was in +33. Just ten years later there was the great expedition of Ma Yuan\(^2\) to Chiao-Chih (Tongking) which involved a fleet of 2,000 'castled ships' (sou chuħan).\(^f\) Subsequently many naval fights between the Chinese and the Champa people (of the Lin-I6 kingdom; modern Annam) are recorded.\(^g\) The term sou chuħan\(^h\) for warships of large size persisted down all through the centuries. By the 8th, the best Thang sources say that they had three decks, with bulwarks, arms, flags, and catapults,\(^i\) but were not very handy in rough weather. When one remembers that Han Yüeh's chief expedition took place just about fifty years before the Battle of Actium, one would like to know much more about these Han warships, and how far (for example) their tactics compared with the boarding technique used by the 'marines' of Rome during the First Punic War (c. -260 to -240).\(^j\) There is some evidence that they engaged in ramming, like Greek triremes.\(^k\)

Sea communications with Kuantung, Indo-China and Malaya began to acquire importance from the beginning of the present era. In +2 Wang Mang got tribute of a live rhinoceroses from those parts, and it certainly came some of the way by boat.\(^l\) This

\(^a\) A certain Tsu Kuang-Ming\(^n\) was appointed Hsia Lai Chiang-Chun (the Torrent-Descending Commander). He was no doubt an expert in the management of ships in those rapids so abundant on the Chinese rivers. See Chhien Han Chh, ch. 14, p. 1b.

\(^b\) His title was Heng Hai Chiang-Chun\(^o\) (the Ocean-Traversing Commander); Chhien Han Shu, ch. 6, p. 31a (tr. Dubs (2), vol. 4, p. 82).

\(^c\) Chhien Han Shu, ch. 6, p. 248 (tr. Dubs (2), vol. 2, p. 90 ff.). Although the expedition was successful and Korea was divided into four Han commanderies Yang Phu's losses were so severe that he himself fell into disgrace and was dismissed.

\(^d\) Ch. 95 of the Chhien Han Shu, which gives the fullest account of all the campaigns and their political background, is available to Western readers only in the antiquated translation of Pfizenmaier (51).

\(^e\) Hou Han Shu, ch. 47, p. 17b. Cf. Kungsun Shu's biography in ch. 43, p. 234 ff.

\(^f\) Hou Han Shu, ch. 56, p. 102a. Cf. Shu Ching Chh, ch. 37, p. 94, and Maspero (18).

\(^g\) De Flines (1). Among the dates are +248, +356, +407. In +431 more than a hundred Cham ships, with superstructures, ravaged the province of Tongking, but were finally beaten off.\(^r\)

\(^h\) TPPC, cit. e.g. in Tu Hung Tien, ch. 160 (p. 848-3), cf. p. 685 below. There are many references to these war-boats or ships in earlier books; as, for instance, the 4th-5th century Han Yi Shih Chu Chh, ch. 2 (end of introduction). This passage concerns the expedition of young men and girls led by Han Fu\(^w\) which set forth in search of the Magical Islands in the Eastern Sea, and the herbs of immortality which were supposed to grow there, at the command of the First Emperor. Cf. p. 532 and Sect. 33a below.

\(^i\) Trebuchets, perhaps also large crossbows fixed to stands. Cf. Sect. 32b below.

\(^j\) Cf. p. 693 below.

\(^k\) Cf. p. 679 below.

\(^l\) Chhien Han Shu, ch. 12, p. 241; Chh, ch. 286, pp. 379b, 404a. Cf. Duyvendak (8).

\(^n\) Taish\(^o\).

\(^o\) 毛並 passed it from the 秦 to 漢, where it is recorded (g) in 漢書.

\(^p\) 楊典 passed it from the 漢 to the 慶, where it is recorded (h) in 漢書.

\(^q\) 楊典 passed it from the 漢 to the 姜, where it is recorded (i) in 漢書.

\(^r\) 漢水CHEMICAL TECHNOLOGY

29. NAUTICAL HISTORY

tribute was repeated in +84 and +94, and continued intermittently as late as the Thang.\(^a\) An interesting passage in the Chhien Han Shu describes Han trade with the south seas.\(^b\)

From the barrièdes of Jhi-Nan\(^n\) (Annam), or from Hau-wen\(^h\) and Ho-phu\(^p\) (in Kuang tung),\(^s\) going by boat for five months, there is the Tu-Yuan\(^b\) kingdom ... [and four other kingdoms are mentioned, all of which had offered tribute from Han Wu Ti's time onwards.]

There are superintendent interpreters (ch chhuan)\(^a\) belonging to the civil service personnel (huang men);\(^b\) who recruit crews and go to sea to trade for brilliant pearls, glass,\(^e\) strange gems and other exotic products, giving in exchange gold and various silks. In the countries where they come the officials and their followers are provided with food and handmaidens. Merchant-ships (ku chhuan)\(^a\) of the barbarians (may) transport them (part of the way) home again. But (these barbarians) also, to get more profit (sometimes) rob people and kill them. Moreover (the travellers) may encounter storms and so drown. Even if nothing of this kind happens, they are away for several years.

As for the great pearls, they may measure as much as two inches in circumference.\(^s\)

This probably refers to the two centuries preceding the time when Pan Ku was writing (i.e. about +90), so we may take it as well applicable to the -1st century, indeed back to the time of Han Wu Ti. Since the furthest country is said in the text to require a sea voyage of just over twelve months, and since the whole account is quite devoid of any legendary quality, Pelliot felt that one should visualise Chinese missions penetrating already at this time as far as the western extremity of the Indian Ocean.\(^f\) Further evidence for these extensive contacts has come from archaeological investigations in South-east Asia; thus Chinese coins of the first quarter of the +1st century have been found in the tombs at Dongson (northern Annam).\(^h\) Chinese pottery of the Former Han, one piece bearing an inscription dated -45, occurs in Sumatra, Java and Borneo.\(^i\) And certain stone sculptures of Sumatra bear a close similarity to those of the Han.\(^j\)

Indeed it is more than likely that the foundations of this maritime trade had already been built (as suggested above, p. 441) by the people of Yüeh in the Warring States period. A passage in Chuang Tsu, seemingly often misunderstood,\(^k\) may be brought

\(^a\) Cf. Pelliot (50); Laufer (15), p. 8a.

\(^b\) Ch, ch. 286, p. 379, tr. auct. adjuv. Pelliot (50); Ferrand (3); Duyvendak (8); Wang Kung-Wu (1).

\(^c\) Cf. p. 669 below.


\(^e\) Phu lui-lui, sug. Pelliot (5, 15). Pelliot considered this term equivalent to the Skr. vaidyajra, and that it meant glass here. On glass in Indo-China see the remarks of Janse (30); Ferrand (8); Wang Kung-Wu (1).

\(^f\) Note that this estimate would place Chinese long-distance navigation two or three centuries earlier than the date normally accepted (see Vol. 1, p. 179). But the text need not mean that Chinese ships themselves went all the way. Still, it is arresting enough to think that Chinese merchant-officials walked with Roman citizens from Greece, Syria and Egypt on the quays of Antike (Vrapatsam); cf. Vol. 1, p. 178 and Wheeler (4), pp. 137 ff.

\(^g\) Goloubec (1).

\(^h\) De Flines (1).

\(^i\) Van der Hoop (I).\(^s\)

\(^j\) Ch. 24 (Phu Chh, ch. 8a, p. 30). tr. auct. adjuv. Legge (3), vol. 2, p. 93. The parallel passage in Lü Shih Chhun Chh, ch. 65 (vol. 1, p. 126), makes it quite clear that seafarers are intended.

\(^k\) Ch. 24. 会籍, 聘派, 聘用, 娶。
forward in witness of this. The Taoist recluse Hsi Wu-Kuei, having had an interview with Duke Wu of Wei, is discussing his good reception with the Duke's minister.

Have you not heard [he says], of the wanderers of Yüeh? When they have been gone from their country several days, they are glad when they see anyone whom they knew there. When they have been absent for weeks or months, they are happy if they meet anyone whom they had formerly seen at home. But by the time they have been away for a whole year they are delighted if they meet with anyone who even looks like a compatriot. The longer they are gone, the more affectionately they think of their own people—is this not so?

Thus the Duke has wandered far from his true native land of the Tao—no wonder he welcomes a messenger from there. But for us the interest lies in the sails of the envoy-interpreters. From the kingdom of Huang-Chih, going by ship about eight months, one reaches Phis-Chang. Going on further by ship about two months, one gets to the frontier of Hsiang-Lin in Jih-Nan. It is said that south of Huang-Chih there is the country of Sau-Chhêng-Pu. It was from there that the envoy-interpreters (i shih) of the Han returned.

We still have no definitive identification of any of these countries, but Huang-Chih is generally believed to be Kâncipura (mod. Conjeveram in Madras, then capital of the Pallava State). This would fit in with the itinerary through four kingdoms omitted in the previous quotation, for it includes a ten-day land journey sandwiched between months of sailing, and this could very reasonably be interpreted as a traverse of the Kra isthmus in southern Siam. Judging by the timings given, however, Herrmann (4) suggested that Huang-Chih could have been the port of Adulis (mod. Massawa in the Red Sea), in which case Sau-Chhêng-Pu would be the oldest Chinese mention of East Africa. Most sinological geographers have frowned upon this view, though not all, and it is still on the agenda.

Representations of boats and ships of the Warring States and Han times were until lately scarce. Some quite small boats are shown on the tomb-shrine reliefs of Hsiao-thang Shan and Wu Liang Tzhu (carved between +225 and +150); they are all sampans carrying two or three people each. It is hard to be sure about their nature; some might be dugout canoes, others look more like reed-bundle craft, and P. Paris (1) surely goes too far in seeing an assured stern-post and stern-post in some of them. More interesting are the Warring States and Early Han bronzes depicting war-boats which show distinctly above the rowers an upper deck carrying spearmen, halberdiers and archers. This is the first appearance of the 'castled ships' or lou chhuan which have already been mentioned. In Vol. 4, pt. 1, for a different purpose, we reproduced in Fig. 300 a bronze vase of the - 4th century, the Yen-Yo Yü-Lieh Thu Hsu preserved in the Imperial Palace Museum, Peking. Below on the left a naval engagement is proceeding; the two ships are meeting bow to bow, their rowers in the characteristically Chinese forward stance, their pennants flying. The 'marines' at the bow fight with short swords in scabbards at their waists. The marines on the upper deck are armed not only with the typical dagger-axe 'halberds' (ko), but alternately with bows. As in the rather older (-4th-century) bronze depicted in Fig. 300, to which the present engraving bears great similarity, there is a drummer at the stern, here beating on two drums, a large and a small. Aft of the ship there is a figure (not shown), seemingly in the water among the fishes, which appears to be pushing the warship along—perhaps a guardian spirit favourable to the warriors.
since the Phoenician or Greek ships sculptured on Sennacherib's palace at Nineveh about —700 have an analogous structure.\footnote{G. Holmes (1), p. 26; Anderson & Anderson (1), p. 35; des Noëtes (2), figs. 23, 24; Smld (1).}

A sidelight on the 'castled ships' of the Han may be obtained from the inscribed bronze drums of contemporary date which have been found in Indo-China. Fig. 960 shows some of their pictures of war-boats, done in the peculiar and characteristic style of the Dôngsön culture.\footnote{Fig. 960. War-boats on the Dôngsön bronze drums of Indo-China; tracings from the photographs of Parmentier (2) and Goloubev (1). Through the peculiar and characteristic style of these —1st-century engravings one can easily make out the helmsman at the stern with his steering-oar, the ritual bronze drum within the after-castle and the archers on its roof, warriors further forward with spears and javelins, and perhaps a stone anchor hanging from the bows. In the complex bow structure an oculus is distinctly visible, and just aft a figure which could be an enchanter casting a spell.} Here again there are superstructures, forerunners of the 'fore-

castles' and 'after-castles' such as appeared so much later in European shipbuilding when the Viking long-ship was turning into the medieval ship.\footnote{The bronze-drums seem to have had steering-oars at both ends (unless the object at the bow is a stone anchor), and warriors are generally much more in evidence than the rowers, who perhaps were hidden by the vessel's sides. The 'castles' are manned especially by archers, and each seems to contain a bronze drum, carried perhaps as a kind of magical Palladium or Ark of the Covenant. No masts or sails occur.} In date these drums are

dated to the —1st century, so that the earliest of them could be contemporary with the Chinese conquest of —111 while the later ones would have been saved from the invaders of +43. Thus we have in these stylised representations a rather precious record of the kind of war-boats with which the 'Wave-Subduing Admirals' Lu Po-Tê and Ma Yuan successively had to contend. The Dôngsön drums are more closely associated with Chinese culture than was previously thought, for very similar bronzes, but even more brilliantly designed and cast, have been obtained in profusion from royal tombs of the State of Tien\footnote{Anon. (28), pl. 126.} excavated at Shih-chai Shan\footnote{See see Hua Xi (1) and Anon. (11), pp. 154 ff. and pl. 103.} near Chin-ning beside the Kunming Lake in Yunnan province.\footnote{As in the case, perhaps, of Tshen Pheng's crews (p. 621 below).} These finds date from the —1st and —2nd centuries and are therefore contemporaneous with those of the Dôngsön culture and with the Chinese conquests of it.\footnote{Smyth illustrates one of these, (1), p. 365; also Hornell (1), p. 249.} In the rubbings so far published, however,\footnote{In the Chinese conquests of this region.} the boats are distinctly less large and elaborate than those depicted on the Dôngsön drums, products of so maritime a region.

Until recently it was thought that no model boat had survived from any Han tomb, but a magnificent specimen has now been recovered from a princely tomb of the Former Han period (—1st century) at Chhangsha (Fig. 961, pl. 9).\footnote{Archaeological report, Anon. (28); short account in English, Wang Ch'ung-Ming (1). These discoveries are of the first importance, not only as revealing a comparatively high culture the very existence of which was previously unsuspected, but because the Tien style has close affinities with the 'animal style' of the Baltic steppes (cf. Vol. 1, p. 159, 167) and even with the art of the Yuxes and Ausecs, as well as with that of Nan Yuh beyond the mountains to the south-east.} This river ship, which is 4 ft. 3 in. long and delicately made of wood, was found complete with sixteen oars and a great stern-sweep twice their length. The build is typically Chinese, flat-bottomed, with strictly rectangular bow and stern, and that part of the bow projecting above the water is very elongated. It is a pity that the model was not fitted with a mast and sails, for this would have given us very important information. Published photographs show considerable differences in the assembly of the parts; in one reconstruction a couple of deckhouses rise one above the other, in a second they follow on fore and aft. The former shows a large stern gallery, the ancestor of those elaborate structures on sea-going junks which cover the rudder housing; the latter, less plausibly, omits it and leaves no room for the steersman. One reconstruction has included the bulwarks pieces, but apparently upside down, for the oar-ports should be lower and the sides would then give protection to the rowers.\footnote{Even the gold seal of the King of Tien, presented to him by Han Wu Ti in —109 (Shih Chi, ch. 116, p. 58), was recovered.} It is not easy to pick out any existing Chinese craft which resemble this boat in detail, but there is something archaic (indeed truly Egyptian) about the long projecting bow and stern, as in certain Indian boats, such as the malar panshi of Bengal.\footnote{As in the case, perhaps, of Tshen Pheng's crews (p. 621 below).} But they are perhaps more 'Naqadian', while the Han boat is more 'Horian' (cf. p. 434 above), and seems almost to prefigure the Ma-yang-tzu. From accompanying inscribed objects, the Chhangsha boat model seems to be datable about —49.

Though in Fig. 960 there is something suspiciously like a tabernacle just forward of the centre of the vessel.

\footnote{Though in Fig. 960 there is something suspiciously like a tabernacle just forward of the centre of the vessel.}
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By great good fortune, excavations in the city of Canton since 1954 have given us remarkable models of + 1st-century craft which complement the river-ship, since they evidently belong to estuaries and to the sea. Some of these are of red pottery rather roughly finished (Fig. 962, pl.); but showing most clearly the typical bluff square-ended bow and stern and the flat bottom of the hull. The thwart timbers overhang the sides and on the arched deck there are the figures of four rowers, but no mast. Both fore and aft the uppermost strike timbers are prolonged so as to form galleries, the former no doubt for handling the anchor, the latter for fixing the steering apparatus, though what this was these models do not show.

To this particular question the greater ships of grey pottery (also in the Canton Museum) have a dazzling answer to make, but we shall say no more of it here since it belongs to the debate on the rudder and its origins. The general appearance of one of these, recovered from a Later Han tomb in the Tung-Chiao district of Canton, is shown in Fig. 963 (pl.), a photograph taken from the starboard side. The hull is of the standard Chinese type, as can also well be seen from Fig. 964 (pl.), which shows the bows, and the anchor hanging from a bollard on them just forward of an ornamental structure which may well be the ancestor of the 'prow yokes' now mostly found on bows, and the anchor hanging from a bollard on them just forward of an ornamental standard Chinese type, as can also well be seen from Fig. 964 (pl.), which shows the rowlocks on each side, between which stand two figures amidships. For two-thirds of which stand three deckhouses, the aftermost one being clearly the steersman's cabin (tho lou). The covered part is flanked by three tall vertical pointed timbers of uncertain function, and by well-marked outboard poling galleries supported on projections of the thwart timbers, with another member of the crew standing on the starboard side. Where the mast was stepped remains a mystery, but the most likely place would seem to be the gap just forward of the covered deck where the poling galleries end (see Fig. 965, pl., a photograph taken from above).

Evidence of mast and rig has gone, but the general resemblance with a traditional Chinese ship of a few years ago being worked upstream can be glimpsed from Fig. 966 (pl.).

The + 3rd century, the San Kuo period, is rich in naval history, but unfortunately the annalists were sparing of detail about the ships themselves. Doubtless the lou chhuan were larger, and we begin to hear of fast fighting ships called ch'eng-chhuan, Taou ko and Tou hsien. Bulwarks were covered with wetted hides to prevent the effect of incendiaries, but sometimes these weapons were very effective, as in the famous case of the Battle of the Red Cliff (+ 207), when Ta-hao Tshao's fleet was destroyed.

Sea-going ships as well as river craft must have been developing, for in + 233 a fleet of the State of Wu was lost in a storm in the Yellow Sea. From a number of descriptions it is clear that detachments of crossbowmen (unknown until much later in medieval Europe) firing from the ships often played a more important part than boarding or ramming.

In the San Kuo period the word pol for sea-going ships or junks, appears. Khang Thai, who travelled to the kingdoms of south-east Asia about + 260 on behalf of the ruler of the Wu State, left a book called Wu Shih Wai Kuo Chuan (Account of Foreign Countries contemporary with Wu), fragments of which have been preserved in encyclopaedias. Thus we find that the Malayan princes of that time used to get horses from the Indo-Scythians (Yueh-chih); and we hear about the ambassador Su Wu sent by Fan Chan, King of Cambodia, about + 250 to a kingdom in India (Thien-Chau), whence he returned escorted by an Indian envoy named Chhen Sung and brought four fine Yueh-chih horses.

We also learn about the earlier arrival in Cambodia (Fu-Nan) of the Hindu cultural missionary Kaundinya (Hun-Thien) who married a naga princess and founded a dynasty. Another lost book of Khang Thai's, his Fu-Nan Chuan, told of a Chinese merchant Chia Hsiang-Li who traded all the way to and from India, and once on his way back recounted to Fan Chan at length the evidence of mast and rig that has gone, but the general resemblance with a traditional Chinese ship of a few years ago being worked upstream can be glimpsed from Fig. 966 (pl.).
customs of that populous country and the success of Buddhism there. All these people travelled in: To the Chinese, for whom the building of sharp-ended boats with stern and stern posts was only a commemorative ritual act, Khang Thai brought knowledge of such craft in full use.

In the kingdom of Fu-Nan they cut down trees for the making of boats. The long ones measure 12 fathoms in length (about 70 ft.) and their breadth is 6 ft. The stem and the stern resemble (the head and tail of) a fish, and they are decorated all over with ornaments of iron. The large (boats) can carry a hundred men. Each man has a long oar, a short oar (i.e. a paddle), and a pole for quanting. From stem to stern there are 50 men, or more than 40, according to the boat's size. In full motion they use the long oars; when they sit down (to row) they use the paddles; and when the water is shallow they quant with the poles. They all raise (their oars) and respond to the shouts in perfect unison.

Such boats have obvious relation with Chinese dragon-boats (p. 436). They continued in use in south-east Asia for centuries. The bas-reliefs of the Banteai-Chmar, and the Bayon of Angkor Thom itself (probably commemorating the victories of the Khmers over the Chams from +1177 onwards), which have been described by Parmentier (1) and P. Paris (2), show similar large canoes with about 20 rowers and steered by quarter-paddles. They have some resemblance to the broader-beamed Viking longships, and with their warriors on an upper deck might be larger versions of the Warring States and Early Han war-boats. Their relation to the Tien and Dongson war-boats is also fairly clear. All this throws into bright relief the enormous progress in shipbuilding made by the Chinese during the +1st millennium.

Chou Ta-Kuan gave a further description of Khmer shipbuilding in +1207. Speaking of Cambodia he said:

The great boats are made of hard wood. The carpenters have no saws and work with hatchets, so that it takes much wood and much trouble to produce a single plank. Knives are also used, even in house-building. For the boats they use iron nails, and cover them (i.e. roof them) with chiao leaves, held in place by strips from the pandan (palm) trees. Such a boat is called a haiia-nuat and is rowed. For caulking they use fish oil and lime. Small boats are made of great hollowed out trees in the form of a scoop (tshiao) softened by fire and water, and enlarged by ribs, so that they are broad in the centre and pointed at the ends. They have no sail (pleng), but can carry several persons, and they row them. These are called phet-lan boats.

His description of the dugout and ribs indicates that these were things unfamiliar to the Chinese of his time.

In the south-eastern districts there are no places lacking means of communication by water. Therefore merchandise is mostly transported by boat. Every year the Transport Commissioners move two million piculs of rice (about 141,000 tons) to Kuan-chung (i.e. the capital in Shen-hsi), through the Chu Chi Canal to the Yellow River. The boatmen of Huainan, however, cannot navigate upon (lit. enter) the Yellow River. The most dangerous places (of the different provinces) are the Three (Yangtze) Gorges in Szechuan, the San-men (rocks) in Shen-hsi, the O-Chhi river in Fukien and Kuangtung, and the Kan-shih rapids at Nan-kang. At all these places the local people do the work (as pilots). . . .

On the Yangtze and the Chhien-thang Rivers they set sail according to the two tides, and Chiangpei is the place where shipping flourishes most.

Sails are plaited from rushes (phat), and the largest of them exceeds 80 sections (fu). From Pai-sha (White Sands) the ships go upstream when they have a north-east wind; this is called the haiia-feng (reliable seasonal wind). In the seventh and eighth months there is the

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1 Shui Ching Chu, ch. 1, p. 94, tr. Petech (1), p. 40; Pelliot (16), p. 277. 2 TPYL, ch. 75a, p. 55; parallel passage, condensed, in Nan Chi Ssu, ch. 58, p. 13a. Tr. Pelliot (19), eng. auct. 3 This probably refers to the iron clamps joining the strakes together.

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1 Bonhote (1), vol. II, p. 72. 2 TPYL, ch. 75a, p. 55; parallel passage, condensed, in Nan Chi Ssu, ch. 58, p. 13a. Tr. Pelliot (19), eng. auct.

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1 Doubtless chiao-chang, i.e. kajang, Malaysian matting made from Pandanus spp. (the screw-pines, pandans). 2 Areta Catusca, the betel-nut palm (R.719). Cf. Fig. 990. 3 Cf. p. 388.
'Upper reliable (seasonal wind)'; in the third they rely on (migrating) birds, and in the fifth they look for (the wind on the wheat). 'Cataapult clouds' presage storm.'

The sailors worship Pho-Kuan (Goddess of Wind and Wave) with sacrifices, and ask the monks to pray for them.

The sailors have a saying: 'Water won't carry 10,000'—this means that the largest ships cannot exceed a load of 8,000 to 9,000 piculs (i.e. 562 to 615 tons).\(^1\)

In the Ta-Li and Chien-Yuan reign-periods (+766 to +779 and +785 to +804) there were the (large) ships of the Ta-Niang.\(^1\) 'The crews of these ships lived on board, they were born, married and died there. The ships had, as it were, lanes (between the dwellings), and even gardens (on board). Each had several hundred sailors. South to Chiangi and north to


This statement is important. As will be seen below (p. 466), Marco Polo, in the +13th century, described river junks ranging in cargo burthens from 224 to 674 tons. Those engaged in the +13th-century grain-transport on the Grand Canal, according to Sung Ying-Hsing (p. 412 above), were smaller, having average loadings of between 140 to 210 tons. The figure for the Thang ships preserved by Wang Tang compels attention, for if we are to accept it they were remarkably large for their time. As is well known, the interpretation of all ancient and medieval tonnage figures bristles with difficulties (cf. Gibson 2; Clowes 2; Lyman 1; P. Gille 3; Brudel 1, p. 249 ff. etc.). 'Tuns burthen' and 'tuns and tunnage' were terms which arose from the Bordeaux wine trade in the +13th century, the former having reference to the number of tuns or barrels which the vessel could carry, and the latter including also the empty spaces between the barrels. For some Chinese parallels of these puzzles see cf. Vol. 3, p. 124 ff. above, in the mathematics section. One ton was reckoned as being equivalent to 60 cuf. ft. or 2,000 lb. We must presumably regard the figures of Wang Tang, Marco Polo, and Sung Ying-Hsing as analogous to 'tuns and tunnage'. The trouble is that in old statements the way of calculating tonnage was not always defined. Confusion with modern definitions of tonnage may arise if it is not understood that the practice of giving the weights of ships in terms of the weight of water displaced ('displacement tonnage' if without cargo; 'deadweight tonnage' if with goods) grew up only after the middle of the nineteenth century. The most suitable unit for comparison with modern figures is perhaps the 'gross tonnage', i.e. the weight calculated from the cubic capacity of all enclosed spaces on the ship at the rate of 100 cuf. ft. to the ton. But such comparisons are difficult because of the space occupied by the engines, boilers, etc. 'Net or registered tonnage' by a percentage reduction.

A ship of 200 'tuns and tunnage' burthen was exceptionally large in +14th-century Europe (cf. Clowes 2, pp. 56 ff., Gibson 3, p. 110). In the following century Prince Henry's famous caravelas redondas reached the larger figure (da Fonseca 1). None of Vasco da Gama's ships exceeded 300 tons and some were much less (Presteige; 1) and for the Santa Maria of Columbus 280 tons is an acceptable figure (Brudel 1). Yet in the middle of the +15th century Chinese junks of 800 'tuns and tunnage' are mentioned, and by the middle of the +16th century the figures are between 1,200 and 1,600. These sizes were about the same as those of the largest Venetian carracks of the +15th century (Lane 1, p. 47, 105, 246 ff.). The average size of the ships of the Spanish Armada of +1588 was still only about 328 tons. 'Tun of tunnage', a term sometimes used for 'tuns and tunnage', is against an average of about 771 in the English fleet (Charnock 1, vol. 2, pp. 11, 66). Only seven out of 132 Spanish ships were over 1,000 tons burthen. In +1602 the largest ship in the English navy was the 995 tons. It is probable that junks of about +14th-century China were larger than those of Europe.

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+838 and +847), there were numerous Japanese embassies, and a great deal of commercial activity went on. One of the most colourful figures of the time was the Korean Chang Pogo, a great shipowner and merchant prince. Having laid the basis of his fortune as an official in China, he returned to Korea in +828 and settled on Wando Island, at the south-western tip of the peninsula, a strategic control point for the Sino-Japanese sea traffic. But later he became involved in the politics of the Silla Kingdom, first as Commissioner of Chhônghajin to suppress a slave trade in Korean peasants, and eventually as king-maker victorious over an usurping pretender. He died by political assassination in +841, after which his maritime commercial network collapsed. His career typifies the importance of the Koreans in the sea trade between the three countries in the +9th century. Unfortunately we have not found any pictorial evidence which would allow us to form an idea of the nature of Chang Pogo’s ships, but there are valuable representations from other Asian regions which have a bearing on the vessels of the Thang time.

Much interest attaches to the ship represented upon the painted walls of one of the Ajanta caves (Fig. 967). It is reproduced in colour by Yazdani & Binyon. If Hadi Hasan (3) is right, it may be identified with a ship bringing Persian ambassadors to the court of Pulakeśin II of the Deccan, just before +628, and the painting would not be

* Emin tells us a good deal about nautical matters. We have noted one of his pieces of information already (p. 308), and shall find more important ones below (pp. 355, 619, 643).
* An account of Chang Pogo’s life and work has been given by Reischauer (2), p. 100 and (3), pp. 287 ff. The primary source for it is the +720th-century Korean chronicle, Songguk Sagí, chs. 10, 11, and 44. On Korean naval history in general see Anon. (69).
* Cave no. 2. Vol. 2, pl. 42. Moll (1), a, 11, o, 12, reproduces a version which wrongly shows four masts.

Fig. 967. The Ajanta ship, a tracing from the reproduction of Yazdani & Binyon (1). The fresco painting is dated in the +6th or +7th century.

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Less confusing, but still apparently not quite characteristic of their culture, are the beautiful paintings of small sailing-boats preserved in the complementary Chinese frescoes of the cave-temples at Tunhuang in Kansu province (Mo-kao-khu or Chhien-fo-tung). There are a good many of these little ships and they occur in all kinds of contexts. For example, the vessel in Fig. 968 (pl.) is obviously the Buddhist Ship of Faith; it is being seen off from the shores of this world by rampaging devils, and its destination is certainly the Western paradise of Amídá Buddha which is visible in the background. The square-ended bow and stern of this early Thang (+7th-century) ship are indeed very Chinese, with a characteristic aft prolongation of the uppermost longitudinal timbers. But here the Chinese elements end—except for the bee-hive hut of straw which someone thought would be the right thing for a deck-house. The bellying square-sail is exceedingly un-Chinese, though suitable for a boat of the Ganges, and the latter would also have arrangements for working the quarter steering-paddles
closely similar to those which the painter drew here at Tunhuang. The resemblance can be seen by comparing this picture with Smyth's sketch (1) of a *malar panchi* (Fig. 969). Perhaps the monastic artist, who had quite possibly journeyed overland from India and never seen either the sea or the great rivers of China, was remembering the ships of Bengal rather than depicting those of Chinadhan. 

All the representations of ships at Tunhuang follow this same pattern. Another large sailing-boat is found in cave no. 45, painted in the 5th or 6th century but rather less well preserved; it closely resembles the one just described save that the mast and sail, stepped almost equally far forward, and bellying almost equally markedly, are in better proportion. The box-built hull with its projecting upper strakes also appears well in another painting of the early Tang period (2) which tells the legend of the arrival of a ferry-boat carrying Buddhist images belonging to the great Indian king Asoka. The bellying elongated square-sails of his country are seen even on the small sampans which the Tunhuang artists of the Tang and Sung included in many of their frescoes. But the most seamanlike of the Buddhist ships is not at Chhien-fo-tung at all, but in a very un-Chinese way) to the neighbourhood of +600 or +610. Perhaps the monastic artist, who had quite possibly journeyed overland from India and never seen either the sea or the great rivers of China, was remembering the ships of Bengal rather than depicting those of Chinadhan.

![Fig. 969. The *malar panchi* of Bengal, a drawing by Smyth (1), for comparison with the ships in Figs. 961 and 968 (p.1). The sheets of the square-sails are echoed clearly in the Tunhuang ship fresco.](image)

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A broad-beamed ship with a single mast, secured (in a very un-Chinese way) in frontispiece, and redrawn by Mrs Nan-ho Tam in 1964; we thank Dr Ellen E. Helm (1), p. 46. The second, heading in the Kyoto mirror the bellying narrow square-sail carries an inscription (same unreadable, Inspector of Thien-ching city in Fonghsing prefecture'). In the Kyoto mirror the foot of the sail has come adrift and it streaming out horizontally in the wind. One gains the impression that these mirrors rehearse the dangers safely overpassed by the Inspector either as a Buddhist monk or as an Imperial envoy. As for the date, the Sien museum assigns it (no doubt for sound artistic and historical reasons) to the neighbourhood of +1150 in the Sung, but if the history of technology can have anything to say, a date in Wu Tai or late Thang, c. +920, would be much preferable. Perhaps a Sung craftsman was being consciously archaic. The Kyoto scholars, on the other hand, regard their mirror as Korean, and place it in the Kori period, i.e. before +668; this seems rather too early.

According to Krom & van Erp (1), who have published the collection of photographs of the bas-reliefs, the best is Krom (in Krom & van Erp (1), no. 137; Taki Seiichi, Naiti Torajiro & Hamada Koei (1), no. 217, entry 132. A broad-beamed ship with a single mast, secured (in a very un-Chinese way) to the neighbourhood of +1150 in the Sung, but if the history of technology can have anything to say, a date in Wu Tai or late Thang, c. +920, would be much preferable. Perhaps a Sung craftsman was being consciously archaic. The Kyoto scholars, on the other hand, regard their mirror as Korean, and place it in the Kori period, i.e. before +668; this seems rather too early.

![Fig. 970. A drawing by Smyth (1), for comparison with the ships in Figs. 961 and 968 (p.1). The sheets of the square-sails are echoed clearly in the Tunhuang ship fresco.](image)
purely Indonesian in nature,* recalling the vessels with which the colonisation of Madagascar must have been completed. Nevertheless it is worth close examination. The hull is probably sewn, not nailed, as is suggested by its panelled appearance; the stem- and stern-posts are much emphasised. To the hull are attached large and complex outriggers upon which the crew could climb, to aid stability, if required. The masts, two of which are fitted in each ship, are drawn (at any rate in some cases) as bipod or tripod in form. They carry very elongated canted square-sails of the characteristic Indonesian type—important because canting was in all probability, as we shall see, the earliest device in the development of fore-and-aft sailing. From the ship with the furled sails we can deduce that some method of roller-reefing was used. Yet the sails belly considerably when set, so P. Paris (1) can hardly be right in believing that they were of matting. In every case a small artemon in Roman style is mounted.

But these are not the only craft pictured at Borobudur. A radically different type intrudes.1 It is shown but once, with a rather numerous crew, and it has no similarity at all to the others. There is no outrigger and no panelling, the stern-post is not emphasised but thwart timbers are prominent, there is only one mast consisting of a bipod or tripod in form. They carry very elongated canted square-sails of the characteristic Indonesian type—important because canting was in all probability, as we shall see, the earliest device in the development of fore-and-aft sailing. From the ship with the furled sails we can deduce that some method of roller-reefing was used. Yet the sails belly considerably when set, so P. Paris (1) can hardly be right in believing that they were of matting. In every case a small artemon in Roman style is mounted.

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main Borobodur type (Fig. 973, pl.). But a south-east Asian sewn hull seems to have co-existed here with Chinese bulkheads. As for the sails, we reserve for the appropriate main Borobodur type (Fig. 973, pl.). Which in what now baffled all commentators. For the word kolindrophonta, applied to the large ocean-going ships of South-east Asia, turns out to be nothing else than a corrupted Greek form of Khun-lun po.

(2) From the Thang to the Yuan

Specific research would certainly deserve much of interest for nautical technology between the + 8th and the + 12th centuries, but as yet only a few notes can be given. Our oldest elaborate descriptions of warships come from just before + 800. Our oldest elaborate descriptions of warships come from just before + 800. Yiin,2 has come down to us. In + 1057 one of his chief shipwrights, Fan Chih-Ku,4 has come down to us. In + 1057 our oldest elaborate descriptions of warships come from just before + 800. Yiin,2 has come down to us. In + 1057 one of his chief shipwrights, Fan Chih-Ku,4 has come down to us. In + 1057 our oldest elaborate descriptions of warships come from just before + 800. Yiin,2 has come down to us. In + 1057 one of his chief shipwrights, Fan Chih-Ku,4 has come down to us. In + 1057 our oldest elaborate descriptions of warships come from just before + 800. Yiin,2 has come down to us. In + 1057 one of his chief shipwrights, Fan Chih-Ku,4 has come down to us. In + 1057 our oldest elaborate descriptions of warships come from just before + 800. Yiin,2 has come down to us. In + 1057 one of his chief shipwrights, Fan Chih-Ku,4 has come down to us.

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1. Yiin
2. Yiin
3. Yiin
4. Yiin
abou t + 1 08 6 on wards. We have already quoted his words (part of the same passage) on the use of the magnetic compass in navigation (Vol. 4, pt. 1, p. 279 above). This is what he says:  

The Pavilion of the Inspector of Foreign Trade (Shih-Po) is by the waterside near the Hai-Shan Tower, facing the Five Islands. Below this, the river is called the 'Little Sea'. In midstream for some ten feet or so the merchant-ships (po chkun)  

take on water for use on their journeys; this water does not spoil, but water from outside this limit, and all ordinary well-water, cannot be stored (on board ship), for after a time it breeds worms. What the principle is underlying this I do not know.  

Ship s sail in the eleventh or twelfth months to avail themselves of the north wind (the north-east monsoon), and return in the fifth or sixth months using the south wind (the south-west monsoon). The ships are built squarely like rectangular wooden grain-measures (hui). If there is no wind, they cannot move. Their masts (chhieng) are firmly stepped, and the sails are hoisted beside them. One side of the sail is close to the mast, (around which it moves) like a door on its hinges. The sails (fan) are made of matting (hui). These ships are called chia-thu—a local expression.  

At sea they can use not only a wind from abaft, but winds from onshore or offshore can also be used. It is only a wind (directly) contrary (ni) which can not be used. This is called 'using the winds of the three directions' (shih sian mien feng). When the wind is dead ahead they cast anchor and stop.  

According to the government regulations for sea-going ships, the larger ones can carry several hundred men, and the smaller ones may have more than a hundred on board. Sea-going ships are several tens of fathoms in breadth and depth. The greater part of the cargo consists of pottery, the small pieces packed in the larger, till there is not a crevice left.  

At sea (the mariners) are not afraid of wind and waves, but of running aground, for if this happens there is no way of getting off again. If the ship suddenly springs a leak, they cannot mend it from inside, but they order their foreign blackamoor slaves (hui ni) to take chincas and oakum (hui) and mend it from outside, for these men are expert swimmers and do not close their eyes when under water.  

Vol. 4, pt. 1, p. 380. We shall quote this later on (pp. 602 and 604) with regard to sails and to the stern-post rudder. Some of the pages of this interesting book which concern shipping have been translated by Faiz (1), but he went astray on several technical points. He also (p. 92) interpreted 'the Court' as meaning the Korean Court, implying that the large ships of the Chinese ambassador (cf. pp. 430, 456 above) were Korean ships, though the text says that the governors of Fukien and the two Chekiang provinces had been responsible for their building.

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1. This passage, the literary counterpart of the Bayon junk, is of much interest. For the end of the + 11th and the beginning of the + 12th century it attests the bulkhead build, the fore- and aft lug (not in Western Europe until c. +1500), the use of taut mast-sails and beating to windward. So also do other books of the same period, such as the Kao-Li Thu Ching of + 1124 (Illustrated Record of an Embassy to Korea) already mentioned.  

II. It is fortunate, too, that we have a document of high importance relating to the river-ships of China, almost contemporary with the description of Chu Yu. This is the painting entitled Ching-Ming Shang Ho Thu, 'Going up the River to the Capital at the Spring Festival', by Chang Tsê-Tuan, made a little before + 1126, when Khaifeng, the capital in question, fell to the Chin Tartars. Some relevant parts of it, depicting the vessels in the river, are shown in Fig. 976 (pl). The detail of the painting is drawn with meticulous care, almost as if the artist had thought kindly of future historians of technology. One ship is shown lowering its bipod mast before passing under the great bridge; others are loading and unloading along the banks or being tracked upstream. The junks are broadly speaking of two different types, freighters with narrow sterns, and passenger-boats and smaller craft with broad ones, but both are provided with large and prominent slung rudders. These are all balanced—a remarkably advanced piece of technique which will be discussed later. Large stern-sweeps and bow-sweeps are in use on two or three of the boats, some worked by as many as eight men.

The history of Chang Tsê-Tuan's great work has been much discussed by scholars; so famous was it that at least one Yuan emperor wrote a poem on his copy. The oldest existing copy of the painting (that reproduced, Figs. 826, 923, 976, 1054, pl.) has been published by Chêng Chen-To (3). Conserved in the Imperial Palace Museum, its silk is recognisably Sung, and among its MS. colophons it bears an inscription by a scholar of the Jurchen Chin which is dated + 1186, i.e. just sixty years after the completion of the picture-scroll. Scholars consider therefore that this is almost certainly the original.
painting. In any case we can accept it with perfect confidence as a testimony of the techniques of +12th-century shipping. The second oldest colophon, by another Chin scholar c. +1190, took the form of a poem, worth reproducing here:

Through the streets carts and horses are rumbling and thronging—
We are back in a year of the Hsiian-Ho reign-period.

One day a Han-Lin scholar presented this painting,
Worthy of handing down the ways and works of a peaceful time.

Going east from the Water-gate one comes to the Canal of the Sui,
The streets and the fields are alike incomparable
(But Lao Tzu formerly warned against prosperity
And today we know it has all become waste-land).

Yet the vessels that sail thousand & thousand on their voyages
With rudders of timber from Chhu and their masts from Wu,
Fine scenery north of the bridge and south of the bridge,
Recall for a time the dream of halcyon days,
One can hear the flutes and drums; the towers seem close at hand.a

Some decades later (+1178) we have Chou Chhü-Fei1 writing on the sea-going ships of the south again.b

The ships which sail the southern sea and south like houses. When their sails are spread they are like great clouds in the sky. Their rudders (66) are several tens of feet long. A single ship carries several hundred men, and has in the stores a year's supply of grain. Figs are red and wine fermented on board. There is no account of dead or living, no going back to forget all dangers. To those on board everything is a matter of precise calculation. 'To make such and such a voyage, with a favourable wind, in so many days, we should sight such and such a mountain, (then) the ship must steer in such and such a direction'. But suddenly the wind may fall, and case, bearings may have to be changed. And the ship (on the other hand) may be carried far beyond (the landmark) and may lose its bearings. A gale may spring up, the ship may be broken to the very roofs (of its deckhouses). A great ship with heavy cargo has nothing to fear from high seas, but rather in shallow water it will come to grief.c

This gives us relatively little technical information, and most other passages have the same defect. In all his discussion of foreign countries and their exports to China, Chao Ju-Kua,1 for example, about +1225, has little to say concerning the technical aspects of the scene would make the previous reign-period, c. +1210 to +1215, a better guess, and there may be other explanations, such as the painter's youth, or his political sympathies, for the exclusion of the painting from the catalogue.

a Tr. Whitfield (I), mod. auct.
b Ling Wu Tai Tu* (Information on what is Beyond the Fasses), ch. 6, p. 78; tr. Hirth & Rockhill mod. auct.
c Cf. Fig. 95b on p. 481.
d Excellent statement of a truth about early sailing too often unappreciated by landsmen obsessed with the illusionary safety of "coasting voyages".

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The ancient history of this has already concerned us (pp. 356, 374 above) in relation to the origins of lock-gates. The second orthodox caliph, +644), to the Nile was re-opened in the +7th century. Cf. Casson (7).
mixed with oakum, instead of pitch, for caulking. These ships had but one mast, one deck, and one rudder. By contrast, his admiration for the Chinese ships, of all kinds, was unbounded. He described the wealth of the cities of Yangiu and Siigiu (Yangchow and Chhuchow) with the 'marvellous great shipping' that frequented them. Of the Yangzte he said that 'more dear things, and of greater value, go and come by this river, than by all the ports in the world.' The boards of the ship, inside and outside, are thus fitted together, that is, they are, in the common speech of our sailors, caulked both outside and inside, and they are well nailed and put away every time they wish, with two sails, according to the state of the weather. Moreover, the boards of the ship, inside and outside, are thus fitted together, that is, in the common speech of our sailors, caulked both outside and inside, and they are well nailed and put away every time they wish, with two sails, according to the state of the weather.

They are indeed nailed in such a way; for they are all lined, that is, that they have two boards above the other. But I tell you that they have the hawsers, or to speak plainly, tow-lines, of nothing else but of canes, with which the ships are towed upstream by this river. You may know that these ships which go on this river, those which go against the current of the water, are towed because the current of water is strong, otherwise they could not go. And you understand that these canes are the thick and long canes of which I have told you, which are quite 15 paces long. They take these canes and split them from one end to the other into many thin strips, and bind them the one with the other, and make them ropes as long as they wish, and then fasten them to the ships like tow-rods, and with this thing they smear their ships and make them ropes as long as they wish, with two sails, according to the state of the weather.

Marco Polo was chiefly impressed, therefore, by the high freight capacity of the river-junks, and by the cables made of bamboo, as they still are today.

His account of the sea-going junks written in connection with his description of Zayton (Chihlianchow in Fukien) is of great interest, and we must give it in full.

Trajan, having been carrying traffic till the end of the +6th. The object was the relief of a famine in the +7th, and this was successfully accomplished. After the time of 'Umar II (r. +717 to +720) the canal silted up again with blown sand, and about +761 the caliph 'Abd al-Mansür ordered it to be closed and filled in for an exactly opposite reason, the denial of supplies to the 'Alid (Shi'ah) leader Muhammad at Medina. Though it never regained any importance, the existence of such a waterway long before the building of the Suez Canal must always be borne in mind in considering east-west exchanges in maritime matters (cf. p. 664 below).

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As to this question, see above, pp. 191, 415, and below, p. 664.

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2. If the quintal be taken as about equivalent to the hundredweight, the two figures given would amount to 224 tons and 672 tons respectively.
3. He means that many cables were made of bamboo, which he calls 'canes'.
4. The Italian pace was very variable, but ranged around a value of about 5 ft., like the Chinese double-pace.
5. As to this question, see above, pp. 191, 415, and below, p. 664. 6. Ch. 147.
7. 1. Ch. 147. 2. It is ch. 138, Moule & Pelliot ed.; Penzer ed. p. 314. Cf. Beazley (1), vol. 3, pp. 126 ff. Some writers, such as Mukerji, have believed that the description applied to contemporary Indian ships, but this was misread by Marco Polo's loose use of the word 'Indies'. In his time, China was part of the 'Further Indies'. The description, moreover, is full of characteristics which, upon other evidence, we know to be distinctively Chinese. This mistake was disposed of by Hornell (177), p. 203.

29. NAUTICAL HISTORY

We shall begin first of all to tell about the great ships in which the merchants go and come into Indi through the Indian sea. Now you may know that those ships are made in such a way as I shall describe unto you.

I tell you that they are mostly built of the wood which is called fir or pine. They have one floor, which with us is called a deck, one for each, and on this deck there are commonly in all the greater number quite 60 little rooms or cabins, and in some, more, and in some, fewer, according as the ships are larger and smaller, where, in each, a merchant can stay comfortably. They have one good sweep or helm, which in the vulgar tongue is called a rudder.

And four masts and four sails, and they often add to them two masts more, which are raised and put away every time they wish, with two sails, according to the state of the weather.

Some ships, namely those which are larger, have besides quite 13 holds, that is, divisions, on the inside, made with strong planks fitted together, so that if by accident that the ship is stayed in any place, namely that either it strikes on a rock, or a whale-fish striking against it in search of food staves it in... And then the water entering through the hole runs to the bilge, which never remains occupied with any things. And then the sailors find out where the ship is stayed, and then the hold which answers to the break is emptied into others, for the water cannot pass from one hold to another, so strongly are they shut in; and then they repair the ship there, and put back there the goods which had been taken out.

They are indeed nailed in such a way; for they are all lined, that is, that they have two boards above the other. And the boards of the ship, inside and outside, are thus fitted together, that is, in the common speech of our sailors, caulked both outside and inside, and they are well nailed and put away every time they wish, with two sails, according to the state of the weather. Moreover, the boards of the ship, inside and outside, are thus fitted together, that is, they are, in the common speech of our sailors, caulked both outside and inside, and they are well nailed and put away every time they wish, with two sails, according to the state of the weather.

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ship would prevent the wind from catching the sails of the smaller, and so the larger would
take 2 or 3 of these large tenders, but the one is larger than the other. And of small ships which we call boats, also they take 10, to anchor and to catch
fish and to wait upon the large ship in many other ways. And the ship carries all these boats
through the water lashed to her sides outside, and when necessary they put them in the water,
but they tow the two large ones astern, which each have their marines and their sails and all
that is needed for themselves and for them. And again I tell you that the said two large tenders
carry small boats.

Moreover I tell you again that when the great ships wish to be decorated, that is, to be
repaired, and it has made a great voyage or has sailed a whole year or more and needs repair,
repair it in such a way. For they nail yet another board over the aforesaid original two all
round the ship, without removing the former at all, and then there are three of them over the
whole ship everywhere, the one nailed above the other, and then, when it is nailed, they also
caulk and oil it with the foressaid mixture, and this is the repair which they do. And at the end
of the second year, at the second repair, they nail yet another board, leaving the other boards,
so that there are four. And in this way they go each year from repair to repair up to the number
of six boards, the one nailed upon the other. And when they have six boards the one upon the
other nailed, then the ship is condemned and they sail no more in her on too high seas but in
near journeys and good weather, and they do not overload them; until it seems to them that
they are no more of any value, and that one can make no more use of them. Then they dis-
mantle and break them up.

For +13th-century junks, then, Marco Polo attests cabins (naturally the first thing a
travelling merchant would notice), rudder (this had already been in use for eighty
years or so in Europe), multiple masts (not yet used in Europe), and bulkhead-built
hull. He makes a particular point of the repair of the ship by the continual overlaying
with new layers of caulked strakes. This system of superimposed timbers (‘doubling’) was
afterwards employed in European warships of the +18th and early +19th centuries. The traveller duly mentions the use of tung-oil and lime (chunam), and
significantly exclaims at the size and tonnage of the ships, which he thought remarkable.
The oars rowed by four men each may well have been yulohs, though the description leaves it uncertain. As for sailing, it would appear that for some reason
or other the smaller ships could sail better to windward than the larger ones, so that under such circumstances towing by the smaller tenders was resorted to. Marco Polo
seems unduly astonished at the accompanying of the great ship by so many smaller
boats, pinnaces and dinghies as we should say, and one can only suppose that such
arrangements were uncommon in the Mediterranean of his day.

When Marco Polo left China in +1292 (it must have been a hard parting for him,
after seventeen years, even though he was going as imperial envoy-ordinary in
The vessels have four decks, upon which there are cabins and saloons for merchants. Several of these ‘mersiya’ contain cupboards and other conveniences; they have doors which can be locked, and keys for their occupiers. (The merchants) take with them their wives and concubines. It often happens that a man can be in his cabin without others on board realising it, and they do not see him until the vessel has arrived in some port.

The sailors also have their children in such cabins; and (in some parts of the ship) they sow garden herbs, vegetables, and ginger in wooden tubs.

The Commander of such a vessel is a great Emir; when he lands, the archers and the Ethiopians march before him bearing javelins and swords, with drums beating and trumpets blowing. When he arrives at the guesthouse where he is to stay, they set up their lances on each side of the gate, and mount guard throughout his visit.

Among the inhabitants of China there are those who own numerous ships, on which they send their agents to foreign places. For nowhere in the world are there to be found people richer than the Chinese.

Ibn Battutah had had his experiences with these ships. At an Indian port the unfortunate man embarked, with a number of his concubines, on a junk, but all the suitable cabins had been reserved by Chinese merchants, so the party transferred to a kaham; then before he himself went on board, the junk with the presents for the emperor sailed out into a storm and was lost with all hands. The captain of the kaham then also left without him, and he never recovered any of the girls or his valuable merchandise. And on the way home he experienced a tempest and escaped a ‘rukah’.

The Moor confirms the Venetian in a number of particulars, such as the cabins, the multiple masts, and the bulkheads, concerning which he speaks as if he had himself visited the Cantonese shipwrights’ yards. He was also impressed by the number of subsidiary boats. But he complements Marco Polo most usefully. He attests the great mat-and-batten lug-sails, much greater in number than were carried by any European or Arab craft of the time, and their capacity to make use of wind coming from almost any quarter. And he tells us about the huge oars worked by several men, which must have been yulohs, as we see by his development of the subject:

And as they work, these rowers raise good voices in a chanty, generally saying ‘la, la, la’ to stay, they set up their lances on

The rope connections make the identification fairly certain.

* Evidently the pursers were not as efficient as the navigation department.
* This is still the case on thousands of Chinese ships; the captain’s cabin is the family home. So it was on Captain Wu’s Upper Yangtze junk (p. 307 above).
* Cf. the ‘black slaves’ of pp. 459, 462 above. Probably these men-at-arms were Malays in Ibn Battutah’s time.
* Elsewhere he describes the ship-captains’ quarter at Hangchow (Lee (1), p. 219).
* McBride (1) draws attention to this passage, and though the identification has been questioned (Waters, 6), he seems to be right.
* See below, p. 628.

In the meantime, Marco Polo’s information (and that of others less well known) had been spreading in Europe. It is agreed that the famous Catalan world-map of +1375 and the world-map of Fra Mauro Camaldolese of +1459 were based upon this information. Here we are not concerned with the geographical material, but with the small drawings of ships which appear, most fortunately, on both these documents. Tracings of them are given here taken from the edition of Santarem (2).

**Fig. 977. Ships, Chinese and Western, on the Catalan world-map of +1375; tracings from Santarem (a).**

- a one of large Chinese junks in the eastern seas, all fivesailed with stout sails
- b one of three crescents marking all Chinese cities from Zayton to Lop
- c flag flown by the junk-like ship in the Caspian Sea, and over all Russian-Mongolian cities
- d flag of three crescents marking all Chinese cities from Zayton to Lop

The eastern portion of the Catalan map (see Fig. 977) shows in the seas three large vessels which differ from one another only in slight details. They are clearly and

* The Carta Catalana is in the Mazarin Gallery at the Bibliothèque Nationale in Paris (MS. Espagnol 30; cf. Yule (2), vol. 1, pp. 299 ff.; Anon. (47), p. 14). It was drawn for King Charles V of France by Abraham Cresques, the great Jewish cartographer and instrument-maker of Majorca. His son Jafuda Prince Henry the Navigator (cf. p. 503 below). A copy of the map may be seen in the Maritime Museum at Barcelona. Besides Marco Polo, Odoric of Pordenone (cf. Vol. 1, pp. 189 ff.) was another probable source of the Cresques’ information. On the East Asian names on this map are also in Hallberg’s dictionary (1).
* It was drawn for King Charles V of France by Abraham Cresques, the great Jewish cartographer and instrument-maker of Majorca. His son Jafuda Prince Henry the Navigator (cf. p. 503 below). A copy of the map may be seen in the Maritime Museum at Barcelona. Besides Marco Polo, Odoric of Pordenone (cf. Vol. 1, pp. 189 ff.) was another probable source of the Cresques’ information. On the East Asian names on this map are also in Hallberg’s dictionary (1).
* A third map, dating from +1445, in the Estense Library at Modena, has been studied by Kretschmer (1). It is like Fra Mauro’s, but the drawings of the ships are less clear. However, they agree with what Fra Mauro said: ‘Le Nave over zonchi che navigant questo Mar portano quatro albori...’
recognisably junks. They have the transom bow and stern, the rails of a stern-gallery, portholes, and notably as many as five masts, with unmistakable mat- and-batten sails, though their cut and rig was evidently not understood by the draughtsman. He was also vague as to where they ought to be placed in the seas of 'the Indies'. One of them is, reasonably, off Java, a second is off the Rann of Cutch (Gujarat), but the third is in the Caspian. The two former are flying an ensign with a square device, and this is the flag which appears over all the Persian cities; that of the cities of China bears three crescents. The junk in the Caspian flies a flag with an indecipherable sign looking like an attempt at Arabic writing, and this is common to all the Russian (Mongol?) cities. Too much importance should probably not be attached to these confusions, for the build of the junks is not to be mistaken. Fortunately, also, the draughtsman provided posterity with a sketch of a European ship near the Canaries, off the African coast. It resembles the Norman ships of the Bayeux Tapestry, and is evidently descended from the Viking longships; its stem- and stern-posts are well shown, and it has a great bellying square-sail oddly in contrast with the stiff flat sails of the junks.

In the following century the map of Fra Mauro shows similar contrasts (Fig. 978). The western section has several sharp-stemmed ships with square-sails, including one off the coast of Portugal and one in the Baltic. It also shows a curious craft by the north-west corner of Spain which seems to have two fore-and-aft sprit-sails, and in Egyptian waters we see the obliquely set yard of a lateen sail. But in the eastern section there are also numerous ships, and the first thing one notices about them is that they are all considerably larger than the European vessels. They have unmistakable rectangular transom bows, and rudders prominently large; moreover, they have four or more masts. Towering deckhouses are also conspicuous. On the other hand, the Italian draughtsman did not understand the Chinese mat sails even as well as the Catalan, for he gave the junks loose bellying square-sails, nor did he limn them very justly. These are in the Indian Ocean, but far to the north, in the Yellow Sea, we find a smaller ship of the same type, towing behind her one of those tenders or pinnaces

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Fig. 978. Ships, Chinese and Western, on the world-map of Fra Mauro, +1459: tracings from Santarem (a).

a-d vessels shown in European seas
e-g vessels shown in the eastern seas
a a ship off the west coast of Portugal showing marked stem-post, and square-sails on main and (apparently) mizzen masts
b a ship with evident stem-post and curious stern off the north-west cape of Spain, apparently an attempt to represent two spinnakers
c bellying square-sails in the Baltic
d obliquely set yard of a lateen sail off Egypt
e a ship in the Indian Ocean west of Ceylon with four masts, transom bow and prominent rudder
f another of the same kind in a more northerly position, also showing the towering poop superstructures
g a very square-ended junk in the Yellow Sea north of Shantung, towing a boat just as Marco Polo described.
which had so much impressed Marco Polo. And indeed very near the two best junka a small scroll inscription in the middle of the Indian Ocean bears words which obviously derive from him.\(^8\)

The importance of the discovery by Europeans that really large ships with multiple masts had been built and could do useful work has been emphasised by Clowes.\(^1\) Of course there had been two- and three-masted ships in Hellenistic times (\(+1\text{st to } +3\text{rd centuries}\)), for the raking bowsprit called the artemon gradually turned into a foremast, and a small mizen was added aft;\(^6\) but these did not survive the collapse of the Roman Empire. The earliest precisely datable medieval three-masted ship in Europe is found about the same time as the map of Fra Mauro, i.e. in \(+1466\), on the seal of Louis de Bourbon.\(^d\)

It was the introduction of the three-masted ship [says Clowes] with its improved ability to contend with adverse winds,\(^*\) which made possible the great voyages of discovery of the end of the \(+1\text{st century}\), of Columbus to the West Indies, of Vasco da Gama to India, and of the Cabots to Newfoundland; and it is a curious thought that this great development may really have been due to the introduction into Europe of accounts of the multiple-masted Chinese junks which traded so effectively in the Indian Ocean... at any rate, it is a fact that no one has yet been able to explain satisfactorily the cause of the extraordinary and rapid development— in the course of only a hundred and fifty years—of the one-masted vessel of \(+1350\), able only to run before the wind, in the three- or four-masted ship of \(+1500\), similar in all essential principles of rig to the three-masted ship of the \(+17\text{th century}\).

In connection with this we must recall that Chinese sea-going ships reached their apogee in the voyages of discovery under Chêng Ho in the first half of the \(+15\text{th century}\), just in the lifetime of Prince Henry. To this remarkable fact we shall shortly return (p. 487). But who could the intermediaries have been? Presumably Nicolò de Conti (who probably visited South China in \(+1438\)) and other travellers of his time.\(^8\)

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\(^1\) Quoted below, p. 572.

\(^2\) The wording in the following quotation from him has been amended so as to conform with modern knowledge.

\(^3\) One can see them on the Ostia mosaics, and in an Etruscan tomb-painting (Monesti, a). Bowen, pp. 221-25, believes, in view of the dates of Roman-Indian commercial contacts (cf. Vol. 1, pp. 172 ff.), that in this case also the idea of multi-masted rigs was brought west from the Indian Ocean. Conversely, the artemon itself appears both at Ajanta and at Borobudur (Figs. 967, 973, pl. ii).\(^8\)

\(^4\) But there is some evidence that the larger Portuguese caravels had carried three masts as early as \(+1435\) (see da Fonseca, i). Until the time of the death of Prince Henry, laten sails were always used on them; after that, laten sails and square-sails were combined in mixed rigs. Two-masted ships go back in Europe to the \(+13\text{th century}\) (see Lethbridge (i), fig. 531, from the Lapidario of Alfonso X), and they may have derived their foremast from the old Roman artemon (see Lethbridge (i), fig. 530a, from the Pisa campanile, datable at \(+1174\)).

\(^5\) This was the mizenmast given opportunity of using a laten sail, which permitted the ship to sail nearer the wind than was possible with square-sails alone. Or such at least is the opinion of some experts, but others (e.g. Cdr. George Nash, in private communication) believe that the mizen laten made the bigger ships handier in steering, but did not enable them to sail closer to the wind. Adam & Denys, for their part, emphasise the importance of the stern-post rudder in this evolution, (i), p. 193, and regard it as one of the cardinal factors which permitted the adoption of multiple masts by European ships. Cf. p. 577 below.

\(^6\) Cf. another quotation from Clowes on p. 610; and Clowes (2), p. 71.

\(^8\) Between \(+1450\) and \(+1550\) there seems also to have been a great increase in the tonnage of European ships, accompanying the increase in the number of masts. It would be interesting to investigate this trend statistically. Cf. Gibson (3), pp. 110 ff., 121 ff.; and Baratier & Reynaud (i) and Mollat (i), both reviewed in Anon. (44).

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29. NAUTICAL TECHNOLOGY

It is a curious fact that just as the Europeans were struck by the larger size of the Chinese ships, so also the Chinese were (or had been) under the impression that the ships of the Far West were also larger than their own. In \(+1178\) Chou Chih-hui-Fei had written:\(^a\)

Beyond the Ocean west of the Arab countries there are countless countries more, but Mu-Lan-Phii\(^b\) is the only one which is visited by the great ships (chê hiên)\(^c\) of the Arbas. Its ships (chou)\(^d\) are the biggest of all. Putting to sea from Tho-phan-ti\(^e\) in the Arabic country one sails due west for an hundred days and so arrives. A single ship carries a thousand men; on board there are stores of wine and provisions, looms and shuttles (for weaving), and a marketplace. If it does not encounter favourable winds it does not get back to port for years. No ship but a very big one could make such voyages. So nowadays the term 'Mu-Lan' ship is used (in China) for designating the largest kind of junk. If one speaks of big ships, there are none as large as those of Mu-Lan-Phii.

And all this was repeated by Chao Ju-Kua in \(+1225\).\(^b\) But there was a seemingly legendary element here, for the accounts go on to mention grains of wheat three inches long, melons six feet around, and sheep the fat of which could be harvested from time to time by surgical operation. It seems that people at both ends of the Old World thought that the other end had the largest ships, but objectively the Europeans were right in this opinion while the Chinese seem to have been wrong.\(^c\)

Or were they? There may be more than meets the eye in the story of Mu-Lan-Phii. The usual identification of the place accepted by sinologists has been Spain, the name deriving from the Almoravid dynasty (\(+1061\) to \(+1147\)) of the al-Murabitun. But the botanist Li Hui-Lin (i), perceiving that the time of 100 days seems impossibly long for an east-west Mediterranean transit,\(^d\) suggests that in fact the journey was a transatlantic crossing, and that the strangeness of the plants and animals described may conceal typical of the Americas.\(^e\) If one follows him in taking the descriptions seriously, the huge cereal grains which keep so long in storage must be maize, the melons could be Cucurbita pepo, which can weigh as much as 240 lb., the unheard-of fruits could be the pineapple and the avocado, while the tall 'sheep' might perhaps be llamas and alpacas. Li Hui-Lin associates the idea of Arab transatlantic navigations with an old story reported by al-Idrisi that in the \(+11\text{th century}\) some Spanish Muslim sailors set out westwards from Lisbon but were never seen again.\(^f\) The greatest difficulties in accepting Li's suggestion arise, however, on the nautical side, for everything that we know of the same ships of Arabic culture (cf. pp. 388, 465) precludes us from believing that they could ever have been built stoutly enough to withstand a return transatlantic

\(^a\) Ling Wai Tai To, ch. 3, p. 49, and ch. 6, p. 84; tr. Hirth & Rockhill (i), pp. 34, 149; mod. auct.

\(^b\) Chi Fan Chih, ch. 1, p. 50. With embroideries, e.g. 'several thousand men'.

\(^c\) Cf. Parkinson (i), p. 321: 'Europeans first arrived in the \(+16\text{th century}\) in crank and leaky ships, vastly inferior to the Chinese junks, and a great deal smaller.'

\(^d\) He identifies Tho-phan-ti as Dinmyt (Damieta, on the shore of the Nile delta). But, on his theory, the name Mu-Lan-Phii is indefinable.

\(^e\) Presently (pp. 546 ff. below) we shall have more to say about pre-Columbian contacts with the American continent.

\(^f\) Deby & de Goeje (i). Cf. pp. 503, 511.
crossing. Moreover, in order to get back to Europe the Muslim sailors would have had to discover the régime of winds and currents in the Atlantic which was laid bare five centuries later by the Portuguese, and we have no evidence whatever that they did so. For the present, then, we may retain the view that Chou Chhi-Fei and Chao Ju-Kua were talking about the Mediterranean, not the Atlantic, and the ships, large perhaps but slow, which sailed therein.

Probably none of the travellers in Sung and Yuan China had sufficient historical perspective to realise that in the Southern Sung a great event had occurred, the creation of the Chinese navy. The development of the maritime south had been a sociological consequence of the wars, invasions and political unrest, even of the climatic changes, in the north, which drove down masses of the population to the Fú and Kúang coastal provinces with their innumerable rivers, fjords, creeks and havens. Since agriculture supported the people less readily here, the regular striking force could be supported at need by substantial merchantmen; thus in the campaign of 1161 some 340 ships of this kind participated in the battles on the Yangtze. The age was one of continual innovation; in 1192 trebuchets throwing gunpowder bombs were decreed standard equipment on all warships, between 1173 and 1183 a great number of treadmill-operated paddle-wheel craft, large and small, were built, including stern-wheelers and ships with as many as 11 paddle-wheels a side (the invention of a remarkable engineer Kao Hsuan), and in 1203 some of these were armoured with iron plates (to the design of another famous engineer, Chinh Shih-Pu). In Kao Taung’s time, about +1210, China was sea-minded as never before, unless indeed one might say that the ancient spirit of Wu and Yuèh had now come into its own, so that a typical Nan Sung scholar such as Mo Chi, the

Director of the Imperial University, used to go out sailing when free from office, and compiled his crews to follow him far to the north. In sum, the navy of the Southern Sung held off the Chin Tartars and then the Mongols for nearly two centuries, gaining complete control of the East China Sea. Its successor, the navy of the Yuan, was to control the South China Sea also—and that of the Ming the Indian Ocean itself.

(3) From the Yuan to the Ching

Under the Mongol rule in the Yuan dynasty naval operations were particularly prominent. First, owing to the nature of the country, the reduction of the resistance of Sung forces in the south had necessarily to take the form of coastal and river fighting. The campaign of +1277 involved large fleets on both sides, and in the final naval battle two years later near Canton, which had been the last temporary Sung capital, no less than 800 warships were captured by the Mongols. The death of the nine-year-old emperor and of his ministers with their families on this occasion occurred because their junk was too large and heavily-laden to escape in the fog with the rest of their squadron. But all this was but the beginning of the naval activities of the unexpectedly sea-minded Mongol government. At the same time as the war against the Sung in South China, Kublai Khan’s urge for world dominion was compelling him to engage in a series of formidable expeditions against Japan. In that of 1274 the fleet was composed of 900 warships, which transported a quarter of a million soldiers across the sea. In +1281 a larger armada of 4,400 ships set sail, but each time the Japanese, aided by typhoons and bad weather, succeeded in repulsing the invaders and inflicting on them very great losses. The emperor intended to mount a third attack in +1283 but had to desist from it on account of the strength of popular disapproval. Undeterred in other directions, however, he despatched a fruitless expedition to Champa in +1282 and another (of 1,000 ships) to Java in +1292; though these were large operations they were too far from home to effect anything permanent. Lastly in +1291 there took place an abortive attempt to appropriate the Liu-Chhiu Islands. Unfortunately, the historical sources which tell us of the extensive naval activities of the Yuan period have never been investigated from the point of view of nautical technology, and much may be expected when this attempt is made. We can at any rate be sure of our ground in viewing the Yuan navy as the continued development of what had been started in the Sung, and the predecessor of the glories of the early Ming.

The account of Mo Chi is in Chhi Tung Yeh Ya, ch. 17, pp. 220 ff. A convenient summary is given by Cordier (1), vol. 2, pp. 296 ff. As early as +1270 the minister Liu Chia had advocated a powerful navy (Yuen Shi, ch. 151, pp. 142 ff.). In +1283 alone no less than 4,000 warships were built.

Interesting illustrations of the ships of the Yuan navy occur in a scroll painting attributed to a contemporary Japanese artist Takezaki Suenaga and entitled Moku Shimu Ekotsu (Poetical Portrayal of the Mongol Invasion). Some of these have been reproduced in Iizuki Hirashii (1). This is the scroll which is so important in the history of gunpowder weapons (cf. Sect. 30h). A small excerpt is reproduced in Purvis (1), fig. 8.
29. NAUTICAL TECHNOLOGY

When the Sung empire was finally conquered the sailors in the Mongol service were called upon to perform a new task, the shipment in guarded convoy of grain supplies from the southern provinces to the northern capital. As far back as the Sui the tribute grain had been carried by a fairly adequate system of waterways from the region of Nanking north-westwards, but now, in +1264, Kubilai Khan fixed his capital far in the north at or near modern Peking, and until the Grand Canal could be remodelled to cope with the new transport requirements, the stability of the new dynasty itself depended upon the success of an alternative route. So successful in fact did the sea route become that an acrimonious controversy arose between the protagonists of the 'blue water' and the canal routes, which lasted for fifty years, much longer indeed than the reign of the Great Khan. We know about it largely because of the survival of an official collection entitled Ta Yuan Hai Yün Chi¹ (Records of Maritime Transportation of the Yuan Dynasty) which originally formed part of Yuan Ching Shih Ta Tien, and a smaller work, Wei Su'² Yuan Hai Yün Chih³ (A Sketch of Sea-Transport during the Yuan).⁴

The first success of the naval service occurred in +1282. A fleet of a hundred and forty-six vessels was gathered by two former privateer commanders who had joined the Mongol forces in the coastal campaign against the Sung, Chu Chhing⁵ and Chang Hsian,⁶ and another naval officer Lo Pi.⁷ After wintering in a Shantung port they unloaded some 3,230 tons of grain at the mouth of the Wei River near modern Tientsin. Very soon the grain transported came to equal that brought up by the waterways, some 19,800 tons, but party politics intensified, especially after the loss of a great grain fleet in a typhoon in +1286, and Chu and Chang were removed from their commands while work on the canals was pushed on more energetically. Nevertheless throughout the next century it remains the more effective, and in +1329 the two old pirates, now admirals, regained control of it.⁸ Although they did not long survive the death of the Great Khan, their successors the Muslima Qobis and Muhammad (Ho-Pi-Ssu⁹ and Ma-Ha-Mo-To¹⁰) carried the service to still greater efficiency, reaching a record annual shipment of some 247,000 tons in +1329.¹¹ After that date the sea transport gradually declined, partly because of increased use of the canals, partly because of foreign pirates, and with the coming of the Ming dynasty the capital shifted again to Nanking.² Even in later times, however, after its return to Peking in +1409, the sea route never regained the predominance which it had in the days of the Yuan navy.³

The archaeological centre-piece of this period was quite unknown to us when this Section was first drafted in 1953, for it still reposed deep in the mud of a swampy dead tributary of the Yellow River at Liang-shan Hsien,¹ about 200 miles from Chianan. It was found three years later by countryfolk planting lotus roots. The village schoolmaster recognised its value as the complete hull of a +14th-century ship, and by the time the provincial archaeologists arrived the peasants were enthusiastically digging it out. The vessel is now preserved in a special building in the Shantung Provincial Museum at Chianan (Fig. 797, pl.).⁴ There is no doubt about the dating, for the anchor bears an inscription of +1372, and a bronze cannon another of +1377. The hull is typically Chinese in character, transom-ended with thirteen bulkheads, and very long and narrow, about 66 ft. from stem to stern, and about 10 ft. in the beam. One can make out the emplacement for the slung rudder and the remains of two masts. The vessel seems built for speed,⁵ and as the remains of helmets and other accoutrements were found in her, it is believed that she was a government patrol boat of the naval police on the Grand Canal and associated waters. Although not one of the greater craft of the time, this relic is of deep interest because contemporary with the Catalan world-map and only a few decades later than the time when Ibn Bat'thah was in China.

Of what was accomplished by the peaceful maritime expeditions of the Ming in the early 14th century much has already been said,⁶ and we must shortly take another view of them in the perspective of the Portuguese voyages of exploration which were proceeding exactly at the same time. But a few details may be given here about the shipbuilding aspect of that remarkable navy which Chêng Ho² commanded, and which may have influenced Europe much more than has generally been supposed. Chêng Hao-Shêng (⁺) tells us that the yards, which were mostly on the Yangtze near Nanking, were at the height of their activity between +1403 and +1423. They were called the Pao Chhuan Chang. Their first order was for 250 vessels (hien po⁸), many larger than ever previously built.⁹ Authority varied, sometimes it was military (the

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¹ This story has already been sketched on pp. 311 ff. above.
² We have met with him already (p. 453 above).
³ The breadth of the ship's bottom narrows to only 3 ft. or so.
⁴ From +1203 onwards the fleet stood well out to sea east of the Shantung peninsula, reducing the time between the Yangtze and Tientsin to ten days. Hence probably the significance of the sailing-directions already mentioned (Vol. 4, pt. I, p. 428). About this time the large sea-going junks were carrying loads of some 640 tons each. Cf. pp. 444, 452, 466.
⁵ It is interesting to compare this figure with that for the record period centering upon +735 (cf. p. 210 above), 165,000 tons, all canal-borne.
⁷ ¹ The Chinh Ho fleet was in China.
⁹ The breadth of the ship's bottom narrows to only 3 ft. or so.
¹⁰ See the corresponding entry in the index to Vol. I.
¹² Some of these figures are given in Dr Lu Gwei-Djen's monograph, 'The Ship Mound at Chianan', published by the University of Pennsylvania Press in 1961, and first translated and published in Chinese by the Chinese Academy of Science, Peking, 1957.
¹³ The breadth of the ship's bottom narrows to only 3 ft. or so.
¹⁴ A few of the wooden vessels were built in southern China, and a few in Manchuria.
Chiin Wei Yu

in Fukien, Chekiang, and Kuangtung produced no less than 1,365 ships of various rates. In the 1420 large-scale naval architecture attained the status of a Board of its own, the Ta Thung Kuan Thi-Chih SaU, and we know the name of the chief designer and builder, Chin Pi-Feng, who made many working drawings (hu yang). The 'Treasure-ship Yards' became so famous that they afterwards figured in a novel, written in 1597, by Lo Mou-Teng. Taoists were appointed to select fortunate days (hao jih tau) for laying down ships, and there were offices for the various kinds of work, organising the carpenters, metal-workers, etc. The best artisans, selected by examinations, were transferred from other work, such as the building and repair of palaces and temples. Thirteen provinces contributed in special taxation. As for the size of the junks, the biography of Chêng Ho in the Ming Shih, which is likely to be reliable, tells us that the 62 largest ships were 440 ft. long, and at broadest beam 180 ft. Each one carried a crew of 450-500 men. The poop had three superimposed decks, and there were several decks below the main one. From other sources, no less than nine masts were stepped in the largest 'Treasure-ships.'

The true size of these great vessels constitutes a cardinal problem of naval archaeology and has aroused much discussion. In the general anxiety to reduce the dimensions, some have suspected that the beam figure may have included the overhang of the timbers by some 20%, so that for the dimensions given a bottom length of about 310 ft. could be assumed, and individual timbers up to 80 ft. long. The shape is very service (cf. p. 478) and re-fitted for naval work in Indian and African waters. The first order of 1403 went to Fuzhouese shipyards for 170 oceangoing vessels, and the first to the Nanking base was in the following year for 30 such ships. Perhaps Yen Tsung-Chien was thinking of the order given to Brigadier Wang Hao in 1407 to convert 249 grain-transports for service on the high seas. In any case, the right figure for the ships laid down in 1403 was 361; rather than 250. We are greatly indebted to Dr Lo Jung-Pang for placing at our disposal the results of his searches in these official records. After 1410 there was an almost complete cessation of maritime shipbuilding orders. This must surely have had something to do with the success of the engineer Sung Li, described in detail on p. 315 above, in perfecting the Yuan Grand Canal summit section by rendering it a fully practical proposition at all seasons. This was in 1411, and soon afterwards, in 1415, the transportation of grain by sea was suspended altogether (Ming Shih Chih Shen Pei Mu, ch. 24, p. 260). At the same time our Lord Chien of P'ing-chiang (already met with on p. 410 above) was authorised to build 3,000 shallow-draught sailing barges for the canal. Thus the shipbuilding energies of the State were diverted to other objectives, leaving the maritime yards idle just when that nursery of deep-water sailors, the grain-import service, was also temporarily disbanded. All this weakened the sea party in the trial strength that was to come (cf. pp. 554 and 557 below).

a Sun Pao Thai-Chien Hsia Hsi-Yang Chi Thung Su Yen I (Voyages and Traffics... in the Western Oceans). See p. 494.

b As still at Hongkong.

c Ch. 304, p. 26.

d Ming Yung-chiang (fort.): 440 ft. and 184 ft. our measure respectively.

e It is not clear whether this figure includes marines and other passengers, or whether they were as many again.

f Pao Tsun-P'eng (1, 1).

29. NAUTICAL TECHNOLOGY

broad-beamed (a length-beam ratio of 1 to 2.45), but this is confirmed by data in another source, which give the dimensions of the second-rate 8-masted ships (Machuan) as 370 ft. long and 150 ft. abeam. None of the sources specifies the draught, but several less official texts confirm the dimensions in the Ming Shih. Collecting them all together, Pao Tsun-P'eng (1, 2) has drawn up a list of all the ship sizes probably standard in Chêng Ho's fleets; they come in 23 rates, ranging from the largest 9-masters down to small 1-masted vessels of one tenth the length, and whenever a beam figure is given, the length-beam ratio remains about the same.

The credibility of the figures for the great Treasure-ships has been discussed by Mills (9) and Lo Jung-Pang (1, 5) as well as by Pao, and what they say should be considered in the context of our note on tonnage (p. 452 above). The Ming Shih figure suggests, according to Mills, a burden of some 2,500 tons and a displacement of about 3,100 tons. Other sources, however, may be taken to imply that the highest tonnage used in the expeditions had a value of 2,000 liao. If Lo Jung-Pang is right in interpreting the liao as a shipwright's cargo unit equivalent to roughly 500 lb., this means a burden of 500 tons (i.e. a displacement tonnage of only about 800)—still much greater, however, than that of contemporary Portuguese ships. Lo supports this conclusion by arguments from the number of crew and marines carried on the individual ships of Chêng Ho's fleets. At the same time he inclines to believe that some of the Sung ships had been larger, notably vessels of 5,000 liao (1,250 tons burden) mentioned, e.g. in the Ming Liang Lu of +1275. This would certainly agree with Marco Polo's evidence of almost the same time (p. 467 above), hard though that is to interpret exactly.

A startling new development occurred in 1962 when an actual rudder-post of one of Chêng Ho's Treasure-ships was discovered at the site of one of the Ming shipyards near Nanking. As described by Chou Shih-Tê (2) this great timber, 362 ft. long and of 1.25 ft. diameter, shows a rudder-attachment length of 19.7 ft. Assuming the usual Chinese 7/8 length—breadth proportions for the rudder blade, this means an area of no less than 452 sq. ft. Chou could therefore calculate, using accepted formulae, the

Fig. 580. A reconstruction of the rudder of one of the great ships of Chêng Ho (c. +1420) based on the dimensions of an actual rudder-post recovered in 1962 near Nanking. The site may be judged from the figure.

a Kuo Tz'u Chi Yü, ch. 1, p. 298. Cf. Duyvendak (9), p. 357.

b Especially the Lung Chiang Ch'uan Chiang Ch'ih, and a state of Chêng Ho described by Kuan Ching-Ch'ung (12) and Hsi Yü-Hsi (13), though now lost.

More on this subject will be found in Pao Tsun-P'eng (1, 2) but the conclusions are necessarily speculative, for different items of essential data are lacking in the accounts of each voyage. We are grateful to Dr Lo Jung-Pang for joining in correspondence on this difficult subject.

AC Ch. 12, p. 172.

NBA
approximate length of the vessel on which it had been used, and obtained lengths of 480 ft. and 556 ft., depending on different assumptions about draught. The discovery of the rudder-post shows that the Ming texts are not 'spinning a yarn' when they give dimensions at first sight hard to believe for the flagships of Ch'eng Ho's fleets.

Then, before +1450, as we shall see, came a fundamental change in policy. The anti-maritime party at court, for reasons still somewhat obscure, got the upper hand, and the long-distance navigations were brought to an end. That it never completely destroyed the traditions of the sea, however, is indicated by the fact that in +1553 a full-dress history of Ch'eng Ho's shipyards was written. This was the Lung Chiang Chhuan Chhang Chih already mentioned (Record of the Shipbuilding Yards on the Dragon River), near Nanking, by Li Chao-Hsiang, whose work must be regarded as one of the treasures of Chinese technological literature. It opens by a brief history of shipbuilding during the Ming dynasty, with an account of the officials who were entrusted with the organisation of it. Then come a number of illustrations and descriptions of ships, but these indicate a decline in the size of vessel built, for only one is a four-masted ship (Hai chhuan), and most of them are two-masters (Ta huang chhuan). There are also a number of single-masted river boats and smaller craft. The fourth chapter describes the yards, giving plans (Fig. 981), and then there follow specifications and dimensions of materials, tabulated with costs in ounces of silver, and details of the number of shipwrights and workmen required for each particular job. Finally, the eighth and last chapter gives one of the best collections of literary and historical references to ships and shipping in all Chinese literature.

A related book which has come down to us from about the same time is the Tsiao Chhuan Chih (Records of River and Canal Shipping) compiled by Hsi Shu in +1501 and enlarged by Chu Chia-Hsiang in +1544. This deals with shipbuilding yards in various parts of the country, and gives lists of types of junk, but there are no illustrations, and in general the text is more administrative than technological.

Attention was first called to this book by W. Franke (3), no. 256.

This view of part of the yards is taken looking approximately south at the strip of land between the walls of the city of Nanking on the left and the Chhin-huai Ho (R.) debouching into the Yangtze at the bottom on the right (as the legend at the top on the right says). The Chhin-huai R., coming from Chiangning, flows all round the south of Nanking outside the city walls, sending a loop through the southern quarter; it got its name from the belief that it had first been canalised in Chhin times, and if not salubrious it was famous for the painted boats of song-nong girls which were moored along the loop end to end. But at its mouth it was big enough to float the great hulls of the ocean-going Treasure-ships of the +15th century.

At the top of the plan is Ma-an Shin, a hill now within the city-walls, and to its left, inside them, Kung-pang Shan is labelled, the Hill of Hanging up the Pass-Lists of Successful Candidates. In the left-hand half of the picture from top to bottom we can make out first the Main Gate (Ta-pang), the Intend­ant's Headquarters (Thi-Chi Sui), the Foremen's Offices (Two Fang), various administrative sections (Fen Su), the Sail Loft (Ph'ing Chiang), and the Naval Liaison Command (Chih-Hui Chi) marked by a flag. All around are wide fields (ya ma shen) in which hemp was grown to yield oakum for caulking. In the right-hand half of the picture two shipyards are seen with their slipways and docks, the Chhien Chhang above and the Hou Chhang below; between them there is a Guard Post (Hsin She) marked by another flag. The entrances of the channels are crossed by two floating bridges, the smaller (Hsian Fou-Chhiao) above, and the larger (Ts Fou-Chhiao) below; these carry the road along the bank of the Chhin-huai R.

The remains of the docks and shipbuilding yards are still visible today near the suburb of Chung-pao-tshu, as basins no longer in connection with the Yangtze, from which they are separated by a high dyke. Excavations at the place have yielded valuable results, cf. Fig. 980.
In its heyday, about +1420, the Ming navy probably outclassed that of any other Asian nation at any time in history, and would have been more than a match for that of any contemporary European State or even a combination of them. Under the Yung-Lo emperor it consisted of some 3,800 ships in all, 1,350 patrol vessels and 1,350 combat ships attached to guard stations (see (1) and (2)) or island bases (ch'ao), a main fleet of 400 large warships stationed at Hsin-chiang-khou near Nanking, and 400 grain-transport freighters. In addition there were more than 250 long-distance 'Treasure ships' or galleons (Pao chhuan), the average complement of which rose from 450 men in +1403 to over 690 in +1431 and certainly overstepped 1,000 in the largest vessels.

A further 3,000 merchantmen were always ready as auxiliaries, and a host of small craft did duty as despatch-boats and police launches. But the peak of the navy declined much more rapidly than it had grown, so that by the middle of the 16th century almost nothing was left of its former grandeur.

With the +17th and +18th centuries we reach the period of intensified intercourse with the West and the end of our archaeological tour. The Chinese literature of this time has a good deal to say on the building and handling of ships, but it can be mentioned more conveniently in specific connections elsewhere in this survey. Towards the end of the +16th century much was written on the problem of grain transport and the relative advantages of the sea route, a perennial debate in the bureaucracy. Liang Meng-Lung's Hai Yun Hsin Khoä of +1579 could be taken as an example. Then in the early decades of the +17th century we have the technical encyclopaedias already drawn upon, and certain important navigational manuals to be described shortly.

The beginning of the +18th century saw the assembly of much of the medieval shipping information in the Thu Shu Chi Ching (1726), and later there were valuable travel books such as the Liu-Chhia Kuo Chih Lüeh used on p. 404 above. At the end of it there were the philological researches of Hung Liang-Chi, and the Fukien ship-building manual. Throughout these centuries Chinese shipping continued to play a highly important part in the maritime trade of South-east Asia; the study of this has been begun in the useful, though small, monographs of Thien Ju-Khang (1, 2).

In the +18th century Europeans began to see a good deal of Chinese ships in practical use. Sometimes also they made use of the services of Chinese shipwrights.

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In its voyage from Macao to explore the north-west coast of America in +1788, John Meares took a company of them along with him. Of course the Chinese artificers in this branch had not the least idea of our mode of naval architecture. The vessels of their nation, which navigate the China and adjacent seas, are of a construction peculiar to them. In vessels of a thousand tons burthen, not a particle of iron is used, their very anchors are formed of wood, and their enormous sails made of matting. Yet these floating bodies of timber are able to encounter any tempestuous weather, hold a remarkable good wind, sail well, and are worked with such facility and care, as to cause the astonishment of European sailors.

Such was the opinion of a great English navigator at the end of the century.

One final scene may complete the story. In +1848 readers of the Illustrated London News learnt that on 28 March a Chinese junk had arrived in the Thames, after having been navigated successfully across the Pacific and Atlantic Oceans. This was the 'Keying', named after the Manchu official and diplomat, favourable to intercourse with foreigners, Chhi-Ying, who had been Commissioner at Canton. She was a junk of 750 tons, 160 ft. long and of 33 ft. beam, built with 15 water-tight compartments. The main-mast was 90 ft. in height, the fore 75 and the mizen 50; the mainsail yard was 67 ft. long and the lug-sails had battens at 3 ft. intervals. The mainsail weighed 9 tons and took some time to hoist, but could be reefed almost instantaneously. The rudder was slung in the classical way. Her master, Capt. C. A. Kellett, described her as 'a good sea boat and remarkably dry'. But she was never to leave England, and was eventually broken up. Other long voyages were subsequently made with Chinese junks, such as that of the 'Whangho' from Hongkong to Sydney in 1908, and that of the 'Ningpo' from Shanghai to San Pedro, California, in 1912-13; all proved to the satisfaction of modern sailors, the seaworthiness of Chinese ships. Such voyages continue still. Not long before the completion of this Section the members of the International Congress of the History of Science assembled at Barcelona were...
privileged to see the arrival at that port in September 1959 of the ‘Rubio’, a 60-ton South Chinese lorchia with typical round-leeched sails, navigated from Hongkong with all success by Capt. José-Maria Tey Planas.¹

(4) The Seas they Sailed

‘Westerners’, wrote Cordier,² ‘have singularly narrowed the history of the world in grouping the little that they knew about the expansion of the human race around the peoples of Israel, Greece and Rome. Thus have they ignored all those travellers and explorers who in their ships ploughed the China Sea and the Indian Ocean, or rode across the immensities of Central Asia to the Persian Gulf. In truth the larger part of the globe, containing cultures different from those of the ancient Greeks and Romans but no less civilised, has remained unknown to those who wrote the history of their little world under the impression that they were writing world history.’ Here then within the compass of this sea-chapter we must do something to redress the balance and to mark how far from home the Chinese captains were prepared to go, voyaging on their own wine-dark waters. On a previous occasion Gibbon’s words were recalled:³ ‘if the Chinese’, he said, ‘had possessed the genius of the Greeks and Phoenicians, they might have spread their discoveries over the southern hemisphere.’ Allowing for the fact that this hemisphere is very largely ocean, that was just what they did (cf. the map in Fig. 98a, opp. p. 560).

It has been suggested that Asian sailors never rounded the Cape of Good Hope because of want of courage rather than of technical equipment.⁴ Assuming for the moment that they did not, it is extremely doubtful whether either of these propositions is true in any sense. The seven ships of Arabia and India were doubtless too uncertain for really long voyages, yet the Indonesians accomplished the colonisation of Madagascar by the sea.⁵ There was much less reason, indeed none, why the great ships of China should not have discovered the west coast of Africa, and the Australian continent too, but social or political circumstances were assuredly the inhibiting factors rather than nautical technology. From Basra to Borneo, and from Zanzibar to Kamchatka, was not an insignificant span for the furthest ranges of the Chinese flag. And the less said about courage the better, as any modern sailor would feel if he found himself invited to undertake a voyage with the same equipment and the same facilities as the Buddhist pilgrims or the Emirs of +14th-century Zayton.

Whoever has had in his life the good fortune both to wander on those Fukienese and Cantonese shores which saw the passage of the great barques of Chêng Ho, and to stand also on that hill which overlooks the Tower of Belem and the Praia de Restelo on the banks of the Tagus, cannot but be powerfully impressed by the strange contemporaneity of the great Portuguese and Chinese voyages of discovery. It is indeed an extraordinary historical coincidence that Chinese long-distance navigation from the Far East reached its high-water mark just as the tide of Portuguese exploration from the Far West was beginning its spectacular flow.⁶ These two great currents almost met, but not quite, and in a single region, the coasts of the African continent. Their winds, angels, their inspirers, were two equally extraordinary men active in maritime affairs, on the one side a royal patron of navigators, on the other an imperial eunuch, ambassador and admiral. The contrast is inescapable, for this was the apogee of Chinese maritime enterprise.

(i) The Admiral of the Triple Treasure

To the assiduous reader of this book Chêng Ho¹ and his assistant commanders will be no strangers, for there was need to mention their exploits in the discussion of intercultural contacts, and more fully in the Section on geography and cartography.⁷ Let us quote once again from the Li-Tai Thung Chien Chi Lan⁸ (Essentials of the Comprehensive Mirror of History), compiled by a group of scholars under imperial order in +1767.

In the third year of the Yung-Lo reign-period (+1402), the Imperial Palace Eunuch (Chung-Kuan¹) Chêng Ho, [gloss: commonly known as the ‘Three-Jewel Eunuch’ (San-Pao Thê-Chhi Chêng), a native of the province of Yunnan], was sent on a mission to the countries of the Western Oceans.

[Comm.] The emperor Chêng Tu, under the suspicion that (his nephew) the (previous) Chien-Wên emperor (Hui Ti) might have fled beyond the seas, commissioned Chêng Ho, Wang Chêng-Hung² and others,³ to pursue his traces. Bearing vast amounts of gold and other treasures, and with a force of more than 37,000 officers and men under their command, they built great ships (ta po⁴) [gloss: sixty-two in number], and set sail from Liu-chia Kang⁵ in the prefecture of Suchow, whence they proceeded by way of Fukien to Chan-Chêng⁶ (Champa, Indo-China), and thence on voyages throughout the western seas.⁷

¹ This was noticed long ago by Mayers (3), who said that the great Chinese voyages of the early +15th century were ‘singularly coincident in time with the heroic undertakings urged on from the opposite side of the globe by Henry the Navigator, Prince of Portugal ... ’ (1875). See also Lévi (2) spoke of these analogous movements, ‘provoked by the rhythm of history’, sixty years ago.

² Vol. 1, pp. 143 ff.; 180; Vol. 3, pp. 536 ff., etc.

³ Ch. 10a, pp. 44 ff., tr. Mayers (3), mod. auct. The present translation amplifies that in Vol. 3, p. 557, and corrects an error in it.

⁴ Chêng Ho’s famous title (borne also by a few other high palace officials) has a markedly Buddhist background, for San-Pao means the Three Jewels (triratna) of pious ejaculation, analogous to ‘the strong name of the Trinity’, i.e. the Buddha (Fo), the Dharma (Fa), and the Satwga (Sang). Yet it is quite certain that Chêng Ho was a Muslim by birth. Such was the syncrétist tendency of Chinese folk religion; perhaps, too, jewels spiritual were confused with jewels temporal.

⁵ Ch. 8 of Vol. 1.

⁶ Down to this point the commentary has followed the official biography of Chêng Ho in Ming Shih, ch. 204, pp. 238 ff., henceforward it is a paraphrase in shortened form. The biography is translated in Pellyot (3a), pp. 273 ff., 277 ff., 204 ff., 399, 300 ff. and 328. The passage in the dynastic history

⁷ It is indeed an extraordinary historical coincidence that Chinese long-distance navigation from the Far East reached its high-water mark just as the tide of Portuguese exploration from the Far West was beginning its spectacular flow. These two great currents almost met, but not quite, and in a single region, the coasts of the African continent. Their winds, angels, their inspirers, were two equally extraordinary men active in maritime affairs, on the one side a royal patron of navigators, on the other an imperial eunuch, ambassador and admiral. The contrast is inescapable, for this was the apogee of Chinese maritime enterprise.

¹ Ed. p. 301, and ed. p. 346.

² Cf. Moreland (1).
Here they made known the proclamations of the Son of Heaven, and spread abroad the knowledge of his majesty and virtue (sei id). They bestowed gifts (tszuh) upon the kings and rulers, and those who refused submission they over-awed by the show of armed might (pu ju tief i wu she chieh). Every country became obedient to the imperial commands, and when Cheng Ho returned homewards, sent envoys in his train to offer tribute. The emperor was highly galled, and after no long time commanded Cheng Ho to go overseas once more and scatter largesse among the different States (pien lai chu pang). On this, the number of those who presented themselves before the throne grew ever greater.

Cheng Ho was commissioned on no less than seven diplomatic expeditions, and thrice he made prisoners of foreign chiefs [gloss telling who, see p. 515 below]. His exploits were such as no eunuch before him, from the days of old, had equaled. At the same time, the different peoples, attracted by the profit of Chinese merchandise, enlarged their mutual intercourse for purposes of trade, and there was uninterrupted going to and fro. Thus it came to pass that in those days 'the Three-Jewel Eunuch who went down into the West' (San-Pao That-Chien hia hai-yang) became a proverbial expression; and all who, in after times, were sent as bearers of commissions to the foreign countries by war, were wont to impress the outer nations with the name of Cheng Ho.

In this interesting summary we see at the outset some of the primary motives of the voyages. There was the search for the deposed emperor, but overshadowing it was the clear desire to impress upon foreign countries even beyond the limits of the known world the idea of China as the leading political and cultural power. There was also the encouragement of overseas trade. Had not one of the greatest of Sung emperors, Kao Tsung, the founder of the Chinese navy, said—‘The profits from maritime commerce are very great. If properly managed they can amount to millions (of strings of cash). Is this not better than taxing the people?' That had been about +1145, when in falling back to Hangchow the government had first become fully conscious of the importance of sea power, but it was no less applicable now, when Timur Lang (Tamerlane) had just completed his general devastation of Western Asia, and all the lands and routes of Turkestan were closed again to Chinese commerce.

has 27,800 men instead of 37,000, and gives the dimensions of the largest ships. To this point we shall return (p. 209 below). After the mention of Hui Ti it also adds: ‘and being desirous of demonstrating to foreign countries the power and glory of China ...' The long-distance navigations involved at least three specialised activities. On the naval side there was the conduct of large fleets of junkas, the greatest vessels then afloat, over many thousands of sea miles to regions where no organised Chinese fleets had been before, working them safely in and out of little-known ports and havens, with a great deal of handling in the narrow waters of the South-east Asian archipelago as well as direct passages on the high seas from Malaya to Africa. On the military side there was the organisation of marines and gunners at sea and ashore, with commanders who proved efficient and successful in certain unexpected emergencies, as we shall presently see, though the duties of the troops were primarily ceremonial. As for the diplomatic or prestige function, what it involved in practice was the giving of rich presents to rulers into whose domains the envoys came, at the same time inducing them to acknowledge the nominal suzerainty or overlordship of the Chinese emperor, and to despatch, if possible, tribute-bearing missions to the Chinese court. Under the rubric of tribute a great deal of State trading was carried on, and besides this there may have been some desire to foster the activities of private traders and merchants. Lastly there was a proto-scientific function. An increase in knowledge of the coasts and islands of the Chinese culture-area was looked for, and the routes to the Far West were to be surveyed. Furthermore, the search for rarities of all kinds was to be actively prosecuted and gathered, minerals, plants, animals, drugs and the like were to be collected for the imperial cabinets. All these functions were the expression of motives, and we shall come back to them when we compare them with those of the Portuguese pioneers. One gets the impression that the more the voyages of exploration developed and the further they reached out, the more important became the collection of natural curiosities and the less important the securing of acknowledgements of tributary status on the part of local princes, while the search for the missing emperor faded into the background altogether.

The seven expeditions from China extended progressively westwards. The first (+1405 to +1407) visited Champa (Indo-China), Java and Sumatra, going the other way as far as Ceylon, and Calicut on the west coast of India. The second (+1427 to +1429), under another commander, Cheng Ho being absent, visited Siam and added Cochín to its Indian ports of call. On the third the fleet went to all the usual places in the East Indies using Malacca as a base, added Quilon in south-west India, and became involved in affairs both distressing and comic on the island of Ceylon (+1429 to +1441). At this time a third able leader, the eunuch Hou Hsien, was joined to Cheng Ho.

* It is not at all easy to tell from the sources what were the approximate overall losses on the expeditions. They were certainly exaggerated by the propaganda of the anti-maritime-party (cf. Vol. 2, p. 537).

* Cheng Ho's absence on this expedition results from the argumentation of Duyvendak (9), pp. 363 ff., but it is very uncertain. Modern Chinese scholars such as Hsiu Yu-Hua (15), Cheng Hao-Sheng (12) and Lo Jung-Pang (private communication) find good evidence to show that Cheng Ho led this expedition like all the other principal ones (cf. the date of the Ceylon stele, p. 523 below).

* Here the ground had been prepared by the successful diplomatic mission of the eunuch Yin Ch'ing in +1403 (Meng Shah, ch. 324, pp. 69 ff., cf. Parcell (3), p. 12). The friendship of the prince Paramesvara and his people assured the use of the port facilities by the Chinese throughout the +14 th century. In al-Idrisi's time, three centuries earlier, Almorad had been the place 'where gather and stay the Chinese ships' (Laurier tr., vol. 1, pp. 84 ff.), but the identification of this seems still uncertain.

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and his ships the Huân-Tê emperor died and now the Chinese Admiralty was doomed at last. Ying Tsung and his successors listened to the Confucian ‘agriculturists’, the scholar-landlords, so that official maritime activities were reduced to the minimum needed to protect coasts and grain-ships from the predations of Japanese pirates (and often below it). This was a decision which had far-reaching results not only for Chinese but also for world history.  

It is clear that the Grand Fleets (Ta tung) 14 separated into a number of squadrons (Fên tung) 14 with particular missions, and that they used a variety of overseas ports as bases, never seeking, however, to establish themselves there in forts and dockyards obtained by military means. Malacca, Ceylon (probably Beruwala rather than Galle harbour), Calicut and Aden were evidently among these. Moreover, their activities were only the culmination of naval diplomatic missions which had been increasing since the end of the Yuan, and which paralleled missions to the western countries by land. Hou Hsiien, who was considered the next most important diplomat (Chêng-Shih Thai-Chien) after Chêng Ho himself, 15 was in Tibet in 1407 and Nepal in 1413, while in 1415 he headed a special embassy to Bengal. In 1403 Ma Pîn 14 had presented compliments (and rich gifts) in a similar way to the Chōka King of Tamil Coromandel (modern Madras).  

Bengal received Yang Min 14 in 1412 and Yang Chêng 14 in 1421, 16 while another eunuch, Hung Pao, 17 who had been in Siarn in 1412, organised an important mission to Mecca 18 in 1422. Chêng Hîo-Chêng 18 and Wu Pîn 19 specialised in relations with the ruler of Quilon, while Chou Man 20 dealt with the ruler of Aden. 21 Most of these men ranked as Assistant Ambassadors and Grand Eunuchs (Fu-Shih Thai-Chien). 22 By exclusion one may suppose that Wang Chêng-Hung was primarily a naval commander, and that this was also the role of men such as Li Hâi, 23 Chu Liang, 24 Yang Chen, 25 Chang Ta 26 and Wu Chêng. 27 A few names of Brigadiers of Marines (Tu-Chîh-Hûi) 28 have come down to us, e.g. Chu Chen, 29 and Wang Hêng. 30 Geomancers, astronomers 31 and physicians 32 were certainly carried, 

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14 For further details cf. p. 344 below.  
15 His biography follows that of Chêng Ho in Ming Shih, ch. 284, pp. 48 ff. See on him Pelliot (2a), pp. 214, 220, (2b), p. 286.  
16 Pelliot (2a), p. 328.  
17 Pelliot (2a), pp. 370, 381, 382.  
19 Pelliot (2a), p. 344 ff.  
20 Duyvendak (9), p. 386.  
21 Liu Ming-Shu (2) has identified the principal ‘Yin-Yang expert’ as Lin Kui-Ho, who sailed on five voyages with the great admiral. He was certainly concerned with weather forecasting and other meteorological and calendrical matters, no doubt also with divinations of success or failure in various special enterprises, and quite probably with astronomical navigation too. It would be quite surprising if such a man did not take lively interest in all kinds of natural phenomena observable during the travels of the fleets. Cf. p. 562 below.  
22 Remarkably enough, quite a number of biographies have come down to us (cf. TSCC, F shu tien, chs. 531, 532, 534). One of the chief medical officers of many voyages must have been the Imperial Physician Chên I-Chêng, known also as a poet and calligrapher; another who gained high promotion because of his services afloat was Yu Chen. Many of these naval physicians, such as Phêng Chêng 33 and

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*Glimpses of how things looked from the Arabic side may be found in Darrag (1), pp. 126 ff., 271 ff.  
* Malindi is a fateful name, for here it was that some few decades later Vasco da Gama would find his Arab pilot to take his ships across to Calicut, thus opening Asian seas to European penetration.  
* Some have identified this place with modern al-Hufuf, near Bahrein Island in the Persian Gulf, others thought Muscat; cf. the discussion in Duyvendak (19).  
* The chief rendezvous port was probably Malacca on all occasions; indeed the Ying Yai Sheng Lan distinctly says so (pp. 36, 37). Many Chinese, of course, live there now, but the weight of the evidence indicates that there was little settlement, if any, before the period of Portuguese domination which began in + 1515. See Purcell (1), pp. 478 ff., (3).  
Nautical Technology

29. Voyages and Discoveries

official publications (Ming Shih, Ming Shih Lu, etc.). The whole of the available literature has been elaborately studied by sinologists in East and West, but further discoveries may yet be looked for. Our documentation would have been even more abundant if the archives of the Ming navy had not been purposely destroyed at a subsequent time (cf. p. 524 below). But what remains is amply sufficient to give us as good a knowledge of the Chinese as of the Portuguese ventures, for which, curiously enough, there are also serious documentary gaps (cf. p. 528).

The expeditions of Ch'eng Ho's time had considerable influence on Chinese literature, parallel in a smaller way to the spread of knowledge of the Portuguese discoveries through Europe. Some MS. books of sailing-directions have come down to us (cf. p. 583 below). Though none of the works just mentioned were furnished with maps, a number of valuable 'portolans' or route-maps in a distinctively Chinese style were preserved in the Wu Pei Chih 1 (Treatise on Armament Technology) compiled by Mao Yuan-I 1 and presented to the throne in +1628. These undoubtedly derive from the cartographers attached to Ch'eng Ho, and we accordingly discussed them in an earlier Section. 1 The illustrated geographical encyclopaedias of the age were greatly affected by the new knowledge brought back by Ch'eng Ho, for instance the I Yü Thu Chhi 1 (Illustrated Record of Strange Countries) compiled between +1420 and +1430 probably under the supervision of the learned Ming prince Chu Chhian (Ning Hsien Wang). 2 This too we have already discussed. 3 Another book with a very similar title, I Yü Chih 1, written before the end of the +14 th century, had inspired Ku Pho, 4 who (at the request of a mutual friend Lu Ting-Yung) 5 wrote the postface to Ma Huan's 'Triumphant Visions of the Ocean Shores', and whose words are worth quoting in illustration of the enlightened Chinese attitude of the time towards foreign parts. 6

In my youth [he said], by reading books such as the I Yü Chih (Record of Strange Countries), I learnt the vastness of the surface of the earth, the differences in customs, the diversity of human beings, and the variety of natural products—which are all truly astounding, lovely, admirable and impressive. However I had some suspicion that these books were perhaps the

1 See Pelliot (sa, e), Duyvendak (8, 9, 10, 11), Mills (5), etc., who built on the earlier investigations of Meyers (3) and Rockhill (1). Cf. Haing Ta (1). The best Chinese biography of Ch'eng Ho is that of Ch'eng Hsiao-Shing (1), cf. (4). Maps and sea-routes have been intensively studied by Fan Wei Thao (1) and Chou Yi-Sun (1) in special monographs; cf. also the paper of Liu Ming-Shu (1). Fan Chih-Ch'ing (1) places the voyages in the general context of Chinese knowledge of the south seas. Filesi (1, 2) assays them in the language of Marco Polo.

2 In and similar later books such as the Wu Pei Pi Shu (Confidential Treatise on Armament Technology) by Shih Yung-Thu. 1

3 Vol. 3, pp. 559 ff. It is good to see the value of these maps now widely recognised, as in the popular treatise of Debenham (1), p. 122. New ed. Haing Ta (4).

4 Alchemist, botanist, mineralogist, pharmacist and an expert in acoustics and music, cf. Vol. 1, p. 147 and Sections 33 and 38.

5 Tr. Duyvendak (10), p. 11; mod. sect. Cf. Pelliot (2a, b), pp. 260; SKCS, TMTY, ch. 78, p. 50. It seems that the original title of the I Yü Chih was Le Chhong Lu 1 (Record of the Naked Creatures, i.e. the Barbarian Peoples) and that it was probably written by Chou Chih-Chang 6 in the neighbourhood of +1566. The name was apparently changed just before +1460 by the elder brother of the official Chih Chi 7 who perhaps re-wrote or expanded the book.

9 See Pelliot (1a, b), pp. 305 ff., amplifying Meyers (3).

10 Tr. Duyvendak (10), p. 51 ff. It is good to see the value of these maps now widely recognised, as in the popular treatise of Debenham (1), p. 122. New ed. Haing Ta (4).

11 Alchemist, botanist, mineralogist, pharmacist and an expert in acoustics and music, cf. Vol. 1, p. 147 and Sections 33 and 38.

12 Vol. 3, pp. 515 ff. It is good to see the value of these maps now widely recognised, as in the popular treatise of Debenham (1), p. 122. New ed. Haing Ta (4).

13 Alchemist, botanist, mineralogist, pharmacist and an expert in acoustics and music, cf. Vol. 1, p. 147 and Sections 33 and 38.
work of busybodies with too much imagination, and I doubted whether there really existed such things. But now I have read the notes which Mr Ma Tsung-Tao, Mr Tsung-Tao and Mr Kuo Chung-Li have made of their experiences among the foreign countries, and I realise that what the "Yu Chih" reported deserved confidence and was no fable.

Lastly the great voyages provided material for one of the famous Ming novels, the "Hsin Thang Shu" written by Lo Mou-Teng and published in +1178. Though containing much fabulous material, it is also, as Duyvendak (19) has shown, a source of reliable information concerning the organisation of tribute missions and their gifts, together with interesting technical details about spectacles, gunnery and the like.

So great was the fame of Chêng Ho and his companions in South-east Asia that they entered at last, like Kuan Yü, into the realms of heroic hagiology. For the admiral was adopted as a tutelary deity by the Chinese communities of the Malayan diaspora, and incense burns to this day in the temple of Sam-Po-Tai-Shan at Malacca.

(ii) China and Africa

But Chinese relations with East Africa were far older than the day of Chêng Ho. From ancient Egyptian times onwards there had been trade down the coast, and Polemy's "Promontorium Prassum" was probably Cape Delgado. Permanent non-indigenous settlement began in the +8th century with the foundation of Arab trading centres such as Magadishu in Somaliland about +740 and Sofala south of the Zambezi River about +780. Gradually these developed into mercantile city-states and from them Arab exploration spread out, Madagascar and the Comoro Islands in the Mozambique Channel being known in the +9th. What is much more unexpected is that descriptions of this part of the world (Azania, al-Zanj) can be found in Chinese literature as early as about +850. When Tuan Chêng-Shih was compiling his "Yu-Yang Tsa-Tu" (Miscellany of the Yu-Yang Mountain Cave) at this time, he included in his accounts of foreign countries an interesting passage on Po-Pa-Li--none other than Berbera, the south coast of the Gulf of Aden. With varying orthography and steadily increasing detail this country is described in the subsequent books on overseas lands, such as the "Chu Fan Chih" (Records of Foreign Peoples) by Chao Ju-Kua in +1235, where it is called Pi-Pha-Lo. This book has also an elaborate description of the Somali coast.

A book called "San-Pao Thai-Chien Hsia Hsi-Yang Chi" (Records of the Barbarian Islands), including not only Berbera, and the Zanzibar coast (al-Zanj) as Tsheng-Yao-Lo, but also the Comoro Islands in the Mozambique Channel.

How many Chinese merchants and sailors actually themselves visited these parts between the +8th and the +14th centuries we have no means of telling. Apart from texts such as those just mentioned there is only the mute evidence of Chinese objects scattered up and down the coast. And these are many indeed, so many that it is rather hard to believe they all came through the hands of intermediate traffickers. Before we briefly consider them, let us look at one positive testimony, from an Arabic source.

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* Ch. 242 b, pp. 119, 5, translated by Duyvendak (8), first translated by Hirth (1), p. 61.
* It was reached by crossing a desert of the Arab and Byzantine realms, together with a neighbouring unidentified country called Lao-Pho-Sa. Both were inhabited by fierce black people. In spite of Duyvendak's opinion, Mr J. S. Kirkman assures us that the distant and desert features of this Mo-Lin cannot fit Kenyan Maldini; perhaps there was some other place with a similar name on the Somali or Berber coast further north. In the Ming, Kenyan Malindi was written differently, as Ma-Lin. Duyvendak also overlooked an interesting point to which Lo Jung-Fong (+) has drawn attention. The account in the "Hsin Thang Shu" must derive from the "Chung Hsing Chi" (Records of My Travels), written by the Chinese officer Tu Huan about +758 when he returned from his eleven years of captivity among the Arabs after the Battle of the T חול River (Ch. 1, pp. 225, 230) for parallel passages occur in excerpts from this (Tulloo Tse (c. +812), ch. 195 (p. 1044.7), and On Hisan Thang Kho, ch. 339 (p. 1829.3), tr. Hirth (1), p. 84). If then one could locate more clearly the native heath of these xenophobic Africans, Tu Huan's account would be the earliest description of the Somali litore, antiquing the "Yu-Yang Tsa-Tu" by about a century. Perhaps in any case it ought to be considered so.

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* Ch. 1, p. 254, tr. Hirth & Rockhill (1), p. 126. The Sung Shih, ch. 490, pp. 218, 224, describes the same region, and records the arrival of ambassadors from it in +1071 and +1083; they were sent home with rich gifts. About a century before Chao Ju-Kua, it had also been described by an anonymous writer in a book called "Tao Tsa-Ta Chi" (Miscellaneous Records of the Barbarian Islands), preserved in Chinese quoted at length in the "Shih Lin Kuang Chi" encyclopedia. Wada Kyutoku (1) reproduces the text.


* All the relevant passages are translated in Rockhill (1), who compares them with the statements in the books of the Ming naval secretaries.

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* An occasional spot of light is cast by a particular name. Very likely Wang Tsu-Yuan met another far-off name here. Either "San-Pao" or perhaps "San-Po-Li"?

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* "Yu Chih" (records of the foreign people) by Chao Ju-Kua in +1235.
of the presence of Chinese merchants on the shores of +12th-century East Africa. The great Sicilian geographer Abū 'Abdallāh al-Idrīsī, writing about +1154, says:*

Opposite the coasts of Zanj are the Zalej (or Zanej) Islands, large and numerous; their inhabitants are very dark, and everything that they grow is dark-dhorra, sugar-cane, phor, etc. One of these islands is called Sherbua ... Another is al-Anjebi, where the chief town is called in the Zangbuchar language al-Anfija, its inhabitants being mostly Muslims though of mixed descent... This island is very populous, with many villages and domestic animals; rice is grown there. There is much commerce, and markets to which all kinds of things for sale and use are brought. It is said that once when the Chinese affairs were troubled by rebellions, and when tyranny and confusion became intolerable in India, the Chinese moved their commercial centre to Zalej and the other islands which belong to it, entering into familiar relations with the inhabitants because of their uprightness, amenity of customs and aptitude for business. This is why the island is so populous and so frequented by strangers.

Here we have only a glimpse, for it is not quite clear what al-Idrīsī had in mind. The Chinese rebellion to which he refers sounds like that of Huang Chhão (+884) during which the Arab quarter of Canton was destroyed, but trouble on the East African mainland would have been a much more likely cause of the removal of Chinese trading stations there to an island. Nor is al-Idrīsī’s reference to India easily understandable. Nevertheless what he says about the story of the Chinese ‘factory’ is itself quite precise, and we may accept it as a picture of such activities about +1000. If there was one such Chinese station on the coast in Sung times there would probably be several, and merchant-junks too, to connect them with home. As for the identity of the Zalej or Zanj Islands, they are believed to be the Mafias, off the Tanzanian coast about 150 miles south of Zanzibar.

Among the things which the Chinese wanted from Africa were elephant tusks, rhinoceros horns, strings of pearls, aromatic substances, incense gums and the like. Statistics preserved in the Sung Shih show that these imports increased ten times between +1050 and +1150. Al-Idrīsī, on the other hand, tells us what Aden (and hence the Coast) received from China and India—iron, damascened sabres, musk and porcelain (typical Chinese exports), saddles, ‘velvet and rich textiles’ (probably silk), cotton goods, aloes, pepper and South Sea spices. Fortunately some of this was hardware and survived until today. ‘I have never seen’, wrote Wheeler (6) in 1955, ‘so many broken Chinese in the past fortnight between Dar-es-Salaam and the Kilwa islands; literally fragments of Chinese porcelain by the shovelful... I think it is fair to say that as far as the middle ages is concerned, from the +12th century onwards, the buried history of Tanganyika is written in Chinese porcelain.’

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Archaeological research in East Africa is now in full swing, and general conclusions can only be provisional. But the positive acquisitions are already extraordinary. Along the entire Swahili coast from Somalia to Cape Delgado ‘an unexpected and improbably large quantity of Chinese porcelain’ has been found and is under study. A single Tanganyikan collector found 400 shards from thirty sites between the Kenya border and the Rufiji River near the Mafias. On these islands themselves, and in the neighbourhood of Kilwa, Wheeler himself saw great quantities of porcelain fragments. But the porcelain is not always broken, for whole pieces are found inset in the plastered walls of houses and mosques, where also there are niches designed to contain them. A pillar tomb near Bagamoyo (opposite Zanzibar Island) was decorated with sea-green bowls of the Yuan period, exactly contemporary with the descriptions of Wang Ta-yuan. Broadly speaking (and perhaps as might be anticipated) the oldest periods are represented most strongly in the north, where Sung celadon finds have been plentiful. Further south the evidence points to a great upsurge of the importation of Chinese wares from the middle of the +14th century, after which no reign-period during the Ming and Ching is unrepresented. Possibly this may be attributed to the decline of the Middle Eastern kilns after the collapse of the Abbasid caliphate in the Mongol invasions. Nor are the finds restricted only to the coastal areas, for many pieces have appeared far inland. Exactly how far south this influence went is as yet hard to determine since few investigations have been reported from Mozambique, but it must at least have reached Sofala. In any case the products of Chinese culture are celebrated in Swahili literature. The late +18th-century poet al-Inkīshāfī, describing the wealth of the city of Paté before its fall, says:

Wapambaye Sini ya kutuwe
Na kula kikombe kinakishiwa
Katika mapambo yanawiriye.†

+ Of the presence of Chinese merchants on the shores of +12th-century East Africa.
† See Duyvendak (8), p. 16, and the elaborate study of Wheelley (1).
‡ Jaubert tr., vol. I, pp. 59 ff. The better translation of Dony & de Goeje (1) does not deal with this part of Africa.
§ Cf. Revington (1).
¶ Vaillant (1).
¶¶ Shih Yu-Chung (1).
\ This is as much as to say:
\\ Their feasts were decked with Seric porcelain bright
\\ Glitter and glow above the napery white.
The other kind of Chinese hardware on the East African coast is monetary—coins and coin-hoards, always so fascinating and yet so difficult to interpret. Out of a total of 506 foreign coins found on the coasts of Kenya and Tanzania and dating from before 1800, no less than 24 are Chinese, and the great majority of them, curiously enough, are of the Sung period. This may not mean that trade was more intense then than at other times, but only that African merchandise was for a period bought with money rather than bartered. The earliest coins date from about +620. An important hoard of Chinese coins was found at Kajengwa in Mozambique; it was the savings of a settler, or of a Zanzibari who had visited India or China? Such Chinese settlers, generally fishermen now speaking only the local languages, have been reported in the Bajun Islands off the Somali and Kenya coasts. In the north, Thang coins, and many of the Sung (+11th century), have been found at Mogadishiu and other places in Somalia. Further discoveries will be of great interest. Meanwhile many other evidences of Chinese contacts with East Africa are being explored.

It is thus clear that before the appearance of European ships in the Indian Ocean Chinese trading influence extended down the eastern coast of Africa almost as far as Natal, certainly to the mouth of the Zambezi, and that the Mozambique Channel was ploughed by Chinese haws. How far south the Ming fleets carried their planned investigations, however, is uncertain. The naval secretaries refer in much detail to Mogadishiu, Brawa and Malindi; there is also mention of al-Jubb (Man-Pa-Sa 3 ) north of it. Since the whole coast was known to the Portuguese later on as Melinde, it is probable that Ma-Lin-Ti in this period refers to a place called Chhi-Erh-Ma, rather than Mozambique (lat. 10° S.).

A special contribution to Yusuf Kamal’s atlas was made by Duyvendak (11) on this subject. Little attention has been paid, however, to the interesting names of mountain-ranges marked on these maps island from the coast. Could Chhiha-erh (perhaps for Chhiha-erh?) be the Chyula hills, and could Ch-ki-lang-lia-lang-lia be Mt Kenya or Mt Kilimanjaro?

Mr. J. V. Mills identifies the Ko-Ta-Kan of the maps as Quantungana Island, in Conduca Bay, 10 miles north of Mozambique.

See the surveys of Freeman-Greenville (1, 3, 5), admittedly only a beginning, and (Fig. 983, pl. from Huisew (5). Cf. Mathew (1).

Both of the cones found at Gedi were Southern Sung (Kirkman, 3).

De Villard (1).

For instance the spread of cultivated plants. A Chinese character has been recognized doing duty as a wall decoration motif in traditional African buildings in Rhodesia (Dart, 1). But cf. Mathew (1).

A special contribution to Yusuf Kamal’s atlas was made by Duyvendak (11) on this subject. Little attention has been paid, however, to the interesting names of mountain-ranges marked on these maps. The map containing South Africa is in ch. 2, p. 870 (Fig. 984). Cf. Vol. 3, p. 551 ff. Identifications in Fuchs (1), p. 14.

Cf. Vol. 3, pp. 154 ff. and Figs. 234, 235. Important studies on it have been made by Ogawa (1); Aoyama (1, 3, 11); Unno (1, 4); and Miyazaki (1). Kwôn-Kún’s astronomical work has been discussed in Vol. 3, p. 275 and Fig. 107.

A pagoda-like object represents the Phare (cf. 661). On South Africa in this map see Fuchs (6).
travellers could bring home about East Asia. The Chinese were in fact a good century ahead. In Europe, one is perhaps see conceptions of Africa in the act of changing, if Kimble (2) is right in his interpretation of the Laurentian world-map. Here two drawings are superimposed, a medieval ink outline with Africa's tip pointing east, and over it a coloured L-shaped continent pointing south. He supposes that the first dates from +1351, while the latter was painted on top of it after +1450, perhaps after +1500.

At the outset of this digression (if such it is) we were content to acquiesce in the conventional view that the Portuguese were the first to double the Cape of Good Hope. But the atlas of Fra Mauro carries two among its many inscriptions which in this context are very curious. In a scroll on the East African coast near Diab (the Cape), the first of these says:

About the year +1420 a ship or junk of the Indies passed directly across the Indian Ocean in the direction of the Men-and-Women Islands beyond Cape Diab, and past the Green Islands and the Dark (Sea), sailing (thereafter) west and south-west for forty days and finding nothing but air and water. According to the estimate of her (company) she travelled 2,000 miles. Then, conditions worsening, she returned in 70 days to the aforesaid Cape Diab. When the sailors went on shore to satisfy their needs, they saw an egg of the bird called roc, the which was the size of the belly of an amphora; and so great was the size of the bird that the span of its wings was sixty paces. This bird, which can carry off an elephant with ease, as well

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a Cf. Fuchs (6), but they did not show the continent's north-west bulge.
b This is the Porolano Laurenziano-Gaddiano, part of the Medicean Atlas in the Laurentian Library at Florence.
c The first printed map of Africa (+1508) by Fracanzano di Montalboddo has just the same shape (see Anon. (47), no. 42, and pl. 118), with the southern projection also inadequately extended. It is interesting, but quite natural in view of the directions from which the continent was approached, that the Europeans should have thought of it primarily as an east-west land-mass, while the Chinese thought of it primarily as stretching north-south.
d Unless we accept the periplus of the Phoenicians under the Pharaoh Necho II (—609 to —594) recorded in Herodotus, IV, 42, and still maintained by modern geographers (e.g. Debenham (1), p. 30), but which, like Gibbon, I have never been disposed to believe'. Cf. Germain (1).
e For him, of course, China was part of the Indies, 'extra Gangem'. The word junk is clearly in the original.

Legend to Fig. 984 (continued)
lakes (Nyasa, Tanganyika, Victoria, etc.) was known. The words Chih-pu-lo-ama (Chih-pu-lo-ha-ma in some versions) undoubtedly stand for Ar. Jebel al-Qamar, the Montes Lunae (Mountains of the Moon) of Ptolemy, as Takahashi (1) and Unno (5) have seen; probably mod. Mt Ruwenzori, on the Uganda—Congo frontier, possibly Mt Kilimanjaro in N. Tanzania, hardly the Drakensberg range in Basutoland (Chang Kuei-Sheng, 2), in spite of its size. The large island off the east coast marked Sang-lo-su-chin (or -chi), for which Fuchs (1) offered 'ford of Hainan' (a mere construct); Chang the more plausible Ar. al-Nil al-Azraq, the Blue Nile; and Takahashi and Unno surprisingly Ar. khatt al-istiwa', i.e. the equator. This, it is true, passes along the north shore of Lake Victoria. Fifteen other islands are scattered in the Indian Ocean, possibly Réunion, Mauritius, the Seychelles, the Maldives, etc., but their Chinese names are not easily interpretable. Few will follow Chang Kuei-Sheng in making Chih-hai-ho-pi-la Kangqiao in near the Antarctic, still fewer his suggestion that Chêng Ho's men (or any Arabs either) went there. In this far southern region the sea gives over, and the characteristic 400-li grid resumes for a terra incognita.
As all other large beasts, does a great deal of harm to the inhabitants of those parts and is extremely rapid in flight. a

And the cartographer continued in another, more southerly, scroll, as part of a passage maintaining the continuity of the Indian and Atlantic Oceans:

Moreover I have had speech with a person worthy of belief who affirmed that he had passed in a ship of the Indies through a raging storm 40 days out of the Indian Ocean beyond the Cape of Sofala and the Green Islands more or less south-west and west. And according to the calculations of her astronomers, his guides, this person sailed 2,000 miles. Whence assuredly we may take him as sincere as those who say that they have sailed 4,000 miles (down the west coast of Africa and back) [i.e. the Portuguese explorers whose charts Fra Mauro says earlier in the same inscription that he had had at his disposal]. b

This is all that we know. A porthole opens to disclose some sea-going junk flying before wind and rain in the Agulhas Current round the Cape, then caught in the South-eastern Trade-winds till finding no land her master comes down again into the Indian Ocean where at some landfall his crew stumble upon the traces of giant birds. Then quickly the view is shut off. But we need have no doubt that the junks of this; the opinion of a most weighty mariner supports us. c Curious, too, that a Tr. auct. after Yusuf Kamal (I), vol. 4, pt. 4, pp. 1409 ff. Everyone was interested in the ostrich eggs of these parts. Says the Ling Wan Tai Tsu (+ 1778) of Madagascar: `There are great phægra birds there, which so mask the sun in their flight that the sundial shadow shifts. If one of these finds a wild camel, it swallows it whole. And if a man should chance to find a phægra’s feather, he can out a water-butt from its quill’ (cf. 3, p. 60): cf. Chu Fan Chih, ch. 1, p. 348. Cf. also Vol. 3, p. 81.

The Indian Ocean, Fra Mauro averred, was quite continuous with the Atlantic, no Austral or Antarctic continent standing in the way. In this he was but following the consensus of opinion among the great Arabic geographers from Ibn Khurdadhbih in the +9th century through al-Birinci in the +11th, down to their disciple Marino Sanuto (+ 1306). e The Arabs, moreover, denied the commonly Western opinion that the south coast of Africa were creeping down the west coast of Africa while the Chinese were examining the east coast at least as far south as Mozambique; during the second half the Portuguese found their way round into the Indian Ocean to meet no one but Arabs and Africans, since a change of policy in China had withdrawn the treasure-fleets for good.

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When Cheng Ho was a boy of about seventeen, revelling in the sunny climate of the +14th century we need not speak in detail here, since it is so widely known, and described in so many useful books. b But in order to make the comparison which is demanded by the contemporaneity of the Chinese navigations, we must give at any rate a summary of it. Of the great epic of Portuguese maritime discovery and expansion in the +15th century we need not speak in detail here, since it is so widely known, and described in so many useful books. b But in order to make the comparison which is demanded by the contemporaneity of the Chinese navigations, we must give at any rate a summary of it. During the first half of the +15th century the Portuguese were creeping down the west coast of Africa while the Chinese were examining the east coast at least as far south as Mozambique; during the second half the Portuguese found their way round into the Indian Ocean to meet no one but Arabs and Africans, since a change of policy in China had withdrawn the treasure-fleets for good.

(iii) The Sea-Prince of the Five Wounds

When Cheng Ho was a boy of about seventeen, reveling in the sunny climate of the +14th century, there was born at the other extreme end of the Old World in an equally beautiful country a boy whom it pleases us now to think of as a key figure of parallel historical importance. c Henry of Avis, called by historians the Navigator, was of birth more exalted than Cheng Ho, since his father was King João I, a monarch whose reign achieved the definitive emancipation of Portugal from the recurring threat of Castilian sovereignty. At the Battle of Aljubarrota (+ 1385) which effected this, the Portuguese were assisted by English archers, and next year King João married an English girl, Philippa of Lancaster, the daughter of John of Gaunt. Dom Henrique "the Navigator" (+ 1394 to + 1460) was their third son, d and while he was brought up in all the usual chivalric mentality of the time, he developed into something altogether more original—a prince who realised the value of ships and could talk
with the rough sea-farers and fishermen who handled them, a medieval noble who did not disdain to commune for many years with men of learning, astronomers and cosmographers, and in the end a visionary imbued with a world-shaking idea. Causes and motives will occupy us later, but there can be no doubt that the men around Prince Henry were convinced of the truth of the Arab belief that south of Africa there was a cape which could be rounded. They knew, moreover, all that 15th-century Westerners could know about the Indies and the Further Indies. They hoped to find help from Prester John in Abyssinia or else in Central Asia. 4 If then the Cape could be rounded, and one came to the Red Sea and the Persian Gulf from the south, establishing links with the Indian and East Indian producers of silks and spices, what would be the position of Islam? The flank of the Arab world would have been turned. 5 And thus the confabulations of the 'School of Sagres', the group of navigational planners gathered round Prince Henry during his long governorship of Algarve at Lagos and at the scientific citadel on the Sagres promontory, 6 with its aim of using all the powers of heaven and earth to find a way of taking the Saracens in the rear, constituted a veritable transition from the medieval mentality of the Crusades to the Renaissance out-reaching towards all possible knowledge. The search for the southern passage was to be the 'Commander of the Faithful' had headed what now seems to us a clearly superior civilisation. Perhaps too secure in that knowledge, the Arabic world did not appreciate that the pans of the balance were slowly shifting; and no Muslim ruler thought to act upon the teaching of his own geographers, sending down expeditions to strengthen the cities of al-Zanj and perhaps to build a giant fortress or a powerful fleet to deny to the Franks that fateful southern portal. Instead, the methodological exploration of the West African coasts proceeded unopposed. Even the definitive European discovery of the Americas was in a way its by-product. 7

The opening rounds were fired at Ceuta. Perhaps the first idea of the House of Avis was for a conquest of Morocco; in any case the city, just across the Straits, was a centre of Moorish naval strength which would have to be reduced if Portuguese ships were to pass freely back and forth along the south-western coasts. The city was therefore taken and sacked in +1415, the year of Chêng Ho's return from his fourth voyage, but doubtless less no word of the great event reached the Chinese flagship lying in the roads of Ormuz. After the fall of the city the Infantes Henry and his brothers wrote a remarkable letter. John, Duke of Bourbon, had challenged them to meet him in single combat, with sixteen knights and esquires 'de nom et darnes sans reproches' on each side. But now they had no time for jousting. They answered that having with God's help won Ceuta they intended to continue and win for Him many other cities and towns in Africa. 8 Though still in a crusading context, their attitude symbolises the change from the departing Middle Ages to something radically new. 9 But perhaps this was not all gain. 10 With the capture of Ceuta', wrote Parry, revealingly, 'the crusading movement passed from its medieval to its modern phase; from a war against Islam in the Mediterranean basin to a general struggle to carry the Christian faith and European commerce and arms around the world. 11

After Ceuta ships were sent out almost every year to sound the ocean, for Henry 12 had a wish to know the land that lay beyond the Isles of Canary and a cape that is called Bojador, because until that time, neither in writing nor in men's memory had it been definitely known what was the nature of the land beyond that cape. 13 For the first dozen years they were concerned mainly with Madeira and the Azores, but in +1426 Frei Gonçalo Velho surveyed the coast of the Anti-Atlas mountains, and in +1434 Gil Eanes doubled Cape Bojador (26° N.). In the former year the last and greatest of the Chinese voyages to Africa was being prepared, in the latter it had just gone home. In +1444 Nuno Tristão reached the mouth of the Senegal River (16° N.), and two years later Álvaro Fernandes was on the Guinea coast (12° N.). The year +1453 was marked by two events, one colossal blow and one seemingly minor affair: Byzantium fell to the Turks, as if to show the Portuguese that they were none too soon in their endeavours, 19 while along the African coast sailed Cid de Sousa, leading the first primary expedition to Guinea with the primary object of trade. 20 Then came the death of Prince Henry, just after Pedro de Sintra had reached Sierrina Leone (8° N.). A lull of some ten years followed, but in +1471 João de Santarém pushed on to Ashanti (5° N.) 21 and three

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5 To understand the crusader spirit of Portugal at this time one should remember that in the Iberian peninsula itself there were Muslim states, including the highly cultured Emirate of Granada, which did not fall till +1492. In a sense, the discoveries of West and South Africa were only a continuation of the reconquista. If Fuchs (7) is right in his interpretation of evidence which we shall consider in Sect. 33, there had been an embassy from Granada to China about +1317.
6 (1), p. 11.
7 From the chronicle of de Zurara; Beazley & Prestage tr. pp. 27, 32. Cf. L. Bourdon (1).
8 This was also a mortal blow for the Venetians, who had always tried to keep on good terms with the Turks, and had hoped that a way for Asian commerce could be kept open for Christendom through the Middle East.
9 A persistent claim has stated that French sea-captains from Dieppe established trading posts on the West African shores as early as +1364 (see e.g. de Louvre & Haffner (1), pp. 65 ff.), but the evidence for it is extremely weak. De Santarém (3) criticised it devastatingly more than a century ago, but no one reads him (cf. Godinho, 1). De Sousa's trading expedition was soon followed by others, notably those of the Venetian Alvise Ca' da Mesto and the Genoese Antonio Uosdimarre, merchant-captains in Prince Henry's service (cf. Prestage (1), pp. 94 ff.). On the historiography of the Portuguese discoveries see Brocchi, M. (1).
10 Here the Portuguese completed, b +1482, their most important West African fortress, El-Mina (Ferreis (1), p. 35). Its present remains are described in A. W. Lawrence (1).
years afterwards the equator was crossed when Lopo Gonçalves came first to Cape Lopez (now in the French Congo, and 2° S.). This was a latitude equivalent to that of al-Jubb, where the Chinese had passed on their parallel south-eastern journeys.

After a period of internecine struggle between Portuguese and Spaniards (who wanted to participate in the profits of West African gold and slaves), the explorations started again on a distinctly larger scale. Between +1432 and +1486 Diogo Cão made two remarkable journeys, marking the places he visited by stone crosses (padroes) which he took out with him from Lisbon, fixing first Cape Sta. Maria in Angola (14° S.), then Cape Cross in Daranaland (22° 2 S.) Now the Portuguese were almost beyond the limit of the Chinese explorations on the other side. At last came the historic voyage of Bartolomeu Dias in +1488, rounding the Cape of Good Hope (about 35° S.) and naming the truly most southerly point, Cape Agulhas. The way was now open for the 'Chinese' area, touched at Malindi in April, just about fifty years after the Ming navy had ceased to frequent those shores. At Malindi he was fortunate enough to obtain the services of one of the leading Arab pilots of the age, Ahmad ibn Majid, who brought the Portuguese admiral to Calicut in India the following month. The die was now cast, the Europeans were in the Indian Ocean for good or evil—and of the latter much.

After this, exploration and the extension of European geographical knowledge went rapidly forward. The second Portuguese fleet which sailed to India, under the command of Pero Alvaredo Cabral in +1500, touched at Brava and on the way took a closer look at the Arab city-states of the East African coast, especially Sofala and Kilwa. A few years later Vicente Sodré landed on Socotra Island off the tip of Somalia. By +1507 the title 'Governor of India' was arrogated to Alfonso de Albuquerque, and by +1510 he had captured the Arab port at Goa on the west coast of Bijapur, one of the Deccan sultanates into which the Bahmani kingdom had split. Within five years, all that remained of the Governor's own life, it had become already a large city, and after +1515 the chief base of the Portuguese empire in Asia. European historians credit him as the first sea commander to appreciate the complex relationships between

flights and ports, at any rate he certainly saw Portugal's need for a permanent fleet and naval bases in the Indian Ocean. One suspects that most of these ideas would have been equally obvious to Cheng Ho and Wang Ching-Hung—but there was a slight difference: they were not engaged in a war of conquest in the regions between Malaya and Natal, and they could count on the co-operation of local rulers when they needed to careen, re-caulk, or even build, when far from home. The year before Goa was taken, Malacca, that old rallying-point, had first been visited by Portuguese, who also 'discovered' the Nicobar Islands on the way, and in the year after, it was stormed by the Governor and appropriated to the empire. Two final features will suffice to complete this summary: in +1512 Francisco Serrão attained at last to the 'spice islands', exploring the Moluccas beyond the Celebes and annexing Timor, and significantly he used a junk to do so; secondly Jorge Alvares came at last to China with a trading ship in +1513. Thence he and his men could look across in the direction of the Philippines which from +1521 onwards were to be Spanish. And so the whole world was 'bouned in a bond', and if four hundred rather than 'four thousand winter' would put it right again, many of the consequences were permanent and irreversible.

It is of much interest that the former Chinese presence on Indian Ocean coasts was soon known, but much misunderstood, in Europe. In the Lusiad Camoens represents certain civilised Africans living between Sofala and Mozambique as telling the Portuguese of da Gama's ships that they were not the only light-skinned navigators of those seas.

In the Arabick-Tongue (which they speak ill, but Fernand Martyn understandeth though) They say, in Ships as great as these we fill, That sea of theirs is travers't to and fro, Even from the rising of the Sun, until The Land makes Southward a Full Point, and so Back from the South to East, conveying, thus, Folks of the colour of the Day, like Us.

* E.g. Parry (1), p. 41. The Portuguese policy of setting up overseas bases was no doubt forced upon them by the hostility of the Muslim traders who were a priori antagonistic to any European activities in Indian waters. They naturally felt that their position as middlemen of the Eastern trade with Italy and other parts of Europe was threatened. In this they were quite right, but the whole situation was a direct legacy of the Crusades. The irreconcilable antagonism of the Levant were thus transferred to poison the whole of the Indies.

* Certain Chinese sources such as the Chhi Lieh Wu Chi give us a picture of what seems like an exceptionally large proportion of carpenters, iron-workers and all kinds of artisans in the crews of the Treasure-ships of the expeditions under Cheng Ho; cf. Pelliot (2a), p. 306.

* This is of course the date of the first 'discovery' under Magellaes; the islands were not colonised in force until the 'eighties'; cf. Misid (3), p. 589. The Portuguese had first encountered Chinese junk at Malacca in +1509, and came first to Canton in +1513. Macao was founded (by Portuguese squatters), the Chinese always used to say) much later, in about +1555, but its importance as a cultural entrepôt proved very great, especially because of the Jonnats (cf. Vol. 3, pp. 475 ff., Vol. 4, pt. 2, p. 436). See the remaining account of life there by Boxer (4).

* For instance the fusion of medieval European and Asian sciences into one universal modern science (cf. Vol. 3, pp. 448 ff., and Needham, 59).

* v. 77, Fanckhawe tr. p. 166; cf. Aubertin tr. vol. I, p. 479; Atkinson tr., p. 135. The epic was begun in Macao about +1556 but not printed till +1572.

* An anonymous Rôstéor of this voyage has been preserved, and translated with commentary by Ravenstein (2). On Ibn Majid see Ssanowski (2, 1) and Brochado (2).

* It is almost invariably said that Sodré discovered Socotra. It is high time that this tiresome convention of European historians was discontinued. A Portuguese ship could not 'discover' an island which had been colonised by Arabs and visited by Chinese for many centuries previously. The junks of the Ming navy certainly went there, and as far back as +1425 there had been an account of the island (Chu Fan Chih, ch. 1, p. 270, cf. Hirth & Rockhill, pp. 131 ff., in which Chao Ju-Kua took care to mention its most characteristic export, the red resin called 'dragon's blood'. This comes from the fruits of palms (Dammorrhops spp.) and of trees and shrubs (Driverm spp.); see Rockhill (1), vol. I, pp. 747 ff., 857 ff. It is used as a dye. Let us say: 'After Sodré's visit, Socotra became known in Europe.'

* From this time (+1500) dates the oldest extant Portuguese chart of the Indian Ocean, on which see Uhden (4). On Portuguese cartography in general see Cortesão (3).

* On Goa see Pernaze (1) and the more popular book of Collins, especially (2). On the history of Portuguese relations with the Malabar coast see Panikkar (2). One of the better points of Albuquerque's policy was not only the general absence of colour bar in Portuguese settlements in Asia but the positive encouragement of marriages between Portuguese and Arabic, Indian and Indonesian girls. Couples were given dowries of boats and other bread-winning gear. Cf. Baiso (1), pp. 72, 74, 125; and, in general, Freyre (1). This was in striking contrast with the attitudes of other European nations in such matters.
Actually the information had come from India. After the return to Lisbon of Nicolau Coelho, one of Vasco da Gama’s captains, but before the arrival of the Admiral himself, a Florentine merchant residing there, Girolamo Sernigi, wrote a report of the great voyage to a colleague in Italy. In this he mentioned that ‘certain vessels of white Christians’ had visited the Malabar ports regularly during the preceding century. Writing in July 1499 he said:

It is now about 80 years since there arrived in this city of Chalicut certain vessels of white Christians, who wore their hair long like Germans and had no beards, except round the mouth, such as are worn at Constantinople by cavaliers and courtiers. They landed wearing a cuirass, helmet and visor, and carrying a certain weapon like a sword on the end of a spear. Their vessels are armed with bombardiers shorter than those in use with us. Every other year they landed, and for this occasion they are, nor what merchandise they bring to this city, save that it includes very fine cloths (da Gama) which may well be, as some have thought, that the Arabs of al-Zanj welcomed the Portuguese at first precisely because they thought they were Chinese, and only became hostile when they found that they were Germans it seems to me that we should have had some notice about them; possibly they may be Russians if they have a port there. On the arrival of the Captain (da Gama) we may learn who these people are. 

This letter was first published by di Montalboddo (1) in +1507, but whether Sernigi ever gained any further enlightenment the available documents do not say. It is quite evident now, however, that the ‘white Christians’ were the Chinese, if only from the description of their characteristic hand weapon. It may well be, as some have thought, that the Arabs of al-Zanj welcomed the Portuguese at first precisely because they thought they were Chinese, and only became hostile when they found that they were Christians from Frankland. A comment in itself, this, sad and paradoxical, on that culture which bore upon its banners ‘On earth peace, and goodwill toward men’.

(iv) Contrasts and comparisons

Now comes the moment for comparisons and contrasts between the sea-farers from East and West. Unanswered questions present themselves in some such order as this—nautical aspects, war, trade and religion. Let us try to elucidate them with all justice to both sides, captains and crews that never met on earth, but only now in the court of history.

From the maritime point of view, central to the present Section, we can see at once that the Chinese achievement of the +17th century involved no revolutionary technical break with the past, while that of the Portuguese was more original. The Chinese had had their fore-and-aft lug-sails since the +3rd century at least, and already in the time of Marco Polo and Chao Ju-Kua their ships were many-masted. If they used

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80 their mariner’s compasses in the Mozambique Channel, they were only doing what their predecessors had done in the Straits of Taiwan right back to the foundation of the Sung navy at the beginning of the +12th century. Though their stern-post rudders were attached in weaker fashion to the hulls than those of the Westerners with pintle and gudgeon, they were highly efficient in more ways than one, and descended from patterns as early as the +1st century. The most obvious difference which would have struck everyone if the vessels of da Gama had met those of Chêng Ho lay in the much greater size of the Treasure-ships of the Grand Fleet (Ta-taung Pao chhuan) for many of these were of 1,500 tons if not considerably more, while none of Vasco’s were over 300 tons and some were much less. In shipbuilding China was far ahead of Europe. But while the Chinese vessels were the culmination of a long evolutionary development, those of the Portuguese were relatively new in type. At the end of the +14th century European ships were equipped only with square-sail rig; the barca might be some 30 tons with one mast, or up to 100 if two. Of this kind, doubtless, were the early vessels sent out by Prince Henry. But finding the North-east Trade-winds quite contrary to their return from the Guinea coast, the Portuguese threw overboard the square-sail rig, and for their famous caravels a adopted a fore-and-aft one, in the form of the lateen sail, from their enemies the Arabs. This permitted sailing much closer into the eye of the wind. For the past half-century, since the fundamental work of Lopes de Mendonça, b it has been clear that the caravel was a capital invention. By +1450 (i.e. by the end of the Chinese period) these ships carried triangular lateen sails on as many as three masts and averaged between 50 and 100 tons. Then, as the century went on, the superior advantages of the square-sail for running before the wind reasserted themselves, and ships began to be built which combined both rigs. Thus about +1500 the caravela redonda (up to 200 tons) carried two rather small square-sails on the foremast, and lateens on the three after-masts, while the nau redonda (of about the same burthen) had multiple square-sails on the fore- and main-masts with a lateen only on the mizen. Columbus’ Santa Maria was so rigged. But the originality of the Portuguese seems somewhat qualified when we remember that the basic inventions they used, the mariner’s compass and the stern-post rudder were

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a The Chinese contribution to the development of the mariner’s compass has been related in Vol. 4, pt. 1, pp. 249 ff. A summary will be found in Needham (39).

b See pp. 452 ff. below, summarised in Needham (40).

c Mills (9) estimates as high as 11,500 tons burthen for the largest. Cf. the discussions on pp. 458 and 480 ff. The average complement rose during the first half of the +15th century from under 450 to over 700 men (Lo Jung-Pang). Cf. Kuan Chia-Ch’eng (1).

d Prestage (1), p. 350. The Chinese ships probably looked something like the junk shown in Figs. 986, 987, (pl.), but much larger.

f An admirable account of the Portuguese contribution to ship design and rig in the +15th century is given by da Fonseca (1).

The word itself is said to be of Arabic origin (da Fonseca (1), p. 47). Oriental influence is also claimed for the hull (Amalier, in Eurasia (1), vol. 2, pp. 25 ff.). On the lateen sail, see pp. 609 ff. below.

Many students confirmed him—Navarette, la Rojrie, Guillen y Tato, da Fonseca.

At the same time it is clear from comparative study that everything the Portuguese did with their caravels could have been accomplished equally effectively with small seas-going junks. Voyages might have taken a little longer—but the crews would have kept much drier.

Notes:

1 From Ravenstein (2), p. 131.
2 Osorius Silvianus, (1), p. 296, quoted by Mickle (1), p. 26. For these interesting references we are indebted to Prof. Donald Lach and Dr Lo Jung-Pang.
3 See pp. 600 ff. below.
4 Cf. p. 467 above.
5 This is quite evident now, however, that the ‘white Christians’ were the Chinese, if only from the description of their characteristic hand weapon. It may well be, as some have thought, that the Arabs of al-Zanj welcomed the Portuguese at first precisely because they thought they were Chinese, and only became hostile when they found that they were Christians from Frankland. A comment in itself, this, sad and paradoxical, on that culture which bore upon its banners ‘On earth peace, and goodwill toward men’.
6 Obviously the crescentic bill or gisarme (chi). Cf. Sect. 30c.
7 From Ravenstein (2), p. 131.
8 Osorius Silvianus, (1), p. 296, quoted by Mickle (1), p. 26. For these interesting references we are indebted to Prof. Donald Lach and Dr Lo Jung-Pang.
9 See pp. 600 ff. below.
10 Cf. p. 467 above.
transmissions from much earlier Chinese practice,\(^a\) the principle of multiple masts was characteristically Asian,\(^b\) and the lateen sail was taken directly from the Arabs. Of the comments of the first Chinese sailors who examined European vessels little or nothing has remained, but from the middle of the +16th century there was a slight admixture of types, as we have seen,\(^c\) though Chinese shipbuilding remained for the most part unchanged. Since Chinese pictures of European ships are rather uncommon, we reproduce in Fig. 988 that of the \(\text{hat po}\)\(^d\) which Fr. Verbiest included in his \(\text{Khan Yu Thu Shao}\)\(^e\) (+1672).\(^f\)

\(^a\) The importance of these two discoveries for the great geographical explorations has been repeatedly stressed by historians; cf. a typical statement in Trend (1), cit. p. 542 below.

\(^b\) Cf. pp. 474 above and p. 602 below.

\(^c\) P. 458 above.

\(^d\) Ch. 2 (p. 213); cf. p. 428 above. The picture was reproduced in TSCC, \(\text{Kuo hsiung tien}\), where it brings up the rear of the shipping illustrations in ch. 178. On the comparative superiority of European ocean-going ships over those of South Asia after +1500 see our comments on Cipolla (1), pp. 513, 514 below.

\(^e\) 海舶

\(^f\) 参阅图说

There was another matter in which the Portuguese showed seemingly more originality than the Chinese, namely the understanding and use of the regime of winds and currents. It would be truer to say that the problems set for them by Nature were much more difficult, and that they rose gallantly to the occasion. For the Atlantic Ocean had never been explored, and these were the seas of which it could most truly be said: ‘por mares nunca de antes navegados’.\(^g\) The general situation can be at once appreciated from any good world-maps of winds and currents (cf. the companion Fig. 989).\(^h\) Almost as far south as Madagascar the Chinese were within the realm of the monsoon winds,\(^i\) the ‘junk-driving winds’ with which they had been familiar in their own home waters for more than a millennium. One sailed south in the winter and north in the summer (broadly speaking).\(^j\) Once free of the narrow waters of the East Indies, one had the North Equatorial Current to help one across from Sumatra to Zanzibar (if one was not calling at Calicut); and the more southerly Equatorial Counter-current might help one back.\(^k\) But the inhospitable Atlantic had never encouraged sailors in the same way, and though there had been a number of attempts to sail westwards,\(^l\) that ocean had never been systematically explored. First the Guinea coast proved to be a trap, for while the North-east Trade-winds helped the ships down, and the Canaries Current and the Guinea Current lent their aid, the journey back meant endless tacking. This (as well as disease) might be the origin of the English nautical adage:

\(\text{Beware, beware the Bight of Benin,}
\text{Whence few come out, though many go in.}\)

But the Portuguese knew well that above the ‘Horse Latitudes’ under the Azores, there were strong westerly winds (accompanying indeed the Gulf Stream) which would blow them home, so in returning from El-Mina, the fortress-factory they had built on the Volta River, they bore out far westwards into the Atlantic with the Trades on their starboard beam, and then came north into the Westerlies to run for the Tagus. This

\(^g\) Camoens, \(\text{Lusiad}\), 1, 1. Of course sailors the world over had been working according to prevailing winds and currents since time immemorial. Cassen (1) has shown that the Roman grain-ships returning from Alexandria used to sail east of Cyprus and touch at North Syria on the way home instead of taking the direct route to Ostia in western Italy by which they had come. Similarly the Persian sailing-rafts were found to be using the inshore current when southbound, but going out to sea to take advantage of the Humboldt Current when northbound (cf. Heyerdahl (2), p. 615, and Col. B. Kennon in Leland (1), p. 71, for the Mexican-Californian coast, as also p. 547 below). But the scale and boldness of the Portuguese hydrographic work in the Atlantic astounds.

\(^h\) Opp. p. 650. See A. A. Miller (1); Sverdrup, Johnson & Fleming (1); C. G. R. Williams (1).

\(^i\) The full strength of the monsoon is said to end about the latitude of Malindi (Fripp, I), p. 71, for the Mexican-Californian coast, as also p. 547 below. But the scale and boldness of the Portuguese hydrographic work in the Atlantic astounds.


\(^k\) It seems unlikely that Chinese ships ever made much use of the South Equatorial Current running westwards, and its accompanying easterly Trade-winds, though perhaps the junks of which Fca Murao heard (p. 501) may have done so.

\(^l\) We hear of at least one such attempt by Moors from Arabic Lisbon (cf. pp. 475, 503) and there were the Genoese Vivaldi brothers in +1697. Usually no one returned. Cf. Dunlop (4).
course was known as the Volta da Guiné or the Sargasso Arc (Fig. 989a). A chronicle of King João II (r. +1481 to +1495) relates an interesting event at his court. Talk turned at the royal table to the sea-ways to Guinea and back, and a notable navigator, Pero d’Alenquer (muito grande piloto de Guiné), boasted that he would bring back a square-sailed nau safely, however large she was. But the king insisted that this might no wise be, and that only lateen-sailed caravels could make the return journey. In fact the Arc was a State secret, all the more important because the Portuguese had acquired particular skill in the building and handling of caravels. Their sale abroad was forbidden, and other countries constructed and sailed them only with much difficulty.

As the Portuguese found their way down the African coast they encountered the opposite hydrographic situation. The northward Benguela Current opposed their progress, and the strong South-east Trade-winds were equally unfriendly. But once beyond lat. 35° S. the Westerly Polar Winds, very strong in summer, would help them on their way. Thus towards the end of the +15th century another great Arc was ventured, the Volta do Brasil, i.e. the Brazil, or Cape St Roque, Arc. Leaving the African coast about Sierra Leone, the ships bore out far into the Atlantic with the wind on their port beam, made landfall if necessary south of that Brazilian cape, and so, sailing on south, circumvented the South-eastern Trade-winds until the Roaring Forties shot them through into the Indian Ocean. Such essentially was the navigation of da Gama and Cabral. The fact that they sailed with barques rather than caravels is highly significant, for it can only mean that previous Portuguese explorers had plotted out the route. How far the +15th-century Portuguese advanced beyond

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**Legend to Fig. 988 (continued)**

In the book the accompanying text says: ‘(A Western) ocean-going ship (hai po) looks both broad and large; it can carry more than 1,000 men; it has more than ten sails needing in all about 24,000 ft. of (canvas) cloth; the masts are 200 ft. in height; the iron anchor weighs over 6,350 catties (c. 37 tons); the cordage weighs more than 14,300 catties (c. 84 tons). Further details can be found in the last section of the Hai Po Shuo (a chapter earlier in the book).’

It must be remembered that this was a far more advanced type of ship than those in which the Portuguese had first entered the Indian Ocean. Already at that time however they were probably superior to those of any South Asian nation, and by the time, thirty years later, when European–Chinese maritime contacts began in earnest, two things had happened: the Ming navy had been completely run down both in individual size and numbers (cf. p. 524), and the ships of the West, built with the new technology and above all armed with the improved ordnance of Renaissance capitalist Europe, could outclass in turn their East Asian rivals. Since the fleets of Chinese bureaucratic society never reached their +17th-century apogee, by a hundred and sixty years later, the time of this picture, the superiority of Western warships was unquestionable, and indeed the period of the Opium Wars was already adumbrated, a period only now in our own time ending.
the level of the Arabs and the Chinese in astronomical navigation during this period is a difficult question, and we may return to it later (pp. 557, 557).

Now we can turn to consider briefly war and trade. Here the contrast is an extraordinary one, for while the entire Chinese operations were those of a navy paying friendly visits to foreign ports, the Portuguese east of Suez engaged themselves in total war. Already in +1444 the first casualties of their campaign occurred, when Gonçalo de Síntia and six others were killed at the Gulf of Arguin in Mauretania while trying to capture some of the inhabitants. But so long as the Portuguese were working down the West African coast their aggressive activities were (apart from slaving) relatively restrained, and it was only after +1500, when they were in a position to carry on terrorist warfare against the East African Arabs, and then against the Indians and other Asians, that European naval power showed what it could do in earnest. 'In the bloodstained history of mankind upon this earth, that portion of the East African shore successively described as Azania, the land of Zanj and the Swahili Coast, certainly had its full share of strife.'c Before the coming of the Portuguese the Arab city-states had no defence-works; they only arose when it became clear that it was the settled policy of the Westerners to destroy the Arab African-Indian trade route and branch. It would be tedious to recount all the savage attacks which took place, the sacking of Mombasa in +1505, the devastation of Oja, Brawa and Socontra in the following year, the burning of Mombasa again in +1528, and so on. In the 'eighties two attempts were made by the Turks under Mir Ali Bey to recapture the coast, but they failed. Meanwhile, Mombasa and Manda were again burnt to the ground by the Portuguese. The records repeatedly say that in many of these sieges no living thing was spared. In India and on the way there the Portuguese behaved in the same way. They battered and sank Arab pilgrim-ships, fired the limbs of executed Muslims over Indian cities, treacherously killed their ally the head of the Javanese colony at Malacca, and blinded with red-hot bowls the relations of the Sultan of Ormus. 'Cruelties,' wrote Whiteway, 'were not confined to the baser sort, but were deliberately adopted as a line of terrorising policy by Vasco da Gama, Almeida and Albuquerque, to take no mean examples. Da Gama [and Cabral] tortured helpless fishermen; Almeida tore out the eyes of a Nair who had come in with a safe-conduct because he suspected a design

on his own life; Albuquerque cut off the noses of the women and the hands of the men who fell into his power on the Arabian coast. To follow the example of Almeida and sail into an Indian harbour with the corpses of unfortunate, often not fighting-men, dangling from the yards, was to proclaim oneself a determined fellow. I mention these facts with reluctance, but they certainly do something to correct the stereotyped image (still met with in Europe) that Asians have been more cruel and barbarous than Europeans. Some of the greatest occidental scholars of the time approved these activities. João de Barros wrote:

It is true that there does exist a common right to all to navigate the seas, and in Europe we acknowledge the rights which others hold against us, but this right does not extend beyond Europe, and therefore the Portuguese as lords of the sea by the strength of their fleets are justified in compelling all Moors and Gentiles to take out safe-conducts under pain of confiscation and death. The Moors and Gentiles are outside the law of Jesus Christ, which is the true law that all must keep under pain of damnation to eternal fire. If then the soul be so condemned, what right has the body to the privileges of our laws? . . . It is true that the Gentiles are reasoned beings, and might if they lived be converted to the true faith, but insomuch as they have not shown any desire as yet to accept this, we Christians have no duties towards them.

What could the Chinese show in comparison with all this? 'They bestowed gifts upon the kings and rulers,' we read above (p. 488), 'and those who refused submission they over-awed by the show of armed might.' This statement demands examination. But on all their expeditions there were only three occasions when they got into difficulties and had to fight. The first was in +1406 when Chhen Tsu-I, a tribal chief of Palembang who had been pillaging merchants, made a surprise attack upon their camp; but he was defeated, captured and subsequently executed in Nanking. The third happened seven or eight years afterwards, when Su-Kan-La, one of the pretenders to the throne of north-western Sumatra, quarrelled over the distribution of the Chinese gifts. He too led forces against those of Cheng Ho, but he was beaten at Lambri and captured with his family. The second occasion was much the most serious. In +1410 the King of Ceylon, Ya-Lieh-Khu-Nai-Eth, 1 ál. Alagakonanné, probably, but

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Notes:

2. After the war, Akbar = Alagakonanné.
5. It is not quite clear what the Chinese are supposed to have done in +1406 and +1410.
not certainly, Bhuvaneka Bahu, entered Chêng Ho's expeditionary guard into the interior and then demanded excessive presents of gold and silk, meanwhile sending troops to burn and sink his ships, which lay, in all probability, in Galle harbour or Beruwala roads. But Chêng Ho pushed on to the capital (undoubtedly Kotte, as Kandy had not been founded), took the king and his weakly defended court by surprise, and then fought his way back to the coast with the captives, routing the Sinhalese army on the journey. The prisoners were taken to Nanking, where they were kindly treated and sent home again after an arrangement had been made to choose a relative of the king as his successor. P. Naval arms might thus indeed something very different in the Chinese and the Portuguese interpretations. This corrects Vol. 3, p. 558, but the question is a complicated one as the Chinese names do not quite agree with those in the Sinhalese histories, nor do the personalities and their reputations coincide. See Pelliot (a), p. 278; (b), p. 284; Hei Yu-Hu (1), pp. 103 ff.; (2), pp. 429 ff. There are several versions of what happened in Ceylon, the fullest and the least interesting being a Buddhist commentary on Hsi-An-Chuang's Ho Yu Chi preserved in TSCC, Pien i tsien, ch. 66, pp. 98, 102, tr. Lévi (2). Here the Sinhalese king is represented as a Hinduiser, and reproved by Chêng Ho for paying inadequate honour to the Tooth relic. Miracles attend the embankment and the safe journey home. Whatever exactly happened, there was nothing to sully Chêng Ho's reputation as a humane emissary and commander-in-chief. The literature contains much more combat material than this, but it stems from a fictional, not a historical, source, the novel Hsi-Yang Chi of Lou Mou-Teng, and is therefore discounted by purists. One narrative in this concerns the siege and bombardment of Al-Ahsa somewhere on the Hadhramaut coast. Ho's Duyvendak (5) went into taking the mention of Hsiang-yang in 1411 to imply large cannon, for as we shall show in Sect. 304, this was a technical term for large counter-weighted trebuchets. That these were often mounted on battle-ships of Sung and Ming times we have already seen (p. 432 above). None the less, it is commonly admitted that the fleets of Chêng Ho were armed with bombards and other gun­powder weapons is undoubtedly correct. Many dated Chinese cannon of the latter half of the 14th century are known (cf. Sect. 304, and meanwhile Sarton & Goodrich (1); Goodrich (19); Goodrich & Fung Chia-Shêng (1) and Wang Ling (1), perhaps the best general account of the development of explosives in Chinese warfare). A bronze bombard 1 ft. 2 in. long, now in the Peking Historical Museum, with an inscription of +1331, is certainly the oldest dated metal cannon in existence, East or West. For an active in Ho's time and provided many of his escort warships and the marines who manned them. There is evidence that these bombards were mounted on a stool-like carriage so that they could be made to swivel for aiming. Lastly, a bombard with a Chinese inscription bearing the date +1412 was found in Java and is now in the Museum f. Völkerkunde in Berlin (cf. Partington (5), p. 275 ff.; Feldhaus (1), col. 244, p. 8). It is remarkable as having a covered touch-hole, yet unknown on contemporary European specimens. One moral of the story is that what the old Chinese novelists said is by no means always to be discounted. Archaeology, which always has the last word, is liable to justify them. But the existence of gunpowder weapons in Chêng Ho's fleets is one thing, and the extent to which they were used is another.

At trade, our knowledge of the inner workings of that matter is as usual still very deficient, but it was only natural that what was done both by the Chinese and the Portuguese was done under the aegis of their respective economic systems, and these were very different. While much further research is needed, it seems at least clear that the Portuguese activities were from the start much more concerned with private enterprise. The search for the 'El-Dorado' which would make one's personal fortune was an integral part of the conquistador mentality. Well before the death of Prince Henry expeditions primarily commercial were wending their way round the West African coast, and the more Africa was explored, the further the expeditions had to go and the more necessary it became to make them financially at least self-supporting. Trading ventures were thus certainly encouraged and licensed by the Portuguese court, but behind it stood the international finance, indeed the developing capitalism of all Europe; and the role of such support is now being actively investigated. By contrast the Chinese expeditions were the well-disciplined naval operations of an enormous feudal-bureaucratic State the like of which was not known in Europe, their impetus was primarily governmental, their trade (though large) was incidental, and the 'irregular' merchant-mariners whose trafficking was to be encouraged were mostly humble men of small means. The bureaucracy in China generally saw to that. Only their numbers made them important. And what was true of trade in general was true also of the slave-trade in particular. The Chinese and other Asian nations had been using negro slaves for many centuries, but the fact that their slavery was basically domestic kept the practice within bounds. Not so the use of Africans in agricultural plantation labour, especially in the New World, which brought it about that between +1486 and +1641 no less than 1,369,000 slaves were taken by the Portuguese from Angola alone. One has only to read the celebrated chronicle of de Zurara himself to see that the Portuguese expeditions down the West Coast of Africa involved kidnapping and slave-raiding forays from the very first. It had been the mutual custom of Moors and Christians all round the Mediterranean throughout the Middle Ages, but now in mournful augury it was extended to those who had never had any part in that quarrel. But the result of this we cannot follow further here.

Thus the paradox appears that while the feudal State of Portugal, hardly emerged Prince Henry seems to have planned a merchant port town near Sagres but it never developed (de Zurara, tr. Beasley & Prestage, p. 21). The first 'factory' was established at Arguim in +1448, and the famous fortress-factory of El-Mina de Ouro on the Volta River in Ashanti in +1482. These were the predecessors of Fort Jesus at Mombasa and all the fortified trading-posts of the East Indies.
from the Middle Ages, founded an empire of mercantile capital, bureaucratic feudalism, though certainly not the economy of the future, gave to China the lineaments of an empire without imperialism. But we must beware of doing any injustice to the first Portuguese merchants battling in the Indian Ocean; perhaps they were caught in a mesh of intractable economic necessity? During da Gama's first visit to Calicut in +1498 a highly significant event occurred. When the Portuguese presented the goods which they had brought, consisting of striped cloth, scarlet hooded hats, strings of coral, hand wash-basins, sugar, oil and honey, the king laughed at them, and advised the admiral rather to offer gold. At the same time the Muslim merchants already on the spot affirmed to the Indians that the Portuguese were essentially pirates, possessed of nothing that the Indians could ever want, and prepared to take what the Indians had by force if they could not get it otherwise.

There is something very familiar about this scene. In fact it symbolised perfectly a fundamental pattern of trade imbalance which had been characteristic of relations between Europe and East Asia from the beginning, and which was destined to continue so until the industrial age of the late nineteenth century. Broadly speaking, Europeans always wanted Asian products far more than the Easterners wanted Western ones, and the only means of paying for them was in precious metals. This process occurred at many places along the east-west trade-routes, but primarily of course in medieval times at the Levantine borders between Christendom and Islam. The Chinese on the other hand probably never had to face an adverse balance of trade, for silk and lacquer were everywhere esteemed, and good in exchange for anything the Chinese ever wanted to buy. As Domingo de Navarrete said in his book of +1675:

* Prestage (1), pp. 264 ff., based on the anonymous Roteiro ed. Ravenstein (a).
* The Mozambic merchants also said that if the Portuguese were entertained 'other vessels would stay away', meaning perhaps those of the Chinese as well as their own, and the country would be ruined. 
* Cf. Gibbon, Decline, vol. I, pp. 88 ff. There are two outstanding treatments of this subject, the book of Warrington (1), now old, but good, esp. pp. 180 ff., and that of Braudel (1), a luminous exposition far wider than its title implies, esp. pp. 34 ff. The full panorama has been well appreciated in an unpublished work by Purcell (a), esp. pp. 159 ff.
* To show the continuity of this historical pattern it is instructive to compare the lists of desirable Asian goods given in the Periplus of +970 +110 (Schoff (3), pp. 248 ff., cf. Vol. I, pp. 178 ff.) and in the letters of Albuquerque, c. +1513 (de Almeida (1), vol. 3, pp. 518 ff.). J. Firense (1) now proposes the later date of +1267 for the Periplus, long ago suggested by Rennaud, but that does not affect our argument. 
* In the +16th century there was a sharp separation at this frontier, for letters of credit, so common and useful within Europe, did not run in the Islamic or Asian countries (Braudel (1), p. 362). The latter had of course their own systems but, as it were, 'outside the sterling area'.
* On the chain of east-west exchanges see Lopez (a), p. 309, but I very much doubt whether, as he thinks, the Chinese had an unfavourable balance in their trade with the Arab and South-east Asian countries in the +9th and +12th centuries. He seems to have misunderstood a passage in Duyvendak (8), p. 16 (taken from Hirth & Rockhill (1), p. 19 and derived from Sung Shih, ch. 186, pp. 404 a, b, 278) where 'units of count' refers to the merchandise, and does not mean coins or weights of precious metal paid by the Chinese.
* It is of much interest that the idea of enriching the country by foreign trade is found in Chinese literature as early as +80. The Yan T'ien Lun (ch. 2, p. 60; cf. Vol. 2, p. 257) says: 'Good rulers exchange the produce of their country for what is substantial for their own economy. Insignificant articles are means of inveigling foreign countries and snaring the treasures of the Chibing and the Ho. Thus a piece of Chinese plain silk can be exchanged with the Huns for articles worth several pieces of gold.' Foreign products (thus) keep flowing in while our wealth is not dissipated...'; tr. Gale (1), p. 14, mod.
* Cummins ed. vol. 1, p. 137.

My Design is only to give some hints of what is most remarkable, which will suffice to make known how bountifully God has dealt with those People... giving them all they can desire, without being necessitated to seek for anything abroad; we have that there can be this Truth.

In the present work we have already met with the European-Asian imbalance twice. During the Roman empire, from about -50 to +700, gold and silver were drained away from Europe to pay for the silk of China and the spices of India, a process which may be followed not only in the Roman coins scattered throughout Asia but in the gold stocks of the Han. Nearly two thousand years later the opium trade with South China (and hence the Opium Wars) arose because the East India Company, alarmed at the drain of silver from Europe to pay for its silk, tea and lacquer, sought for some substitute commodity. Indeed, the Mediterranean region acted for two millennia as a kind of monstrous centrifugal pump continually piping off towards the East all the gold and silver which entered into it. Alexandrya might pay partly with glass, contemporary Western Europe partly with slaves, Venice with mirrors and England with tin, but the Arabs, the Chinese and the Indians took little interest at any time in the most typical European products such as woolen cloth or wine, and when all the barter was over

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29. VOYAGES AND DISCOVERIES

A fact here relevant, but not perhaps as well known as it might be, is that the Hon. East India Company, founded in +1600, developed directly out of the Levant Company, founded in +1581.

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29. NAUTICAL TECHNOLOGY

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[Continued in subsequent sections]
there remained a large perennial insoluble deficit. And even after the discovery of the Americas and the exploitation of Potosi silver, the Asian suction still asserted itself and much of the metal found its way westward through the Philippines instead of continuing to fill the coffers of Spain. Thus in the presence of the somewhat discomfited admiral at the term of one of the greatest sea-journeys of history, the imbalance of the Lisbon trade reappeared exactly in its classical form.

What then, were the Portuguese sea-captains to do at the end of the 15th century? First, crusading apart, spices they must have. The European demand for pepper was sure and certain, it was the expression of a very real need, it was not (as is so often said) a ‘luxury trade’. Until the full development of winter fodder a couple of centuries later, European animal husbandry could keep each year only the animals needed for labour and reproduction; the others had to be killed and their meat preserved by salting. This was the process which needed pepper by the shipload, the pepper which

1 In a word, Asia was indifferent to European staples. As the Ch'ien-Lung emperor wrote to George III in often-quoted words (s. 1793): ‘Strange and costly objects do not interest us. As your Ambassador [Lord Macartney] can see for himself, we possess all things (that we need). We set no value on rare and ingenuous objects [i.e. “sing-songs”], cf. Vol. 4, pt. 3, p. 532 ff., and have no use for your country’s manufactures… There is, therefore, no need to import the goods of foreign barbarians in exchange for our produce. But as the tea, silk and porcelain of the Chinese Empire are necessities for European nations, we have permitted as a mark of special favour that foreign warehouses should be established at Canton so that your wants may be supplied and your country thus participate in our benevolence’ (tr. Backhouse & Bland (1), p. 324 ff., mod.).

2 This was one of a number of factors in the drying-up of the Peruvian-Bolivian consignments of silver to Spain in the middle of the 15th century. Cf. Hamilton (1), p. 35 ff., Braudel (1), p. 415.


5 This prediction is acknowledged by all students of medieval Western agriculture (e.g. Gans (1), p. 15; Franklin (1), p. 48, 124; Curwen (6), p. 84; Parini (1), pp. 123, 127, 132, 135 ff.). Turnips, native to Europe, could have been used from antiquity onwards, but the open-field system imposed too great a uniformity on crops, and implied general autumn stubble grazing incompatible with a planned winter-feed policy. Clover and lucerne (alfalfa, cf. Vol. I, p. 175), the ‘artificial grasses’ from the Middle Ages. El-Mina seems to have tapped rich sources of gold from the Nile, now independent, but the whole vast savannah territory between the Sahara in the north and the Congolese equatorial rain-forests in the south (cf. Davidson (I), pp. 88, 89; Postan (I), p. 169; Lopez (4), p. 261).

6 The usual idea (cf. e.g. Prestage (1), p. 267; Jensen (1), p. 83 ff.; Drummond & Wilbraham (1), p. 34) is that pepper and other spices were simply for table condiments or sauces designed to disguise the pungent taste of meat. But as the tea, silk and porcelain of the Chinese Empire are necessities for European nations, we have permitted as a mark of special favour that foreign warehouses should be established at Canton so that your wants may be supplied and your country thus participate in our benevolence’ (tr. Backhouse & Bland (1), p. 324 ff., mod.).

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of course from an early time; the first mass in West Africa was celebrated by a Fr. Polono at Arguim in +1445. But before the end of the century the war against all Muslims was being extended to all Hindus and Buddhists too, save those with whom the Portuguese might find it expedient to arrange a temporary alliance. In +1560 the Holy Inquisition was established at Goa, where it soon acquired a reputation even more unsavoury than that which it had in Europe. It subjected the non-Christian as well as the Christian subjects of the empire to all those forms of secret-police terror which have disfigured our own century, yet more abominable here perhaps because enlisted in the interests of high religion.\(^b\) On board the Chinese ships what a contrast. Without forsaking the basic teachings of the sages Khung and Lao, Cheng Ho and his commanders were 'all things to all men'; in Arabia they conversed in the tongue of the Prophet and recalled the mosques of Yunnan, in India they presented offerings to Hindu temples, and venerated the statues of the Buddha in Ceylon.

Ceylon provided the scene for a particularly interesting example of this almost excessive urbanity. In 1911 a stele with inscriptions in three languages (Chinese, Tamil and Persian) was unearthed by road engineers within the town of Galle.\(^a\) This had commemorated, as was soon clear, one of the visits of the Ming navy under Cheng Ho, and took the form of an address accompanying religious gifts. Owing to differences in controlling influence ennobles and converts, inspiring acts of love and giving intelligent understanding and enlightenment by Thy miraculously responsive power. Wherefore according to the Rites we bestow offerings in recompense, and do now reverently offer them in the name of our Emperor, in recompense for the blessings of Thy beneficent protection. They have escaped disaster or excessive urbanity. In 1912 commanders were 'all things to all men' in Arabia they conversed in the tongue of the Prophet which have disfigured our own century, yet more abominable here perhaps because enlisted in the interests of high religion.\(^b\) On board the Chinese ships what a contrast. Without forsaking the basic teachings of the sages Khung and Lao, Cheng Ho and his commanders were 'all things to all men'; in Arabia they conversed in the tongue of the Prophet and recalled the mosques of Yunnan, in India they presented offerings to Hindu temples, and venerated the statues of the Buddha in Ceylon.

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How did it all end? Greater robers came to prey upon the lesser. During her temporary dynastic union with Spain the empire of Portugal remained intact, but its foundations were insecure. When the Portugese shook off this unwanted association in +1640 it was too late to save the first Ming dynasty, which is essentially a long trade route dotted with fortresses—from Mombasa to Muscat and Goa, to Cochin and on to Colombo, thence to Malacca, north to Macao or east to Timor. They could no longer be supplied sufficiently with men and munitions; Portuguese long-distance shipping could no longer bear the burden. The great eastern centres fell to the Dutch one by one; Malacca in +1641, Muscat in +1648, nodes of the network, then Colombo in +1656, Quilon in +1661 and Cochin in +1662. Goa, the ‘Rainha do Oriente’, declined into a grassgrown poverty. The Dutch had no high-flown ideas about the conversion of Asia to Christianity, what they minded was business; but others too could play at that game, perhaps with more subtlety, perhaps with better resources, and the Netherlands empire in turn passed first to the French and then the British. With the decline of colonialism in our own time the wheel has come full circle and Asia resurgent takes a rightful place in the counsels of the world.

The decline of Chinese long-distance shipping had set in even faster. In Portugal there had at first been some critics of the Western explorations but they were soon silenced by the evident profits arising from gold, slaves and other commodities. In China the critics had always been far more numerous and determined. The Confucian bureaucracy, with its country landlord's basis, was always liable to look askance at any intercourse with foreign countries. These countries were of no interest in themselves and could offer nothing but unnecessary luxuries. But according to the classical Confucian motif of scholarly austerity, to which in the national ethos the imperial court itself was theoretically bound, unnecessary luxuries were deeply wrong. And since all real needs of food and clothing, including even the magnificent products of Chinese craftsmanship, were available in abundance at home, what good could it possibly do to spend money on seeking strange jewels or other things with dubious properties abroad? The Grand Fleet of Treasure-ships swallowed up funds which, in the view of all right-thinking bureaucrats, would be much better spent on water-conservancy projects for the farmers' needs, or in agrarian financing, 'ever-normal granaries' and the like. Indeed, the Confucians were not in favour of too much grandeurisation of the Court, for in practice it meant of course the grandeurisation of the Grand Eunuchs thereof. It was thus no accident that the admirals of the fleet (strange though it may seem in Western eyes) were mostly eunuchs; in fact the whole episode of the great Italian voyages was only one engagement in that administrative battle between Confucian bureaucrats and Imperial eunuchs which had been going on since the Han Dynasty (I), p. 156.

As yet there is no full sociological study of the eunuchs in Chinese history, but a good account of another engagement, also in the Ming, but later, is given by Hucker (t).

ref 1. See Duyvendak (9), pp. 388 ff.
ref 2. Reference and a full account will be found in Duyvendak (9), pp. 395 ff. Some important passages are contained in the Shu Yu Chou T'ou Lu (Record of Dispatches concerning the different Foreign Countries) compiled from official documents by Yen Taghung-Chien. Minor officials were beaten for not being able to find dossiers which had been made away with by their own superiors.

ref 3. It is fair to say that not everyone accepts the account of these events which Duyvendak worked out. According to the Ming Shi, ch. 18a, p. 146, the documents which Liu Ta-Haia hid (not burnt) were concerned only with the planning of the invasion of Annam in the Yung-Lo reign-period, an invasion which Wang Chih wanted to repeat, and not with the naval expeditions of Ch'eng Ho. Ming Shi Chi, Shih Shi Mu, ch. 22 (p. 14) ch. 37 (p. 71) states the matter precisely in +1480. We are indebted to Dr Lo Jung-Pang for this context. But Duyvendak's case is still a strong one.
as important. Very great profits accrued to the Chinese State from the tribute-trade system of Chêng Ho’s time, but by the middle of the century a severe currency depreciation had set in, the value of the paper notes falling to 0.1% of their face value. Had the long-distance voyages been continued, China would have had to export precious metals. At the same time there was an increase in private trade beyond what had been contemplated at the beginning of the century, porcelain and new cotton products being exchanged directly at southern and western ports for the goods needed at home. There was also an unexpected technological revolution. For centuries canal carriage and sea transport had competed in the essential function of grain shipment from south to north, and now a heavy oscillation took place in favour of the former. It was in +1411 (as we saw above, p. 315) that the engineer Sung Li perfected the watersupply of the summit section of the Grand Canal, thus converting it into a full-capacity all-seasons proposition at last, and in +1415 the maritime grain-transport service was abolished while thousands of Chhen Hsüan’s new sailing-barges were put in hand. Thus at one and the same time a great nursery of deep-water sailors was lost, and orders flowed no longer into the maritime ship-building yards, which were run down to maintenance levels. Military events also intervened. The serious deterioration of the north-western frontiers diverted all attention from the sea, and in +1449 at the disastrous Battle of Thu-mu, that Chinese emperor who had suppressed the Treasure-ship fleets was himself taken into captivity by the Mongol and Tartar armies. At the same time there was a significant shift of population from the south-eastern seaboard provinces, reversing the trend which had been so strong at the beginning of the Southern Sung. Finally one should not overlook the development during the +15th century of a sterile conventionalised version of Neo-Confucianism, markedly idealist in metaphysics and Buddhist in religion, which led to a loss of interest in geographical science and maritime techniques, replacing the energetic valour of the early Ming by an introspective culture and a political lethargy. This was, indeed, but one aspect of a general decline which reflected itself severely in many branches of science and technology.

The navy simply fell to pieces. By +1474 only 140 warships of the main fleet of 400 were left. By +1503 the Têngchow squadron had dropped from 100 vessels to 10. Desertions occurred wholesale and the corps of shipwrights disintegrated. In the +16th century the anti-maritime party grew ever more powerful. Perhaps the government feared the disturbing social consequences of large ships in the trades of the world, and orders flowed no longer into the maritime ship-building yards, which were run down to maintenance levels. Military events also intervened. The serious deterioration of the north-western frontiers diverted all attention from the sea, and in +1449 at the disastrous Battle of Thu-mu, that Chinese emperor who had suppressed the Treasure-ship fleets was himself taken into captivity by the Mongol and Tartar armies. At the same time there was a significant shift of population from the south-eastern seaboard provinces, reversing the trend which had been so strong at the beginning of the Southern Sung. Finally one should not overlook the development during the +15th century of a sterile conventionalised version of Neo-Confucianism, markedly idealist in metaphysics and Buddhist in religion, which led to a loss of interest in geographical science and maritime techniques, replacing the energetic valour of the early Ming by an introspective culture and a political lethargy. This was, indeed, but one aspect of a general decline which reflected itself severely in many branches of science and technology.

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methods at the time of the Opium Wars, in the "forties of the last century," if the short­sighted landmen of the Ming court had not won the day. Indeed before the +16th century was out, their policy laid the coast open to ferocious attacks by Japanese pirates which were overcome only with great difficulty. The resulting increase of naval strength proved valuable at the end of the century, when between +1592 and +1598 squadrons from Shantung, Fukien and Kuantung fought side by side with those of the gallant Korean admiral Yi Sunsin, successfully repelling the fleets of Japan. Then in the +17th century the last remnants of the Ming navy fought under Cheng Chheng-Kung1 (Koxinga) against the Manchus and their allies the Dutch, whom he had expelled from Formosa in +1661. The Chhing emperors were not at all interested in the sea, and under them the navy languished.

We have seen how Chinese officials in the +15th century destroyed documents of incalculable historical value. At the other end of the Old World an earthquake did the same job. But the destruction of a large part of Lisbon in +1755 would not have been able to effect this if there had not been a persistent practice of secrecy on the part of the Portuguese rulers of the +15th century. The disappearance of documentary proof of many alleged Portuguese discoveries has caused great heartburnings among modern historians, but it seems that those who have maintained the existence of a policy of secrecy are being justified. For example, in +1485, three years before the voyage of Bartolomeu Dias, a "speech of obedience" was made at Rome by the representative of the King of Portugal, Vasco Fernandes de Lucena, in which he said that his country­men had attained to the Gates of India, 'almost to the Promontorium Prassum, where the Arabian Gulf begins.'d Nothing further was divulged. These words have always been difficult to explain unless some caravel captains had been exploring the East African coast a few years before the success of Dias. Similarly, Vasco da Gama has always been regarded as the first European to sail up the coast to Sofala. Yet when the manuscript rutter of Ahmad ibn Majid came to light a few years ago in Leningrad, he was found to say quite distinctly that a Frankish (i.e. Portuguese) expedition had been shipwrecked near Sofala as early as +1495, three years before the coming of da Gama.e Thus there is another interesting parallel between China and Europe in the destruction of records of the greatest naval age of both.

a The monograph of Chhen Chi­Thien (1) gives many particulars about the revival of shipbuilding at this time, and another one (3) on Tso Taung­Thang describes the foundations of the Fuchow Dockyard. See also Rawlinson (1); Anon. (2a).

b Cf. Vol. 3, p. 517. These incursions became severe from +1515 onwards. In the navy during this period see Hsi Hwa Hsien Thong Khow, ch. 132.

c Cf. pp. 683 ff. below.


e Brocado (1), pp. 79, 102.

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Amid the thundering billows and surges rearing mountain-high, helped by their flying masts and labouring oars, now with their cordage tightly strained and now under loosened sails, the envoys journeyed many myriads of li, and in their voyaging to and fro spent well-nigh thirty years...

Then, their vessels filled with pearls and precious stones, with eagle-wood and ambergris, with marvellous beasts and birds—unicorns and lions, hyalines and peacocks—with rarities like camphor and gums and essences distilled from roses, together with ornaments such as coral and divers kinds of gems, the envoys returned.

Some of the specimens had a particular symbolic value for the Chinese court; the giraffe, for example, was identified with the mythical animal chih-lin which according to age-old legend was one of the greatest auspicious signs appearing in Nature to signalise an imperial ruler of perfect virtue. Even the morose Hsia Yuan-Chi joined in and animals, was more marked in the former. Before long, of course, the humanistic Renaissance curiosity about all exotic things asserted itself strongly in the West, but this was an old Chinese tradition too which had been very powerful, for example, during the Thang period. Said Huang Sheng-Tsing.

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29. NAUTICAL TECHNOLOGY

Chîh (Illustrated Record of Strange Countries), which almost certainly profited from knowledge gained by the voyages, was also connected with him. For materia medica in general the place to look will be the Pen Tshao Pin Hui Ching Yao (Essentials of the Pharmacopoeia Ranked according to Nature and Efficacy), imperially commissioned by the Hung-Chîh emperor, and finished by Liu Wên-Thai and others in +1505. Between +1485 and +1506, the date of Monardes' book, there were at least three substantial Chinese pharmaceutical works, and then in +1506 came the 'Great Pharmacopoeia' (Pen Tshao Kang Mu) of Li Shih-Chen. In view of the very rapid spread of plants such as tobacco and maize in China after the discovery of the New World, it would even be surprising if the great voyages had brought no new drugs home.

The time has come to draw all these threads together. Sofala, by the sea-routes, was just about half-way between Lisbon and Nanking. Might it not perhaps have changed the course of history if the first Portuguese vessels coming past Sofala to Malindi had met much greater fleets of bigger ships with company more numerous than their own—and people, too, with very different ideas about the proper relations between civilised men and barbarians? 'Coming into contact with barbarian peoples', wrote Chang Hsieh in +1618 in a passage we shall shortly read, you have nothing more to fear than touching the left horn of a snail. The only things one should really be anxious about are the means of mastery of the waves of the seas—and, worst of all dangers, the morals of those avid for profit and greedy of gain. And indeed it was in accordance with this enlightened conception of inter-cultural contact that the Chinese set up no factories, demanded no forts, made no slave-raids, accomplished no conquests. Their total lack of any proselytising religion precluded friction from that source. The governmental character of their enterprises helped to restrain individual avarice and the crimes to which it could give rise. On the other hand, it is clear enough that the Portuguese behaviour originated as a development of the Crusader mentality. They were at war. But if the naval struggle against the Muslim mercantile States on the shores of the Indian Ocean was a continuation of the 'Holy War' for the holy places, it

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8 See p. 493 above.
9 Cf. Bertuccolì (1).

It may not be without significance in the present context that Li's friend Wang Shih-Chén, who wrote the preface for his book, was also interested in the voyages of Chêng Ho, and wrote several notices about them. For Li's biogegraphy see Lu Gwei-Djen (1).

One must remember here the good order and discipline of the Ming. The dynasty was not decadent in the +15th century, not comparable with the late Chhing and its position of rank inferiority in-the Western powers.

P. 584 below.

It is regrettabley evident that the doctrine of the curse of Cain, which made all Africans slaves by nature, was already familiar in de Zurara's time (Beasley & Prestige tr., p. 24).

If so, too, well emphasises this, (1), p. 42.

That the Chinese did not have a legacy of century-long religious wars is a feather in the cap of Chinese humanism. It would not be unfair, however, to say that the millennial struggles of the Chinese against the north-western nomads, from the Han and the Huns onwards, paralleled in a way the Crusades. But these were never wars of religious fanaticism, and (more important in the present context) they in no way affected Chinese attitudes to the peoples of southern Asia.

1 水草品嘉atcher
2 魏文泰
3 水草圖目
4 李時珍
5 王世貞
turned insensibly into something quite different, an insatiable thirst for gold, not only Muslim gold, and an obsessive desire for power over all African and Asian peoples, whether or not they had anything to do with Islam. And now too there began to come into play that decisive superiority of armaments which the scientific Renaissance was to give to Europeans, enabling them to dominate the Old World and the New for three centuries. 'From the Cape of Good Hope onwards', wrote Capt. João Ribeiro in 1585, 'we were unwilling to leave anything outside of our control; we were anxious to make everything in that huge stretch of over 5,000 leagues from Sofala to Japan... There was not a corner which we did not occupy or desire to have subject to ourselves.' And if there had been no weaker than she was, this vulturine ambition would not have spared her.

As we have seen, the 'Portuguese Century' was also the 'Chinese Century'. Our feelings of ambivalence towards the Portuguese explorers and conquerors cannot be overcome. Their great and courageous actions compel all admiration. Their behaviour and policy towards Arabs and Asians is often excused by the roughness and violence of the time. But the Chinese crews and captains were exact contemporaries of the Portuguese empire-builders, and their proceedings were not under the sign of Mars. Let us cherish the memories of those Lusitanians who were truly great, not so much Albuquerque and Almeida, but the navigators and cartographers, the astronomers and the naturalists. The stature of Dom Henrique is nothingButtoned; he remains for ever an inspiring and lovable figure. And from lesser men we have plenty to choose: João Fernandes who lived friendly with the Arabs and negroes of Mauretania, Fernão Queirós who went for the doings of his countrymen in Ceylon, Tomé Pires the amiable and unfortunate apothecary-ambassador, Sebastião Manrique the Augustinian who did not hesitate to take the yellow robe with a bhikku his companion to visit some Portuguese sailors exiled in the mountains of Arakan. Let us celebrate too the insight of a man not always approved of, the writer of the first autobiographical novel, Fernão Mendes Pinto. His famous Peregrinação of 1614 was not a plain unvarnished account like those of the other early Portuguese travellers in and near China, but rather a great work of art, a dramatic judgment on the exploits of his nation. A veiled criticism of the Western attitude to Asians runs all through it, a conviction that imperialism rested on irony. These are the voices of the just men who suffice to save Lisboa for our perpetual affection.

So there we leave them—voyagers from the East, the Chinese, calm and pacific, unencumbered by a heritage of enmities; generous (up to a point), menacing no man's livelihood; tolerant, if more than a shade patronising; in panoply of arms, yet conquering no colonies and setting up no strongholds—voyagers from the West, the Portuguese, crusader-traders out to take hereditary enemies in the rear and wrest a mercantile foothold from unsympathetic soil; hostile to other faiths yet relatively free from racial prejudice; hot in the pursuit of economic power, and heralds of the Renaissance. In all the maritime contacts between Europe and Asia in that dramatic age our forefathers were quite sure who the 'heathen' were. Today we suspect that these were not the less civilised of the two. And here we shall leave also that great arena the Indian Ocean, and turn our eyes to the seas of other continents and those who may have sailed them.

in the World, I have often with no little pleasure reflected how easily Lewis the Great would subdue those Provinces, if Nature had made us a little nearer Neighbours to China; he whom the stoutest Places in Europe can at best withstand but during a few days (1, p. 73). Finally even Macartney in +1794 had his ideas about invasion projects (Cranmer-Byng ed., pp. 205, 212). How fortunate it was for the future cultural synthesis of the world that Chinese civilisation was never overcome by European arms.

It was certainly sharpened by the fact that they were so unwelcome in the Indian Ocean. But they expected enmity, and were prepared to use all the force at their command to overcome it.

b We cannot forbear from referring to a former page which spoke of a strange astrological difference between the Romans and the Seres (Vol. I, p. 157).

c S. G. Ferrera (1).

d Collis (a).

e See the brilliant interpretation and paraphrase of Collis (l).
Who first navigated the waters of Australia? We know that New South Wales was first contact in +1560, study of the northern, western and southern shores by Zeechans, Edels, Nuyts and Tasman between +1612 and +1657, the naming of Western Australia as New Holland in +1660. Sixteenth-century recognitions are more controversial, but it seems quite probable that Cristóvão de Mendonça in +1522 or Gomes de Sequeira in +1525 trod upon Australian land and met its aboriginal people. A French claim for +1503 is still more shadowy. In recent times, however, the question of a possible pre-European discovery of the great island continent by Chinese sailors has been raised in serious form.

The subject is interesting partly because of the wide area of the Southern Seas over which Chinese discovery and traffic did certainly extend. The Chinese had maritime and commercial relations with the Philippines, Java, Bali, Borneo and Sarawak, and the Moluccas and Timor, not only in the time of the great Ming expeditions, but also flung Indonesian island countries is shown today (as in East Mrica) by the omni-

portuguese navigators in the East Indies must have got this information from Chinese or Malay maritime
tourists. It may be interpreted as implying early Chinese knowledge of Australia rather than early French. These maps depict consistently (as no earlier ones do) a large continent (Greater Java) south of Java. Collingridge (1), p. 306, after exhaustive study, came to the conclusion that the early Portuguese navigators in the East Indies must have got this information from Chinese or Malay maritime sources (cf. his pp. 166 ff., 180 ff., 192, 220, and passed it on to the French. The tradition of two island Javas, a "Great" and a "Little", goes back much further, for it is found in Marco Polo (Yule (3), pp. 36 ff.). Before +1536 these appear on European maps just as two large islands (cf. Collingridge (1), pp. 26 ff., 44, 106, 120). It is true, as Lo Jung-Pang (2) has pointed out, that there was a similar confusion between two Java (Shih-gho* and Chao *-kai) in the Chinese literature, but Schlegel (2) added much evidence to show that while one was modern Java the other was some place on the Malayan coast: moreover they were not distinguished as the greater and the lesser. Though the question is complex, there is much interest in Lo's suggestion that one of the Chinese Javas might have been Australia.

A rich Chinese traffic with Borneo, for example, especially active in the Thang, traded ceramics, beads and metal tools for the edible birds' nests of the Niah caves, for hornbill ivory, and for rhinoceros horn. The abundance of fine Thang ware, such as jars, in various parts of Borneo, demonstrates that the trade was already old in the time of Chao-Ju-Kua. But Sarawak affords dated pieces of Chêng Hô's century also. And much further evidence assuredly remains to be discovered.

Since Timor is just only over 400 miles from Port Darwin, there seems no inherent improbability in a visit of Chinese ships to that part of the Australian coast at any time from the +7th century onwards. Hence the interest of the new study of Fitzgerald (7a, b), who, after disposing of several baseless claims, drew attention to the finding, undisputedly authentic, of a Chinese Taoist statuette, about 4 in. high (cf. Fig. 991, pl.), near the shore at Port Darwin. It represents Shou Lao (1) the 'spirit of longevity', mounted on his vehicle the deer, and carrying the peaches of immortality in his hand. The discoverers in 1879 found this 4 ft. below the surface of the ground among the roots of a banyan tree at least 200 years old which had to be removed in the course of road-making. Black with age when unearthed, the statuette is in style Ming or early Chêng, quite reasonably contemporary with Chêng Hô. Its deposition may thus well have antedated the earliest European discoveries of Australia. That the image is Chinese is certain, but it would be hard to prove that it was left there by the crew of a Chinese junk rather than by Malay or Sundan fishermen who, like all South-east Asians, have treasured cult-objects of Chinese origin. The Macassarese and Buginese used to make annual visits to the Australian coast, following the monsoons in going and returning, and written records of their periodical residences are plentiful from the +18th century onwards. In exchange for natural products such as turtle-shell, fish and pearls, they traded food, cloth, tools, tobacco and similar goods. These visits were broken off by the Australian Government in 1907, but the aboriginal inhabitants still look back (not, it seems, altogether justifiably) at their contacts with the Malays as if to a Golden Age. That the Chinese themselves were not far out of the picture, however, is shown by the fact that all the things which the Northerners came for, trepang was

* For the Philippines see Cole & Laufer (1).
* Details in Harrisson (1), from whom these words are taken. Domingo de Navarrete noted much china-ware in Borneo in +1637; cf. Cummins ed. vol. I, p. 171, note 16.
* This comes from the helmeted hornbill, Rhalmax vultur. An interesting account of Chinese carvings in hornbill ivory has been given by Cammann (6).
* Harrisson (6) describes the trade, and Jeynes (4) reviews Chinese carvings in rhinoceros horn as well as the old beliefs about its magico-medical efficacy. The classical treatment of this still remains, however, Laufer (13).
* See Harrisson (4, 5). On Sung ware see Noakes (1); Harrisson (2, 3, 7); Sullivan (5, 6, 7, 8).
* See Thien (1); Pope (1).
* Cf. the evidence given in Vol. 3, p. 274, that an astronomical expedition from China in +744 went as far south from Sumatra as about 15° S. See also p. 567 below.
* See Dore (1), vol. 1, pp. 696 ff.
* The site, fixed by chain measurements and therefore still precisely identifiable, is near one of the only two fresh-water springs around the land-locked harbour of Darwin, and in a gully leading down to a small cove with a sandy beach.
perhaps the most important. This fishery produces the dried and smoked body-walls of sea-slugs (Holothuria edulis and many other genera and species), known in Chinese as hai shen and made into glutinous soups, a delicacy, be it noted, which has always been exclusively Chinese. Moreover, the Chinese alone have been successful in the preparing-trade, which involves drying and smoking by means of mangrove-wood fires. There is thus much significance in the report of Worsley (1) that according to aboriginal tradition the Macassarese were preceded by a people they call the Bajini, much lighter in colour and possessing an advanced technology. If these were indeed from China, then perhaps the Shou Lao statuette is a true record of their visits, and the latter half of the 15th century remains a possible time.

So far little light has been thrown by Chinese cartography on early contacts with Australia, but that is because no serious investigation has yet been made. Contrary to certain published statements, the lacquer David Globe (see p. 356 below), made in 5th century remains a possible time.

This desideratum is certainly not fulfilled in the interesting though curious book of Wei Chü-Haien (4), whose concern it is to show that the Chinese were in contact with Australia from very early times. Towards this end he has assembled a large collection of quotations from ancient and medieval Chinese texts, which do sometimes suggest, but never conclusively prove, a knowledge of the inhabitants and the fauna and flora of the Australasian region. Thus for example a number of passages from the Liu Chiho period onwards concerning the throwing of crooked knives (pei jen) are interpreted as allusions to weapons of the boomerang type. Similarly the chhiung-chhiung of the Shen Hai Ching or the Shan Hai Ching ('the book of the deities of the Shang-Yao') is identified by Liu Chhao as the 'dusky dwarfs' of the Roman world, an animal like a rat in front and like a rabbit or a hare behind, which carries its young and leaps about, is identified with the kangaroo. More convincingly, perhaps, Wei Chü-Haien draws attention to a country called Chiao-Yao Kuo, mentioned in many texts from the Shao Hsüan era onwards, where the people are but three feet tall; these may well be references to the negro pygmies of New Guinea, though they cannot refer to the African aborigines. For Chiao-Yao means essentially 'dusky dwarfs', having as synonyms Chu-Ju Kuo and Hao-Jen Kuo. If the ATA pygmies of the Philippines were clearly described by Chao Ju-Kua in +1245 (cf. Hirch & Rockhill (1), p. 161), associated with these races are lands in which the seasons are reversed, summer there corresponding to winter in China. This statement first occurs in a lost Ch'in (+4th-century) book, the Wei Kuo Po (1) (Illustrated Account of Foreign Countries), quoted by Tao-Shih in +668 in his Fa Yuan Chu Lin. If it was not a pure cosmographical deduction (which seems unlikely), it must refer to experiences in regions about 30° lat. south, and if South Australia was not the place the only other possibility is South Africa—also a land approached through regions where pygmies dwelt. It is thus of particular interest that the Kua Ti Chu (2) (Comprehensive Geography; cf. Vol. 3, p. 520) says that the Chiao-Yao pygmies live south of the Roman Empire (Ts-Chhin, cf. Vol. 1, p. 156 et passim), i.e. in Africa, adding a reference to the famous Western fable of their battles with the cranes (Vol. 3, p. 155). Cf. TPYL, ch. 796, p. 7 a, and on the fable itself Lauffer (9) and de Pley (5). An illustration can be found in TSSC, Pien shang tien, ch. 42, p. 6.8 (Fig. 992). It is remarkable that knowledge of this kind could travel so far in those ancient times.
+ 1623, shows only New Guinea and Antarctica; Australia is indeed present on the
eamed Rosthorn Globe (though joined to New Guinea and to Tasmania) but the date
of this may be as late as + 1770. The date of the first appearance of Australia in Chinese
maps, and its first mention in books concerned with geography and navigation, presents
an intriguing problem which further research will no doubt solve.

(viii) China and pre-Columbian America

The alleged discovery of the American continent by Buddhist monks from China in the
+ 5 th century is one of those youthful indiscretions at which modern sinology is
accustomed to blush. As usual, Joseph de Guignes was the enfant terrible; having
proved in + 1758 that the Chinese were a colony of the ancient Egyptians (1), he
announced three years later (4) that he had evidence of Chinese navigations on the
west coasts of America in pre-Columbian times. This, he thought, would account for
the 'politesse' (a rather curious term in this connection) which distinguished the
indigenous Mexicans, the Aztecs in fact, from the other barbarians of the continent.
De Guignes astonished his contemporaries by appending elaborate and beautiful
copper-plate maps showing the journeys of the Chinese to Alaska and California in
+ 458, countries which they knew, he said, under the name of Fu-Sang. The
texts from which de Guignes drew his conclusions are perfectly sound as far as
they go. The basic description in the Liang Shu (6) dates from the neighbourhood of
+ 458; what it says is that in the year + 409 a monk named Hui-Shen (7) appeared in
the capital and gave a circumstantial account of what he had seen in Fu-Sang, a country
east of China and lying + 20,000 le of Ta-Han (the Buriat region of Siberia). He
described the curious trees from which the land took its name, saying that they afforded
food and that bark-cloth and a kind of writing-paper was made from them. The people
lived in unfortified wooden houses and were un-warlike, they had oxen and horses,
and drank the milk of deer. Gold and silver were not esteemed among them, and they
had copper but no iron. Hui-Shen further described their mating and funeral customs,
the absence of taxes, and the cyclical changes of the colour of the ruler's vestments. He

1 Matteo Ricci's Chinese world-maps of + 1584 and + 1600 are also like this; the former has a confused jumble of continents in the south seemingly labelled Magellania, the latter knows New Guinea but makes it a promontory of Antarctica. See d'Elia (4), vol. 2, pp. 58, 60; Wei Chu-Haien (4), p. 179.

2 One thinks of the Hien Pin Lu of + 550 and the Yang Hai Yang Kho of + 1618, both discussed in St. J. V. Mills informs me that he could find nothing relevant in the former (private communication, April 1959), nor is there any clue in the informative introduction of Wada (1) to the latter, which needs detailed study. News of an Indonesian tradition of a south-eastern antipodean continent probably reached the Jesuits in China from Malacca by about + 1610, but whether this influenced any Chinese cartographers remains uncertain. Chiben Lu-Chung's Hai Kuo Wu Chien Lu of + 1744, however, seems to contain a reference (p. 314) to the French claim for the first sight of Australia. A certain gulf between the practical sailors and the literary scholars can always be assumed in Chinese culture.


4 Ch. 54, pp. 316 ff, fully translated by Schlegel (7a). The passage was copied in Nan Shih, ch. 79, pp. 74 ff and in Wen Hsin Thung Kuo, ch. 327 (pp. 2569 ff), whence de Guignes no doubt first got it. It is also to be found in abridged form in various encyclopaedias. An elaborated and fictionalised version occurs in the Liang Shu Kang Chi (c. + 695).

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added that formerly the Fu-Sang people did not know the law of Buddha, but that in
the year + 458 five Kashmiri monks had gone there, and that since that time their
way of life had much improved. He also appended to his story an account of a country
of Amuzons (Nü-Kuo), even more fabulous, which lay beyond Fu-Sang to the east yet
further. And the texts conclude with a statement that in + 507 a Fukienese ship
was blown by a tempest far east in the Pacific to an island where the men had faces like
dogs and the people subsisted mainly on small beans.

Now Fu-Sang had a long background in Chinese literature which de Guignes did
not quite know. In the Shan Hai Ching (Classic of the Mountains and Rivers), that
ancient magico-geographical text of the late Chou and early Han periods, the Fu-Sang
tree growing far in the east had branches upon which the ten suns perched before taking
off on their journeys of the ten-day week. Other Han texts such as the Shang Shu Tu
Chuan and the Hai Nei Shih Chou Chi recount similar fables. But this does not mean
that Fu-Sang was not thought of in later times as a real place. We have already met
with a story of envoy's bringing glass or rock-crystal from a country of that name in the
Liang period, and Yang Chiung (2) in + 676 in his Han Thien Fu (Ode on the Celestial
Spheres) mentions it as being somewhere on the shores of the Eastern Ocean (the
Pacific). The Yu-Yang Ta Tzu in + 863 again says that in + 581 a Korean was
carried east to Fu-Sang in a storm, though the story is facetious and seems to refer to
the Ainu. The + 7th-century astronomer Li Shun-Fêng (2) is on record as saying that
Fu-Sang is somewhere to the east of Japan just as Japan is east of China. In short, no
one knew exactly where Fu-Sang was. Schlegel (7a) in 1892 satisfied himself that its
most probable location was the long island of Karafuto or Sakhalin, north-east of Japan,
and if Kamchatka and the Kuriles may also be considered there is no better means of
identifying it at the present day.

It would be easy enough, but it is not worth while, to expatiate on the literature of
controversy to which de Guignes' famous memoir gave rise; we may notice only the
book of Leland (1) who took up the cudgels on his behalf in 1875 and went to all kinds
of lengths to show that features of the Amerindian civilisations corresponded to items

5 Nan Shih, ch. 79, p. 14; says also that a Taoist came to China from Fu-Sang between + 520 and + 546, but perhaps this refers to Hui-Shen.

6 It is interesting that these stories of Amuzons and Cynocephali were very much in the mind of Columbus when he came to Cuba, Venezuela and Honduras between + 1492 and + 1502 (cf. Lauffer, 38). They were part of the common stock of Hellenistic, Indian and Chinese legend (cf. Vol. 3, pp. 505 ff). It is even said that 'cannibal' is a corruption of Carib because of this. Cfr. the River Amazon. 

7 Ch. 9, p. 34, ch. 14, p. 31, etc. Cf. the 'Arbores Solis et Lumen' in Vol. 3, Figs. 212, 213, 228, 242.

8 Schlegel (7a), p. 109. The orthography varies, e.g. Fu-Sang.

9 Cf. Schlegel's translation (7a), pp. 118 ff. See also Shih I Chi, ch. 3, p. 266.

10 Vol. 4, p. 1, p. 114; the source is the Liang Shu Kang Chi of + 695 referring to about + 520, in TSCC, Piam i lien, ch. 41, pp. 34, 36.

11 The passage is not in the Yu Hui version, but occurs in TSCC, Piam i lien, ch. 41, p. 58.

12 Ch. 14, p. 88.


14 In late Chinese literary usage Fu-Sang was often used as a loose poetical term for Japan itself.

15 Already in 1851, Kalipoth (4) had dismissed de Guignes' theory as incredible. Neumann ten years later, and Purvey, seem to have defended it, but we have not been able to see their papers.
in Hui-Shen's account. Thus the fu-sang tree was the maguey plant, the lack of iron pointed clearly to the Mayas and Aztecs, the milking of hinds was noted by the early travellers in Central America, and the 'small beans' were certainly frijoles. Yet although Leland and his comrades-in-arms could be discounted on every particular item, there remained an insoluble residuum, the implicit belief that connections of travellers in Central America, b and the 'small beans' were certainly frijoles. Yet even with us. The sinologists however, c undeterred, exposed without mercy all the nonsense of Laufer, d Cordier e and others, the Fu-Sang thesis was stone dead. f

In November 1947 I found myself in Mexico City as one of the secretariat of a United Nations specialised organisation, and for a couple of months had golden opportunities of tasting a culture not only Spanish but also still profoundly Amerindian. I sat at the feet of great Amerindianists such as Alfonso Caso and Sylvanus Morley, studied the wonderful collections of the National Museum in the capital with Miguel Covarrubias and Julian Huxley; and visited the imposing remains of Aztec and Mayan culture from Teotihuacán and Xochicalco to Chichén-Itzá where my friend Alberto Ruiz-Lhuillier was then Resident Archaeologist. When I consult my shelf of books on Amerindian studies I vividly recall the sense of keen intellectual adventure which a personal acquaintance with these cultures can give to one who comes to them with an Asian background. This adventure, indeed, had some of the quality of the *dój vu*, and I was deeply impressed during my stay with the palpable similarities between many features of the high Central American civilisations and those of East and South-east Asia. g Was it not striking, to begin with, that the former all arose on the western side of the continent, as if fertilised or induced or stimulated from across the Pacific (see Fig. 993)? h Then the predominance of the horizontal line in the terraces and monumental stairways of Central Amerindian temple and town patterns, the pyramidal *teocalli* notwithstanding, i the omnipresent sky-drone motifs, j the split-face designs k resembling *thao-thieh*, l the teponatli designs m like *mu-yü*, n the tripod pottery reminiscent of li o forms, p the terra-cotta figures and groups, q even paintings, r such as those of Chhu and Han, the dresses made of feathers, s the double permutation system of language and art, t the omnipresent sky-dragon motifs, c parallelling the *niigas*, u the split-face designs v resembling the sacred enclosures and stepped pyramidal platforms of the *shen* and Heaven and Earth, etc., w in Chinese culture has been pointed out by Ling Shun-Hsing (9, 2, 3, 4, 5, 6, 7).

Fig. 993. Distribution of the high cultures of Central America (after Kriekkeberg, 1).
the Maya and Aztec calendars, a ideographic script, and the far-reaching parallelisms in symbolic correlations (colours, animals, compass-points, etc.) and cosmological legend—all combined to give an overwhelming impression of cultural influences known ethnological facts, as in the sphere of games, divination (even extending to scapulimancy), computing devices, art forms, etc., which pointed unmistakably to Asian influences. It was strange enough that jade should have been so treasured by the Aztecs and Mayas, as dearly as by the Chinese, but even stranger that on both sides of the Pacific, jade beads or cicadas should have been placed in the mouth of the dead; and astonishment turned to conviction when one learnt that in all these civilisations the jade corpse-amulets were sometimes painted with the life-giving colour of red cinnabar or haematite.

If this conviction was a highly reluctant one it was due to the fact that Amerindianists cherished the persistent years of a notion of Monroe Doctrine, denying any external influences on the development of the high indigenous cultures of Central America. But this orthodoxy is now, twenty years later, fast disappearing, and periodical Asian influences are becoming every day more and more accepted. A mountain of evidence is accumulating that between the 7th century and the +16th, i.e. throughout the pre-Columbian ages, occasional visits of Asian people to the Americas took place, bringing with them a multitude of culture traits, art motifs and material objects (especially plants), as well as ideas and knowledge of different kinds. Current researches in haematology, ethno-botany, and ethno-helminthology are throwing much light on


It was not of course denied that America had been peopled from Asia across the Behring Straits in the +10th century. But these early peoples had their own character of culture, and the new finding of physical anthropology; the debate concerned only cultural influences during the past three millennia.

For reviews see von Heine-Geldem (3, 7, 10, 11); Covarrubias (2); M. W. Smith (2); Ekholm (2); as also in Gladwin (1) and Raglan (1), p. 154 ff. The characteristics of the Amerindian cultures can be studied in Gladwin (1); de Sahagún (1); Spinden (1); Morley (1); Recinos, Goetz & Morley (1); Ruz-Lhuillier (1); Armillas (1); Vaillant (2).

See Layrisse & Arenal (1); Lewis, Ayukawa et al. (1) on the Digo blood group antigen.

This subject has recently been reviewed by von Heine-Geldem (9) and D. F. Carter (2). Here the race of resistance is maize, classically regarded as native to the American continent (de Candolle (1), pp. 387 ff.; Vavilov (2, 4), p. 40). The usual view, established in a classical paper by Leifer (16), as that it was unknown in East Asia until the +16th century when it was introduced to China from America (possibly by Europeans) via India and Burma, perhaps also directly to coastal areas. This is strongly upheld by Mangelstorff & Reeves (1, 2, 3); Reeves & Mangelstorff (1, 2); Ames (1), pp. 91 ff.; H6ng-Ti (1) and others. But a primitive race of maize has been found deep in the Andes in Peru by Don & Chung (1) (cf. Hatt (1), pp. 902 ff.), who concluded that this must either have originated in Asia, or have been taken there in pre-Columbian times. As Heyerdahl said, it could have 'spread with man in drifiting craft to... Oregon or California by a southern branch of the Kuroshio or North Pacific Current' (2, p. 494) Against this, Mangelstorff (1, 2) has found fossil maize pollen some 8,000 years old in Mexico, while Mangelstorff & Oliver (1) could match the American maize with South American counterparts. On which side of the Pacific maize was first cultivated thus still remains undecided; the balance of evidence points tentatively towards an American priority, but the question is still subject to revision. More work is needed.

The other outstanding example is that of cotton. According to the work of Hutchinson, Silow & Stephens (1); Hutchinson & Sauer (1), which has been criticised but not overtaken, Old World cotton (Gossypium herbaceum) with 17 large chromosomes must have been brought somehow to cross with the New World cotton (G. Raimondii) with 13 small chromosomes, so as to give the cultivated Peruvian Inca cotton which is a polyploid of 26 chromosomes, half of them large and half small. Again this points to pre-Columbian voyages across the Pacific. Stebbins (1) suggests the Inca cotton was not turned to use until the 17th century, but this mission must have occurred before the -1st millennium if the earliest Peruvian textile dairings are correct. Many other plants useful to man also figure in this still continuing argument. At present the evidence, especially that from South America, looks as if fruit-pulling and Polynesian contact seems very likely; see the review by Layrisse & Arenal (1).

The distribution of patterns of housework infestation has ethnological significance; cf. Darling (1, 2); Soper (1). Mixed infestations of Anopheles gambiae and Neotropical America exist both in the...
these events, while comparative studies in metallurgy, paper-making, religious art and architecture, Great Walls and roads, musicology, folklore, divinatory games, agricultural practices, social organisation, and perhaps even ideas are elaborating the general picture. We have to visualise the arrival from time to time of small groups of men (and doubtless of women also) with a background of high culture, never any massive invasion like that of the Europeans in the 16th century.

When the sinologists gave the quietus to the Fu-Sang story they were reckoning without the sailing-raft. Ignorance of practical techniques and their development proved once again the Achilles heel of literary history. Moreover they were writing in the pre-Heyerdahl era. For in earlier months of the same year that brought our expedition to Mexico, Heyerdahl and a number of companions, desirous of demonstrating that the isles of Polynesia had been peoples from South America, made a courageous journey themselves from the Peruvian coast to Rarotonga, one of the most northerly islands of the Tuamotu archipelago, not far from Tahiti. Their vessel was a sailing-raft of balsa logs built as nearly as possible like those of the ancient Peruvians. The successful accomplishment of this voyage depended on the north-westward flowing Humboldt Current and the westward South Equatorial Current, as well as on the South-eastern Trade winds blowing in the same direction. With the main theory of Heyerdahl (2, 4, 5) regarding the origin of the Polynesians we are not here concerned; it is still immensely achieved by severe difficulties, notably on the linguistic side, but even its strongest opponents, such as von Heine-Geldern (8, 14, 15), are at one with Heyerdahl in admitting the navigability of the Pacific for sailing-rafts, to say nothing of more conventional millennia) the necolithic pottery closely resembles that of the Jomon period in contemporary Japan; see Estrada & Evans (1) and Kidder (1). One of the most remarkable features is the occurrence of nailed drums and the use of sonorous stones... Except for a few universal instruments, all relatives of American instruments are exclusively features in a territory comprising China, the arc between China and Japan, and the archipelagic and the Pacific lands. More than 50%, can be located in the Beringian and adjacent countries... In other words, as a sinologist might say, the TI and the Jung, with regard to the pan-pipes a remarkable discovery was made by von Hornbostel (2) who found that the absolute pitches and scales of American, Melanesian and East Asian examples were in striking conformity. The pan-pipes of Chinese culture were of course tuned to the 13 lu (c.f. Sect. 26), six being Yang and five Yin; and the American forms are also often in two sets, male and female, sometimes consisting of two frames connected together by a long cord (Mead, 1). Lastly, in the exceptional antiquity and importance of the metal bell in Chinese culture, its occurrence in pre-Columbian America is very remarkable (cf. Covarrubias (3), pp. 99 ff.; see Laufer (1)). As for the usages, we rely upon the current map in Baudin (1), esp. p. 83; see Toscano (1). The chronology of the high American cultures is of course still far from settled—a review of the present state of the question will be found in the two large volumes of Covarrubias (2, 3). According to Spinden (1), p. 153, the 7th baktun of the Mayan day count started from -613, and the month count from -580, but the shorter time-scale accepted by Morley (the Thompson—Goodman-Martinez-Hernandez correlation) preferred the date -151. A comparative table is given in Covarrubias (2, 3), p. 219. The oldest dated Mayan object belongs to +60 on the Spinden system, or to +730 if we adopt the shorter scale (Miller, 1933, p. 277 above; with their ball-throwing between teams of young men and girls, has been fully pointed out. But I suspect also a connection with that divinatory ‘star-chess’ developed in +6th century China, about which much was said in Sect. 261 (Vol. 4, pt. 1, p. 312 ff.).

One of the most remarkable features of Central American culture was the ball game played in elaborate courts forming striking architectural patterns, as at Chichen-Itza. Here the two sides had religious and divinatory significance, the struggle symbolizing that between day and night, between light and darkness—indeed between Yin and Yang. The connection between these and the sexual jouets or mating festivals in ancient China so much studied by T. H. Green, Vol. 3, p. 277 above; with their ball-throwing between teams of young men and girls, has been fully pointed out. But I suspect also a connection with that divinatory ‘star-chess’ developed in +6th century China, about which much was said in Sect. 261 (Vol. 4, pt. 1, p. 312 ff.).

E.g. the use of night soil as fertilizer (Vaillant, 1856, p. 355), and the elaborate terracing of hillside of the coast of Peru (Covarrubias, 2, p. 65).

Has not the socialist empire of the Incas always recalled the feudal-bureaucratic society of China? One may even find echoes of such a system in certain Inca customs; see esp. p. 83; Tschopp (1).


Cultural complexes in which a number of traits of probable trans-Pacific origin are found together now recognize. Ecuador seems to be a focal region, already in the Formative Period, and was probably never again occupied by the same people for so long a time. The present-day inhabitants are, however, believed to have migrated from the north, possibly by way of the Isthmus of Panama.
non-European vessels. And it is quite clear that what could be done by balsa rafts, with sails and centre-boards, from east to west along lat. 0° to 25° S., could also be done by sailing-rafts of the South Chinese and Annamese pattern navigating (or drifting) from west to east along lat. 25° to 45° N. For they would take advantage of the strong Kuroshio Current and the North Pacific Current flowing eastwards, as well as the westerly winds, particularly powerful in the winter and early spring (Fig. 989.6). They would be helped, too, by the climate of the North Pacific at these times, except for the particularly powerful winds (Fig. 989.6). This is the reason why the folklore of the South China Sea, the Philippines, and the islands of Indonesia is so rich in stories of raft voyages across the Pacific.

It is interesting to ask how far back a knowledge of the eastward currents can be traced in Chinese and Japanese literature. The Japanese name of the Kuroshio Current (the 'black tide'), which diverges into the Sub-arctic and North Pacific Currents, has got into world geographical literature as such, but the Chinese name for it was different, Wei-Lü. 1-3 Already in the Warring States period this great gulf stream

1 During the nineteenth century East Asian junks were driven to American shores as often as about once every five years (v. Heine-Geldermann, 12). Reliable eighteenth-century evidence also exists (Sitōta, 1). Similar facts were reported by Col. B. Kennon (in Leland, 1), p. 77; cf. pp. 43 ff.) and there is a wealth of data in the reports of C. W. Brooks (1) and H. C. Davis (1). So numerous were these wrecks that they formed the main source of iron and copper for the Indians of British Columbia (Richard, 1). It is not generally known that an occurrence of this kind played a part in the emergence of Japan as a modern nation. In the early 1850s Nagashima Manjū, 6 a fisherman, was blown off course and to the west of Hawaii, where he was picked up by an American ship. Befriended by a clergyman, he was taken to San Francisco, where he learnt English, and later on making his way back to Japan he became a counsellor to the Shogun and adviser on foreign affairs in the first years after the opening of the country (Cf. Perry's famous visit. For knowledge of this story we are indebted to Dr Charles D. Sheldon. Finally on 12 August 1864 Hera Kenichi, a Japanese 23 years of age, arrived in San Francisco Bay having crossed the Pacific single-handed in a 19-ft. sailing-boat (Birrell, 1). His advent could not have been more appropriately timed, as the International Congress of Americanists was on the point of discussing trans-Pacific contacts.

2 Cf. Heyerdahl (4), pp. 77, 81, 494, 599, (3), p. 356, all envisaging west-to-east transmisions across the Pacific. Such sailing-raft voyages are now commonly accepted, as for instance by Liu Tun-Li (1). Those who knew the Pacific well saw their feasibility long ago, e.g. Col. B. Kennon, in 1874 (in Leland (1), p. 74). The archaeological 'emptiness' of the Aleutians (cf. Covarrubias (2), pp. 157, 163) also seems to be rather a hydrographers formality than an aid to navigators (cf. de Bisschop, 1), but the temperatures there, even in summer, would have been too cold for the sailing-rafts. Birrell's transmission from China to Peru is dug by this difficulty.

3 For further discussion of the physical oceanography see the review of Heyerdahl (6) on all the possible routes to and from the Americas, strongly supporting the view here expressed. The fundamental fact about the hydrographic and meteorological situation in the Pacific is that it favours west-to-east transmissons. The Kingdom of Women (Nii-Jen Kuo 3 ) lies there. This second appellation could lead us off upon another tack, for we-Lü might be translated 'the ultimate drain' or 'cosmic cloaca', and another term for it is 'converging and pouring away'. People sometimes said that it was a great rock, with an abyss or whirlpool into which the sea evermore discharged itself. In + 1607 Suuma Kuan was quite sure that the Fu-Sang country was to the west of the Wei-Lü Current, i.e. on its hither side, a fact which had much influence on later European sinologists. By + 1744 Chien Lun-Chiu spoke with the voice of centuries-long tradition when he said that the Wei-Lü was the ancient name of the current now known as the Kuroshio. Possibly the fable of the abys discharged now and then some sailors of the Chinese coasts from launching forth on to the main—but very similar stories plagued the mariners of Europe.

4 A search in the maritime literature of old China would certainly fish up much about currents as well as the belief in the maelstrom, the 'old notion', as Hirth & Rockhill put it, of a hole in the Pacific into which the waters of the Ocean emptied'. In his Liang Wei-Lü Ta, speaking of Java (She-Pho), Chou Chü-Fei says: 'East of She-Pho is the Great Eastern Ocean Sea, where the waters begin gradually to slope downwards. The Kingdom of Women (Hsin-Kuo) lies there. Still further east is the place where the Wei-Lü drains into the world from which men do not return.' The statement about the point of origin of the Kuroshio current was right enough, though we should say the Philippines instead of Java; and perhaps the 'bourne from whence no traveller returns' was the American continent rather than the abys. In the legends perfTU}ally perpetually flowing north-eastwards seems to have been known, for in the Chuang Tsau book we read: 8

5 Of all the waters under Heaven there is none so great as the Ocean. A myriad rivers flow into it without ceasing, yet it is never full, and the Wei-Lü (current) carries it continually away, yet it is never empty. Springs and autumns cause no change in it; it takes no notice of floods and droughts. Its pre-eminence over the Yangtze and the Yellow River no measures nor calculations can express it: it takes no notice of them; it is dogged by the seasons. Its pre-eminence over the Yangtze and the Yellow River is that it is not empty; there is no hole in the Pacific; it is not empty; it is immersed in the Abyss. In the legend of the abys of Peking, where the sphere of the earth is upheld by a great rock, with an abyss or whirlpool into which the sea evermore discharged itself, this second appellation could lead us off upon another tack, for we-Lü was adopted as a technical term in Taoist mystical (microcosmic) anatomy for the proctodeal orifice (rectum and anus), and later by extension the coccyx. The former use is prominent in the Nei Ching Thu, a remarkable diagram of an uncertain date inscribed on stone at the Pai Yün Kuan Taoist temple near Peking, and reproduced in scroll paintings as well as rubbings. A copy of the latter, with a note on the great kindness of Mr Bewl Aslin to the capital in 1952. The terminology for the microcosmic coccyx has been mentioned by R. A. Stein (4), but the only treatment of the Nei Ching Thu as a whole remains that of Rouselle (4, 5). We intend to deal with it in Sect. 43 below. A reference to ne-Lü as the coccyx will be found in Sheh Chi Tsung Lu, ch. 191, p. 248; this was the great medical encyclopedia issued by imperial authority in + 411.

6 E.g. Chih Ch'eng-Hai-Lin-Ying, in his Ts'ang commentary on the above passage; Chuang Tsu Fu Ching, ch. 3a, p. 36.

7 Wu Yen Chi Yün, quoted in Kiang-Hai Ts'ui Ten, p. (1493), sub u.-

8 Hai Kuo Wén Ch'ien Lu, p. 128.


12 Ch. 17, tr. Legge (5), vol. 1, p. 375, mod. auct.

13 This second appellation could lead us off upon another tack, for for-Lü was adopted as a technical term in Taoist mystical (microcosmic) anatomy for the proctodeal orifice (rectum and anus), and later by extension the coccyx. The former use is prominent in the Nei Ching Thu, a remarkable diagram of an uncertain date inscribed on stone at the Pai Yün Kuan Taoist temple near Peking, and reproduced in scroll paintings as well as rubbings. A copy of the latter, with a note on the great kindness of Mr Bewl Aslin to the capital in 1952. The terminology for the microcosmic coccyx has been mentioned by R. A. Stein (4), but the only treatment of the Nei Ching Thu as a whole remains that of Rouselle (4, 5). We intend to deal with it in Sect. 43 below. A reference to ne-Lü as the coccyx will be found in Sheh Chi Tsung Lu, ch. 191, p. 248; this was the great medical encyclopedia issued by imperial authority in + 411.

14 E.g. Chih Ch'eng-Hai-Lin-Ying, in his Ts'ang commentary on the above passage; Chuang Tsu Fu Ching, ch. 3a, p. 36.
about the Country of Women there are many features which point to Japan. Chou's statement of + 1178 was copied in identical words by Chao Ju-Kua in + 1225, who added, in his entry for Nü-Jen Kuo, '(Here) the water constantly flows to the east, and once in several years it overflows and drains away.' But the best account of the ideas of the sailors of the Sung is in the Ling Tai Tai Tzu. Chou Chu-Hsi-Fei wrote:

South-west of the four commanderies of Hai-nan is the Great Sea called the Sea of Chiao-Chih (Tonking). In it there are three currents (san ho liu) carrying away the scudding waves and spume in three directions. A southward one communicates with the seas where the various barbarian countries lie, and a northward one flows past the provinces of Kwantung, Fukien and Chekiang. The third makes eastward into that boundless deep the Great Eastern Ocean. Southern ships in their voyages have to breast three currents; if they have favouring breezes they are safe, but if they meet with danger, when there is no wind, they cannot avoid it, and must drift to destruction with the currents. I have heard say that in the Celestis Ocean (chiu yu liu) in length, and near by is the Wei-Lii, the place where the water pours down into the Nine Underworlds (chü ye). In times gone by a certain ocean-going junk was driven by a great westerly wind to within hearing distance of the roar and thunder of the waters (falling into) the Wei-Lii of the Great Eastern Ocean. Southern and Chekiang. The third makes eastward into that boundless deep the Great Eastern Ocean. No land was to be seen. Suddenly there arose a strong easterly wind, and the junk was saved.

The distinction between three currents was quite reasonable, for though inshore the tide is the Wei-Lii, the place where the water pours down into the Nine Underworlds (the junk) was saved.

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The ambassador of the Han, Chang Chhien, wrote Chang Hua about + 385, 'won through across the Western Seas to reach Ta-Chhin (the Roman Empire)... but the Eastern Ocean is yet more vast, and we know of no one who has crossed it.' Perhaps this was because no one ever came back. A corollary of the hydrographic situation just described is that once any group of people had sailed from Asia to America on primi­

craft there was very little chance of their ever returning, since before relatively modern times no general understanding of the regime of winds and currents could develop. Of those who made the journey, within the span of the - 1st and + 1st millen­nia, many were probably fishermen or traders, involuntary carriers of culture to the Americas, but assuredly sometimes the great voyage was undertaken purposively for

one reason or another, though not with knowledge of the landfall. Surprise is often expressed that the Chinese did not 'explore' the Pacific, but only by those who lack acquaintance with Chinese literature. In a moment we shall return to this, meanwhile the problem of the origin of the sailing-raft remains. In view of the much greater antiquity of high culture along the Chinese and Indo-Chinese coasts than of anything which America can show, it seems almost quixotic to believe that the craft originated first in Central America. It is surely preferable to suppose that the sailing-raft was not only the oldest form of transport between the two culture-areas, but one of the first of the gifts of the Old World to the Amerindian peoples.

All these considerations cast rather a new light on the statements in ancient Chinese literature about voyages into the Pacific. To be brief, we must concentrate attention on the Chhin period, when the rulers of China were convinced that drug-plants giving longevity or immortality were to be found on islands in the Eastern Ocean. In the late -3rd century many sea-captains were sent out in search of these, generally without success, but although the only name which has come down to us is that of Hsii Fu, the whole story of their activities is of such interest for the early maritime history of China that it is worth examining in some detail. Sauma Chhien recurs to it four times in his great Shih Chi, the oldest of the dynastic histories, finished in + 90, and his texts have much to tell us. First, in his chapter on the national Feng and Shan sacrifices, he says:

From the time of the Kings of Chhi (State), Wei (r. - 378 to - 343), Hsian (r. - 342 to - 354), and King Chao of Yen (State) (r. - 311 to - 279), people were sent out into the ocean to search for the islands of Pheng-Lai, Fang-Chang, and Ying-Chou. Three holy mountain (isles) were reported to be in the midst of Po-Hai within the Yellow Sea, not so distant from human (habitations), but the difficulty was that when they were almost reached, boats were blown away from them by the wind. Perhaps some succeeded in reaching (these islands). (At any rate, according to report) many immortals (kien) live there, and the drug which will prevent death (pu su chih yao) is found there. Their living creatures, both birds and beasts, are perfectly white, and their palaces and gate-towers are made of gold and silver. Before you have reached them, from a distance they look like clouds, but (it is said that) when you approach them, these three holy mountains sink down below the water—or else a wind suddenly drives the ship away from them. So no one can really reach them. Yet none of the lords of this age would not be delighted to go there.

When Chhin Shih Huang Ti, having united the empire, came to the shores of the (Eastern) Sea, the magicians and technicians reported all kinds of (extraordinary) things about (lands in the ocean). As the emperor considered that if he himself went to sea he would probably not be successful (in finding the magic islands), he ordered a certain person to embark with a crew of

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* See Schlegel (7).
* See Sverdrup, Johnson & Fleming (1), chart VII.

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a It is true that by the time Chinese shipping developed to a technical level which made it fully capable of crossing the Pacific back and forth, the predominantly agrarian tone of the civilization had set in. The ideas of the far north were unattractive, and the Pacific seemed quite empty.

b We have already discussed it on p. 959 above.

c We have touched upon the subject at an earlier stage, cf. Vol. 2, pp. 85 ff., 173, 240 ff.

young men and girls, and to search for them. Their ships cruised in the ocean, but after some
time they returned, saying in excuse that although they had seen (the isles) from afar, they
could never get near them on account of (contrary) winds.

Here the atmosphere is all legendary, Taoist, magical, alchemical. Hsü Fu is not
mentioned by name. But more substantial facts follow. The next passage refers pre­
cisely to the year -219, when Chhin Shih Huang Ti was on one of his periodical
excursions along the eastern coasts.8

After this affair (the setting-up of commemorative steles on the shore at Lang-ya and else­
where), Hsü Fu of Chhi and others made request to (the emperor) saying: ‘In the midst of the
(Eastern) Sea there are three magic mountain islands, Pheng-Lai, Fang-Chang and Ying­
Chou, inhabited by immortals. We beg to be authorised to put to sea, after due purifica­
tion, and accompanied by (a suitable number of) young men and girls, go forth in search of these
islands.’ (The emperor approved this petition and) despatched Hsü Fu with several thousand
young men and maidens to go and look for (the abodes of) the immortals (hidden) in the
Eastern Ocean.

One would give a good deal to know what kind of craft they sailed in, and one would
not be surprised to discover that whole fleets of sailing-rafts were employed.9 These
voyages have been well compared with those of the Far West which sought for the
immortals and the drug of everlasting life have come down to us. We have already encountered
the mentions of ‘the magician (jang shih)’ Hsü Fu and others for the drugs of
immortality, the historian continues:6

Several years having passed without any success, and great outlay having been made, (the
sea-captains) feared that they would be blamed, so they spun a yarn and said: ‘To obtain the
drugs of Pheng-Lai is quite possible, but we have always had difficulties with great sharks
(ohio), and this is why we have never succeeded. We beg that excellent archers should be
sent out with us so that when these fishes appear they can be killed by the use of multiple-bolt
arcuballistas (lien mui).’

In the bizarre and dramatic sequel, Chhin Shih Huang Ti dreamt that he was fighting
a sea-god with a human face, after which he ordered that the ships of those who went
to sea should be suitably armed to kill the objectionable fishes. Meanwhile he himself
patrolled the coast with multiple-bolt arcuballistas, and in the end he killed a great sea­
animal at Mt Chih-fou. Soon afterwards he fell ill and died in –210 at Sha-chhion on
the way back to the capital.

Chhin Shih Huang Ti also sent out Hsü Fu by sea to search for magical beings and strange
things. When he returned he invented excuses, saying: ‘In the midst of the ocean I met (on
an island) a great Mage who said to me ‘Are you the envoy of the Emperor of the West?’, to
which I replied that I was. ‘What have you come for?’ said he, and I answered that I sought
for those drugs which lengthen life and promote longevity (yen nien i shou yao).’ ‘The
offerings of your Chhin King’, he said, ‘are but poor; you may see these drugs but you may
not take them away.’ Then going south-east we came to Pheng-Lai, and I saw the gates of the
Chih-Chên Palace, in the front whereof there was a guardian of brazen hue and dragon
form lighting the skies with his radiance. In this place I did obeisance to the Sea-Mage twice,
and asked him what offerings we should present to him. ‘Bring me young men’, he said, ‘of
good birth and breeding, together with apt virgins, and workmen of all the trades; then you
will get your drugs.’ Chhin Shih Huang Ti, very pleased, set three thousand young men and
girls at Hsü Fu’s disposal, gave him (ample supplies of) the seeds of the five grains, and
artisans of every sort, after which his (fleet again) set sail. Hsü Fu (must have) found some
farms of fertile plain, with broad forests and rich marshes, where he made himself king—at
any rate, he never came back to China.

Sauma Chhien thus suggests that though Hsü Fu humoured the emperor’s Taoist
beliefs, he really knew that there were good and vacant lands away in the east, and
planned to make off there. Later generations sometimes believed that he had settled in
Japan, and a tomb shrine of Jofuku (as he is there called) exists to this day at Shinji-in
in Wakayama prefecture. But this has not the value of an independent tradition since
Japanese scholars all through the ages were familiar with the Shih Chi. Archaeological
evidence is more compelling, for Chinese influence reveals itself strongly in the arti­
facts of the middle Yayoi period (-1st and -1st centuries). Nevertheless it may be
almost equally likely that the story of Hsü Fu’s disappearance conceals one voyage at
least to the American continent. Where he and his people went we shall probably
never know. But what sails the settlers had, or what means they took to steer their
vessels over the broad waters, are matters not beyond all conjecture.10

References

Shih Chi, ch. 6, p. 299, tr. sect. adjuv. Chavannes (1), vol. 2, pp. 184, 190 ff.
Shih Chi, ch. 6, pp. 138 ff.
1 方土
2 船
3 泰
4 韓
5 東
6 東
7 伐
8 探
9 伐
10 探

Exploratory voyages into the Pacific continued through most of the Former Han dynasty, but
especially under Han Wu Ti. Thus the alchemist Li Shao-Chhien (cf. Sect. 53 below), favoured at
court in -133, had spent much time at sea communing with the immortals, whose islands he claimed to have

But the best account of Hsü Fu’s proceedings is given by Sauma Chhien in his bio­
ography of the Prince of Hwu-Nan. There incidentally he says:8

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things. When he returned he invented excuses, saying: ‘In the midst of the ocean I met (on
an island) a great Mage who said to me ‘Are you the envoy of the Emperor of the West?’ to
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farms of fertile plain, with broad forests and rich marshes, where he made himself king—at
any rate, he never came back to China.
CONTROL (I), NAVIGATION

THE THREE AGES OF PILOTRY

Some short account of the techniques of Chinese navigation can now no longer be postponed. We have come close to the subject several times, notably in the first volume where the maritime trade-routes were described, then in the third with regard to maps and sailing-charts, again in Vol. 4, pt. 1, in connection with the history of the magnetic compass, and now with great force in the contrast between the Portuguese and the Chinese long-distance navigations. It might perhaps have been more logical to defer it until after the description of the development of the forms of the steering-gear itself, but the topic is so intimately concerned with the history of Chinese shipping and with all that was involved in men, routes and destinations, that it seems good to place it here. We shall give detailed documentation only for new material, and for the rest refer the reader to the relevant foregoing Sections.

To recapitulate or even condense the rich literature on the history of navigational methods in the western part of the Old World would of course be out of the question, yet we must try to summarise in a few paragraphs what is known of it so that we may not lack standards of comparison. The conventional periodisation of this history has caused some discomfort to its students, and we shall therefore prefer to distinguish three periods, those of (a) primitive navigation, (b) quantitative navigation, and (c) mathematical navigation. I propose to date the beginning of the second period at about +1200 in the Mediterranean (as we shall see, it was nearer +900 in East Asia), and the beginning of the third period at, or a very little before, +1500. Let us survey their characteristics in turn.

It cannot be said that the mariners of the primitive period were without astronomical guidance; from very early times they steered (i.e. they oriented themselves) by the stars and the sun. By night they could tell the time by the circumpolars and the culminated. In the same year Khuan Shu, a level-headed official who was afterwards Minister of Sacrifices, was despatched to sea in charge of an expedition to search for Phæng-Lai. In the 1st century B.C., however, the experts were, we must not miss the significant point that this discovery of the magnetic compass now became known and used there, causing a veritable revolution in the sea-faring art. Not only could the way forward be known through days and nights of overcast cloud or storm, but also the quantitative accuracy of azimuth dial readings brought many important developments in its train. Naturally the wind-rose became more complex, but in addition it transferred itself to parchment in the form of those portolan charts with their interlaced loxodromes or rhumb-lines radiating from a centre to a series of points, which we have already described. The earliest dated example of such a chart, ascribed in Vol. 3, p. 129, is of +1311, but historians of cartography customarily date its elaborate counterpart, the Carta Pisansa, at about +1275, and there is some textual evidence for sea-charts probably of this type from the

3. Thirty-six constellations selected in Egyptian astronomy, one for each 10° of celestial longitude; cf. Vol. 3, p. 122 and Vol. 2, p. 27, also Boll (1); Bouché-Leclercq (1).
4. Luuan, Pharsalia, viii, 172 ff., c. 64; cf. Taylor (8), p. 27.
8. Cf. Vol. 3, p. 139, on Timotheus of Rhodes, c. 266, a contemporary of Aratus.
9. For an ancient Indian account of this practice see Raha-Davids (4), quoted in Taylor (8), p. 72.

A general review of it was written by Hornell (16). Cf. p. 633 above.

A Supâragha was none other than the Buddhâ in a previous incarnation. The source is the Jātakârâta by Añatasatta, translated into Chinese before +444 (Lévi (7), p. 86, quoted by Fernald (7), p. 177).

3. Lane (3) analyses the economic effects of this revolution.
year +1270 when St Louis was on his way from Aigues-Mortes to the Crusades. We may freely date their beginning during the second half of the +13th century. In the new precision of these bearing-and-distance plots further practices were implicit, notably time-and-distance measurement, so that the more accurate determination of time spent on a particular course became vitally important. Hence we are not surprised to find much talk of 'orologes de mer' from about +1310 onwards, 'dyolys' from +1411, and 'running-glasses' from about +1490, all being one and the same thing, namely the hour-glass or sand-glass, regularly turned (with chant) by the petty officer of the watch. Moreover, the pilot might well be obliged by the winds, as of old, to follow a course rather different from what he intended, but from about +1300 onwards the new discipline (new to Europe) of trigonometry supplied him with sets of traverse tables from which he could calculate very easily how much of his intended course he had made good after a certain time, and how far he would have to sail to get back on to it. Of this 'Toleta de Marteloio' we have no example before +1428, but we know from passages in the writings of that great though eccentric Catalan philosopher-alchemist Raymond Lull, c. +1290, that it was developing in his time—significantly contemporary with the rise of trigonometry in the work of men such as Richard of Wallingford. Doubtless an absolute limiting factor for the appearance of these composite pilots of the late +13th and early +14th centuries was the popularisation of the Hindu-Arabic numerals, which came to completion just after the first use of the magnetic compass by Mediterranean sailors (late +12th century), though the new figures had first become known to the West before the end of the +10th.c As for the compilation of ratners, our oldest extant example of this period is the Italian Compendio de Navigare of +1255, which describes the whole Mediterranean in terms of the bearing-and-distance system which the portolan charts were shortly to embody, together with much more valuable piloting information.f

So far there is no dispute, but real difficulty arises when we come to the quantisation of that astronomical guidance which even the most ancient navigators had relied upon, the extension, in fact, of the new standards of measurement, in some practical form, to

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*b This was the oldest marine clock since neither sundial nor clepsydra could conveniently be taken to sea. The bear discussion of the sand-glass as a navigating instrument, with full references, is by Waters (11), who believes that it must have been in use in the +13th century because of its obvious association with the portolan charts. The meaning of the term 'dial' was for some time in doubt because of the presumed existence of Norse 'bearing-dials' or wooden wind-rose antennas to the magnetic compass, but an object found by Solerer (1) can be interpreted in other ways, and the suggestion of Nazilli (1) that the +12th-century dyoll' was the sand-glass is now generally accepted. The crucial evidence is perhaps the mention in a late +15th-century English rutter of 'smaile dace sonde' on the sea-bottom in 65 fathoms off Belle-isle (Anon. (51), p. 41). It is natural enough to find the first use of the term 'dial' in +1411 (Moore, 2), because the new mechanical clock had acquired its dial in the just preceding century (cf. Vol. 4, pt. 3, p. 511). It is also natural that its name should have changed again at the beginning of the following century for then it became necessary to distinguish it from the new portable watches and combined sundial-compasses. We shall return presently to the question of the origin of the sand-glass.

From the +17th century, as Grover at al. (1) have shown in an interesting paper, very finely powdered calcite from egg-shells was used in sand-glasses rather than sand.

c See Taylor (8), pp. 117 ff.; (10); Waters (15), pp. 49 ff.; Beaujouan & Pouillé (1), p. 106, etc. The portolan, the compass, the sand-glass and the marteloio form a rather closely knit group of complementary techniques.

d Cf. Vol. 3, pp. 15, 16; Taylor (10).
* See Motzo (1); Taylor (8, 9, 10).
Most probably what came first were those empirical sailing arcs in the broad Atlantic which we have already described (pp. 511 ff.), and it was these long voyages far from sight of land which impressed upon the Portuguese that something more was necessary than the rhumb bearings of the portolan charts, namely a way of determining the latitude at sea. The fact that the Guinea arc was already in full use by +1440 pleads in favour of the use of the mariner's astrolabe or quadrant already at that time, but no evidence, textual or archaeological, sustains it. The use of such devices on the Brazil arc, which came about 47 years later, strains our credulity the less.

A question of Arabic influence on the Portuguese navigators of the +15th century has been raised, though not yet answered—-with all the contacts which they had at the eastern end of the Mediterranean, Ibn Mjjid was surely not the first Arab pilot ever encountered by them. The hard problem is to know just what the Catalan influence in Portugal at the beginning of the century, the deliberations of the School of Sages towards its middle, really amounted to. Certain it is that in the second half of the +15th century many navigators and teachers of navigation were following methods which went back to the beginning of the period—-notably Alvise Ca' da Mosto on his Gambia voyage in +1455; while in the north Pierre Garcie in +1481 still lacked even the portolan chart, though he made history by his sketches of prominent landmarks like those still used in Admiralty Sailing Directions, and his deep knowledge and tabulation of the tides.

This is the time, however, the threshold of the Renaissance, which marks the transition from the second to the third period, from quantitative to mathematical navigation.

a As da Mota (1), p. 131, has emphasised. The intermediate stage was latitude navigation; comparing the polar or noon sun height at the place with that known for Lisbon. b Criticising the conventional views (e.g. da Costa (1), p. 12; Taylor (8), p. 159; Waters (15), p. 46). Benjouan (1) has analysed destructively the only three pieces of textual evidence for its use before the last two decades of the century. One of these is interesting because it shows navigators then felt about the old portolans. Either Digo Gomes or Martin Behaim is speaking, about +1483 and as there is doubt the passage cannot be dated earlier. 'And I myself had a quadrant when I went down to those places (Guinea), and I marked the altitude of the north pole upon its face (or table). I found it much better than the map, for while on the map you can certainly see the route to be followed (i.e. the bearing), once you go wrong you can never get back to your original objective.' In other words, 'finding and running down' the latitude is much better than trusting to compass and marlote alone. This was the beginning in the West of a method that lasted for centuries, but it was what the sailors of the East had been doing for some time already (p. 567 below).

Another passage studied by Benjouan (1) also applies Western and Eastern methods. When Alvise Ca' da Mosto was at the mouth of the Gambia in +1455 he found the Southern Cross standing 'at the height of a lance.' Evidently he had no quadrant. The only other known use of this expression occurs in a conversation of another Venetian, Marco Polo, about +1300, recorded by Pietro d'Alassio; the great traveller said that a celestial body which must have been the main Magellanic Cloud in Doradus could be seen from various parts of the southern hemisphere, near the antarctic pole and 'at the height of a lance.' What this suggests to us is that Chinese navigators, knowing the great use of the gnomon by their own astronomers, not only at home but in many places abroad (cf. Vol. 3, pp. 274, 282 ff.), set up such styles when they touched at different places, and expressed star altitudes roughly by their aid. It was, after all, the simplest possible kind of cross-staff method.

The so-called perpetual or patent log, due to Foxon and Russell (+1754), was taken to sea, and the compass swing in gimbals. While at the same time accurate advances were made in the measurement of the ship's speed, and the old rough rules for estimating it were abandoned in favour of the log and knotted log-line (+1743), or the accurate timing by minute-glass of the passage of an object in the water past two marks on the ship.

The continuously working screw log came in the eighteenth century. Finally, there were advances in the written records of word, chart and terrestrial globe. Rutters

From +1500 onwards new aids for the sea pilot came tumbling out of the cornucopia of the 'new, or experimental, philosophy' in a wealth almost as bewildering as that of the aerofly or transistor age. Beginning again with the astronomical field, first there was the introduction of sun declination tables for computing polar altitude (+1485), quadrant tables (+1497), Southern Cross tables (+1503), sun culmination tables (+1514), sun amplitude tables (+1595), all eventually leading to publications of the nautical almanac type (+1678 onwards). Then there were continual improvements in instruments, the first vernier-type graduations (+1542), the suplementation of the cross-staff by the Davis back-staff (+1594), and the coming of the reflecting sextant and octant (+1731). With the development at long last of accurate mechanical time-keeping machines, marine chronometers, suggested in +1530 but not accomplished till +1760, the problem of the longitude was solved; and with the production of the marine barometer +1700, forecasting of weather became possible at sea. Meanwhile knowledge of magnetic phenomena steadily increased. Declination having become known to Europeans in the last decades of the +15th century, its variation in different localities, first plotted by João de Castro and others from about +1535, was mapped on a world scale in Halley's voyage of +1699—important knowledge for mariners, though the hopes that it might solve the problem of the longitude were to prove illusory. From +1500 onwards the Cardan suspension was taken to sea, and the compass swing in gimbals. At the same time great advances were made in the measurement of the ship's speed, and the old rough rules for estimating it were abandoned in favour of the log and knotted log-line (+1743), or the accurate timing by minute-glass of the passage of an object in the water past two marks on the ship.

The continuously working screw log came in the eighteenth century. Finally, there were advances in the written records of word, chart and terrestrial globe. Rutters
became ever more detailed from +1500 onwards, gaining stimulus from the experiences of Europeans in the Indian Ocean, while latitude charts with graduated meridians led directly to the projections of Mercator (+1569) and others, corrected by Harriot and Wright (+1599) so that the nautical triangle drawn on them would show latitude and longitude, bearing and course, approximately correctly. Great circle sailing was explained by Pedro Nunes and many others from +1577 onwards. Thus we are brought to the world of the nineteenth century and all our modern techniques of echo-sounding, ship's wireless, radar and the like. In what follows we shall see clearly enough that although Chinese pilots never by themselves entered the third of the three phases, mathematical navigation, they had sailed into the second phase, that of quantitative navigation, some two or three centuries ahead of Europeans. They too, then, deserve their praise.

If Pilots painful toil be lifted then aloft
For using of his art according to his kind,
What fame is due to them that first this art outsought,
And first instructions gave to them that were but blind.

(2) Star, Compass and Rutter in the Eastern Seas

It is hardly to be questioned that from the earliest times when Chinese shipmasters sailed their vessels out of sight of landmarks they steered by the stars and the sun. Chang Hêng was probably referring to their starcraft when he wrote in his Ling Hsien (+118): 'There are in all 2,500 (greater) stars, not including those which the sea people observe.' Here hai jen could equally well have been translated 'sailors', and so indeed we made it when we cited the passage in full. This raises the ghost of a literature long lost, and now hard to interpret, but perhaps highly relevant. At that same place we mentioned in a footnote the fact that the Khai-Yuan Chan Ching, the great treatise of the Thang on astronomy and astrology, often quotes an ancient Hai Chung Chan, i.e. 'Astrology (and Astronomy) of (the People in) the Midst of the Sea (or, of the Sailors)'.

The antiquity of a text of this name is certain because it appears (with ampler title) in the bibliography of the Chhien Han Shu, completed by the last decades of the +1st century, and is quoted several times in the Hou Han Shu commentary written about...
Fig. 989 (a). Comparative map of the Chinese and Portuguese discoveries and navigations in the 4-15th century; routes of the Chinese in blue, routes of the Portuguese in red. Dotted lines denote conjectural voyages suggested by textual or other evidence. Chinese dates are bracketed if drawn from textual evidence before the 4-15th century; dates given for that period indicate at least the earliest visit recorded. Cf. the maps of Cheng Ho's voyages by Cheng Ho-Tsing (1) and Hsiang Te (1). Full discussion in text.
Fig. 230 (b). Map to illustrate the meteorological and oceanographic background of the Chinese and Portuguese discoveries and navigations in the 15th century: prevailing winds in green; principal currents in brown. Winds from Miller (1), currents from Sverdrup, Johnson & Fleming (2). Full discussion in text. Stereographic projection of Gell, 1:40,000,000 at the equator, 1:8,000,000 at the 45th parallel.
+ 502 by Liu Chao. The books that we find in the Han bibliography are named as follows:

**Hai Chung Hsing Chan Yen** (Verified Stellar Prognostications of the Sea People).
**Hai Chung Wu-Hsing Ching Tsu-Shih** (Manual of the Five Planets for Divers Occasions according to the Usage of the Sea People).
**Hai Chung Wu-Hsing Shan Ni** (The Forward Motions and Retrogradations of the Planets, a Sea People's Manual).
**Hai Chung Tih Yüeh Hua Hung Tsan** (Miscellaneous Prognostications by Sun, Moon, Comets and Rainbows, according to the Usage of the Sea People).

There are three interpretations of the expression hai chung: (a) that it meant the people of some foreign countries or islands overseas, (b) the Chinese as opposed to overseas (hai wai) people, (c) the sea-faring men of China's coastal provinces. Moreover the material of the books could have been primarily astrological or primarily concerned with navigation. The first alternative of the three has been favoured by Western sinologists (so often prone to doubt Chinese originality), though he did not explain why Hai-Chung should have been used when Chung-Kuo was the normal term, and hai nei the obvious antonym. We agree with Lao Kan (2) that the third is the most reasonable. So also thought the great scholar Wang Ying-Lin about 1280, who in his Han I Wen Chih Khao Cheng (Textual Criticism of the Former Han Bibliography) wrote:

In the astronomical chapters of the Hou Han Shu, the commentary quotes a Hai Chung Chan, and this is cited again in the section on astronomy in the Sui Shu, together with a Hai Chung Hsing Chan Hsing Thu (Star Charts and Stellar Prognostications of the Sea People), each composed of one chapter. These are what Chang Hêng referred to as the 'mariners' observations'. In the astronomical monograph of the Thang Shu it says that in the 11th year of the K'ai-Yuan reign-period (+714) the Astronomer-Royal was instructed by decree to proceed to Chiao-chou (mod. Hanoi) to measure sun-shadow lengths. While there at sea (hai chung) in the eighth month, looking southwards, they observed the remarkably high altitude of Canopus (Lao jen). Below it there were numerous stars brightly shining, including many large ones, but these had not then been recorded on the celestial maps, and their names were not known.

* Sê Chih Lu, ch. 30 (ch. 10, p. 7).
* Though it is rather strange that sailors should have occupied themselves with geographical astrology, the influences of stars on particular places (cf. Vol. 3, pp. 245 ff.) and on the officials of the bureaucracy. So Chinese a trait as this last pleads for a home rather than a foreign origin.
* In Erh-shih-nu Shih Pu Pien, p. 1435, 2. Tr. sucit.
* Or 'reckonings', or 'prognostications'.
* We are very familiar with this story from Vol. 4, pt. 1, pp. 44 ff.
* a Carinae.
The words hai chung are in the Chiu Thang Shu text, so that the phrase certainly meant star observations at sea in the +8th-century documents from which the +10th-century writer drew. Probably we shall not go far wrong if, with Lao Kan (2), we identify the Hai Chung (‘sea-going’) corpus as the work of those ‘magicians’ of the Warring States period and Early Han who lived along the coasts of Chhi and Yen, the ‘mathematical practitioners’ of the earliest stages of Chinese navigation. Their skills were doubtless undifferentiated, and it would be impossible to disentangle in them the components which today we should call astrology, astronomy, stellar navigation, weather-prediction, and the lore of winds, currents and landfalls all the more so since (as in the work of Dee, Hargill, Good, Gaudby, and many others) these elements were still wholly confused down to the end of the +17th century in Europe. At all events we can now form some idea what kind of men those ‘sea-going’ magicians were doubtless undifferentiated, and it would be impossible to disentangle in them the weather-prediction, and the lore of winds, currents and landfalls; all the more so that Wang Chung, who lived in Shantung, ‘delighted in Taoist techniques and was well versed in astronomy’, so when trouble came during the rebellion of the Lü family about -180 he put out to sea with all his people and sailed eastward to Lo-lang in Korea, where he settled in the mountains.

Chinese pilots in the period of primitive navigation certainly made use also of all those other ancient aids which we have already mentioned. But it was they who brought this period to an end by being the first to employ the magnetic compass at sea. This great revolution in the sailor’s art, which ushered in the era of quantitative navigation, is solidly attested for Chinese ships by the +10th-century appearance in the Chinese explorations of the Pacific in search of the Isles of the Immortals. After all no ancient mariner would have found it easy to distinguish between prognostication of a safe voyage and the lore of winds, currents and landfalls.


After all, no ancient mariner would have found it easy to distinguish between prognostication of a safe voyage based on planets and stars that had been observed on seasonal winds and other meteorological factors associated with the recurring positions of stars. Here we must not forget the Hai Tao Shun Ching (Sea Island Mathematical Manual) by Liu Hui, wholly devoted to survey geometry, which appeared in the +28th century. At some intervening period the frictional drag of the spoon on the plate had been thus been invented, but although these primitive arrangements seem still to have been used as late as the +13th century, Chinese sailors did not (so far as we know) employ them. For at some time between the +1st and +6th centuries the discovery had been made that the directive property of the lodestone could be transferred by induction to the small pieces of iron or steel which the lodestone attracted, and that these also could be made to float upon the surface of water by suitable devices. The earliest extant description of a floating compass of this kind dates from just before +1044 and involves a thin leaf of magnetised iron with upturned edges, cut into the shape of a fish. To floating compasses of one kind or another Chinese navigators remained faithful for nearly a millennium. We have detailed accounts of their use from the +11th century. But in the +16th there came Dutch influence, mediated in part through the Japanese, as a result of which the dry-pivoted needle and then the magnetic bearing and sounding, together with the study of sea-bottom samples. Two further accounts in the +12th century follow before the first European mention, each emphasising the value of the compass on nights of cloud and storm. The exact date at which the magnetic compass first became the mariner’s compass, after a long career afloat, is not known, but some time in the +9th or +10th century would be a very probable guess. Before the end of the +17th (Marco Polo’s time) we have compass bearings recorded in print, and in the following century, before the end of the Yuan dynasty, compilations of these begun to be produced. In all probability from the beginning of its use at sea, the Chinese compass was a magnetised needle floating on water in a small cup. A thousand years earlier, the first and oldest compass had been a spoon-shaped object of lodestone rotating on a bronze plate. At some intervening period the frigidic drag of the spoon on the plate had been overcome by inserting the lodestone in a piece of wood with pointed ends, which could be floated, or balanced upon an upward-projecting pin. The dry-pivoted compass had thus been invented, but although these primitive arrangements seem still to have been used as late as the +13th century, Chinese sailors did not (so far as we know) employ them. For at some time between the +1st and +6th centuries the discovery had been made that the directive property of the lodestone could be transferred by induction to the small pieces of iron or steel which the lodestone attracted, and that these also could be made to float upon the surface of water by suitable devices. The earliest extant description of a floating compass of this kind dates from just before +1044 and involves a thin leaf of magnetised iron with upturned edges, cut into the shape of a fish. To floating compasses of one kind or another Chinese navigators remained faithful for nearly a millennium. We have detailed accounts of their use from the +11th century. But in the +16th there came Dutch influence, mediated in part through the Japanese, as a result of which the dry-pivoted needle and then the
compass-card—a (doubtless an Italian invention) were adopted on Chinese vessels. The Chinese compass-makers, however, employed a very delicate form of suspension which

tional technique. By great good fortune, certain maps of portolan character b dating from about this period, which trace the routes followed by these and other Chinese ships and convoys, have been preserved intact. Early in the +17th century they were printed as the last chapter of an important treatise on military and naval technology, the Wu Pei Chih, c and part of a map showing the Indian Ocean with the openings of the Persian Gulf and the Red Sea has been reproduced in Sect. 22d above. These charts are extremely distorted but schematic, and ships' courses are drawn across their oceans like the tracks in the maps issued by modern steamship companies. The lines of travel are accompanied by legends giving detailed compass bearings, with distances in numbers of watches (k'eng 1 or ching1), and notes of most of the coastal features which could be important in navigation. The bearings are always given in the form ‘hising ting wei chen’ (sail with the needle between Ting and Wei azimuth points, i.e. due S.S.W.), or ‘yung keng shen chen’ (use the needle pointing between Keng and Shen, i.e. due W.S.W.), while ‘tan k hun’ (bear on red, or single, Khun) meant sailing with the needle pointing directly to Khun, i.e. within 36° on each side of S.W. Thus the general formula is: ‘sail on x° for y watches.’ The notes include indications of half-tide rocks and shoals as well as ports and havens. Routes are given for inner and outer

cities, and distance run. A best, in Mills (1), has explained the ‘double bearings’ by which some have been puzzled in these texts. They meant only the usual procedure of setting off on the first course, and then changing to the second upon raising the island or point which acted as the intermediate landmark. He also plotted and ‘swung’ the bearings given so as to fit a modern map; the excellent result indicated that the Chinese navigator of the +15th century was using a compass with a declination about $5°$ W. of true N. Cf. Table 19 in Vol. 1, p. 310; and Smith & Needham (6). Treble bearings are also known.

c. Duyvendak (1); Mills (1).

c. Some five miles up the Krung Pasai River on the north coast. On this place-name, see Gerini (1), p. 214.

d. Some five miles up the Krung Pasai River on the north coast. On this place-name, see Gerini (1), pp. 642 ff.; Fellows (2), p. 214.

e. Some five miles up the Krung Pasai River on the north coast. On this place-name, see Gerini (1), pp. 642 ff.; Fellows (2), p. 214.

Here again we have an instance of the classical Chinese preference for decimal metrology (cf. Vol. 3, pp. 82 f.). The k'eng was also generally considered to be the equivalent of $90°$ (Hsi-Yang Ch'uan Kang Tien Lu, Liu-Chin Kuo Chih Lien and many other authorities, cf. TSCC, I, shu tien, ch. 31 f., p. 98), but apparently sometimes 45° (Min Tien Shu, cf. 5°), a Ching work quoted by Liu Ming-Shu (4), p. 59. The Ming was being over 300 miles, the way made in an hour was 8.73 miles (or 10.45 miles if the k'eng was assimilated to the double-hour). If the Later Han and Ch'in length of 0.258 mile persisted as a measure sea, the figures would be 8.3 miles and 7.7 miles respectively. If the Ch'in length of 0.357 mile is used with a Ching k'eng of 42 li, the results are very similar. 0.45 miles and 7.75 miles respectively. A speed of 6 li to 10 li would be quite reasonable for Ch'eng Ho's ships (cf. Vol. 3, p. 561).

For a description of the Chinese system of azimuth measurement see Sect. 261 above (Vol. 4, pt. 1, Table 5). It has 48 sections of $73'°$ each.

On these matters see Muider (1), with some reservations.

1a, 1b 12 行丁未針 2 用水申針 3 丹砂 4 周逢乙

29. NAVIGATION

passages of islands, sometimes with preferences if outward- or homeward-bound. Much attention has been given to the accuracy of these diagrams and descriptions by modern scholars, and to the identification of the place-names in them, with the result that a high opinion has been formed of the knowledge and precision of these Chinese navigators' records. Some idea of the skill of the pilots may be gained by the fact that in circumnavigating Malaya they laid their course through the present Singapore Main Strait, which was not discovered (or at least not used) by the Portuguese until they had been in those waters for more than a hundred years.

The interest of the last chapter of the Wu Pei Chih, however, is not exhausted by these schematic charts. Four instructive navigational diagrams are given, summarising the star positions to be maintained during as many regular voyages. Here we reproduce (Fig. 994) the diagram of pilot's directions for that between Ceylon (Hsi-lan Shan) and Sumatra (Su-men-ta-la), Kuala Pasé, modern Sumatra. A reading of the notes concerning the ‘Guiding Stars’ (chhien hsing) which are distributed round the central picture will lead us into the heart of the matter.

[Above] The Pole Star (Pei chhen) to be 1 chih above the horizon, and the 'Imperial Baldwin' (Hua kai) 8 chih. [To the left] In the north-west the Pu ssu stars to be 4 chih above the horizon; and the same in the south-west. [Below] The 'Frame' or 'Bone' of the 'Lantern' (orthographically Teng lung ku) (i.e. the Southern Cross) to be 14 chih above the horizon. The twin stars of the 'Southern gate' (Nan men) to be level at 15 chih. [To the right] In the north-east the 'Weaving girl' (Chih nü) to be 11 chih above the horizon.

a. Cf. Mills (1); Blagden (1).

b. Here the chief work was done by G. Phillips (1).

c. Best, in Mills (1), has explained the 'double bearings' by which some have been puzzled in these texts. They meant only the usual procedure of setting off on the first course, and then changing to the second upon raising the island or point which acted as the intermediate landmark. He also plotted and 'swung' the bearings given so as to fit a modern map; the excellent result indicated that the Chinese navigator of the +15th century was using a compass with a declination about $5°$ W. of true N. Cf. Table 19 in Vol. 1, p. 310; and Smith & Needham (6). Treble bearings are also known.

d. Cf. Duyvendak (1); Mills (1).

e. Some five miles up the Krung Pasai River on the north coast. On this place-name, see Gerini (1), pp. 642 ff.; Fellows (2), p. 214.

29. NAVIGATION

It is a common assumption (e.g. in Schlegel (5), p. 352; 554) that the Southern Cross was unknown to the Chinese before the arrival of the Jesuits. No doubt the name Shih t'ui chi derivé from them, and by this it has since been known in the astronomical repertories, but in Teng Lung we must have a sailors' name which was never included in such official lists. I have not found it on any of the old Chinese star-charts, nor in those of encyclopaedias (TSCC, STTH, etc.) compiled long after the +15th century. But it is obvious that the pilots could never have done the work they did without being familiar with it. Here may be another example of the gap between the knowledge of the semi-literate artisans and the all too literate scholars.

4 The directions for this route have been minutely studied by Mills (10).

5 This astereism cannot be found in lists such as those of Chien Tuan-Kuei (7) or So-ch'eng (5); its name here used was probably current only among sailors. Yen Tun-Chieh (19) suggests Aurigae.

6 It is a common assumption (e.g. in Schlegel (5), pp. 352, 554) that the Southern Cross was unknown to the Chinese before the arrival of the Jesuits. No doubt the name Shih t'ui chi derives from them, and by this it has since been known in the astronomical repertories, but in Teng Lung we must have a sailors' name which was never included in such official lists. I have not found it on any of the old Chinese star-charts, nor in those of encyclopaedias (TSCC, STTH, etc.) compiled long after the +15th century. But it is obvious that the pilots could never have done the work they did without being familiar with it. Here may be another example of the gap between the knowledge of the semi-literate artisans and the all too literate scholars.

a. e. f. Central and stars in Circinus.

b. e. f. Centre and stars in Circinus.

c. e. f. Some five miles up the Krung Pasai River on the north coast. On this place-name, see Gerini (1), pp. 642 ff.; Fellows (2), p. 214.

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NAUTICAL TECHNOLOGY

The explanation of all this lies in the fact that for measuring the altitudes of the pole-star and other stars the pilots did not use the degrees of the astronomers but rather another graduation in finger-breathths (chih), each of which was divided, possibly into 8, more probably into 4, parts (chio). Moreover, for this voyage the pole-star was very low on the horizon or invisible, and it was therefore necessary to substitute for it a circumpolar markpoint, the Hua kai constellation. Altitude on this would be measured each night when it culminated, and the altitudes of all the other guiding stars taken presumably at the same time. The Wu Pei Chih charts give Hua kai altitudes for a number of places.

Once we realise that the navigators of the China Seas and the Indian Ocean depended quite as much on polar altitudes as the Portuguese came to do towards the end of the 15th century, a host of fascinating questions arises. Unfortunately we know as yet neither exactly how far back this quantitative oceanic navigation went in Eastern waters, nor how far the Europeans of the Atlantic border were influenced by it during the explorations of the West African coast. Certain it is that when the Portuguese showed him their astrolabes and quadrants in the summer of +1498 Ibn Majid was not in the least surprised, saying that the Arabs had similar instruments, but the Portuguese were very astonished that he was not surprised. Moreover, there are a number of points at which we may suspect East Asian influence on Europe, or where at least we have to grant considerable East Asian priority.

First, it is clear that the Chinese navigators of Ch'eng Ho’s time, besides their compass-bearings, knew the method of finding and running down the latitude. In the Hai-Yang Chiao Kung Tien Lu, for example, there is talk of a voyage from Bengal (probably Chittagong) to Malé in the Maldive Islands by way of Ceylon, and the polar elevations are given for every stage of the journey. Thus a certain Ceiloneese mountain will be sighted when the altitude has sunk to 1 chih 3 chio. We are still uncertain, however, as to the instruments which the Chinese used. By +1400 quadrants would have been quite possible—the armillary sphere had had a long and elaborate history in China, and some such apparatus had been used overseas as far back as the beginning of the 10th century, when 1-Hsing’s meridian arc survey teams took altitude measurements from Indo-China to Mongolia. That was the time, too, when a southern hemisphere astrographic expedition had been sent to map the constellations to about 20° from the}

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antarctic pole. Astrolabes as known in the West would not be in the picture, for reasons already given," but a simplified armillary ring with swinging alidades or the characteristically Chinese sighting-tube may well have been used ashore. Even more probable, seemingly, would be the simpler types of cross-staff, for elsewhere evidence has been given that Jacob's Staff was known in China and used by surveyors three centuries before the description of Levi ben Gerson, i.e. by +1086 rather than +1321. This would also be more in line with the practices of the Arab and Indian pilots, as we shall see.

The problem of the maritime charts is also very obscure. That they existed is implicit in many Chinese texts, but the only one which have survived are the schematic diagrams, almost like the 'Puteinger Tables', preserved in the Wu Pei Chih. Nevertheless, the tradition of quantitative cartography was much stronger in China than it was in Europe, so that already by +1137 a superb map on a scale of 100 li to the division could be produced, and there is little reason to think that the much larger map of Chia Tan on a similar scale in +801 was any less good. Indeed, the principle of the rectangular grid went back to Phei Hsia in the +3rd century, and never gave place, as quantitative cartography did in Europe, to the discoidal fancies of the religious cosmographers. It is thus of particular interest that in the work of Shen Kua late in the +11th century we do have a hint that the grid was combined with compass-bearing rhumb-lines, just as occurred two or three centuries later in the Mediterranean, but his work was terrestrial, not nautical, and it did not survive. Lastly, the projection of rhumb-lines, just as occurred two or three centuries later in the Mediterranean, but his work was terrestrial, not nautical, and it did not survive. Lastly, the projection of

Gerard Mercator in +1569 was a great advance, but he never knew that he had been preceded by Su Sung five centuries earlier in a celestial atlas, in which the hour-circles between the huin (lunar mansions) formed the meridians, with the stars marked in quasi-orthomorphic cylindrical projection on each side of the equator according to their north polar distances. With such a brilliant background, we must hope that archaeological discoveries will yet reveal what charts were used by the master-mariners of the Sung, Yuan and Ming. As we look 'a' the magnetic compass, the portolan chart, the sand-glass and the astrolabe formed a closely connected knot of complementary techniques. Little can be said of traverse tables, which have not so far been recognised in Chinese cutters, but the use of sand for time-measuring opens up curious perspectives. Wang Chen-To (5), who went into the matter in his work on the history of the mariner's compass, concluded that the sand-glass was not known or used on Chinese ships until the end of the +16th century when they acquired it from the Dutch or the Portuguese. But since the time of Wang's memoir much information has come to light about an important development in the history of Chinese mechanical clockwork which occurred about +1770, namely the substitution of sand for water in clocks of the classic scoop-wheel type.

Whether or not these continued the link-work escapement or adopted reduction gearing remains unclear, but they certainly involved something new for Chinese clockwork as well as for the more recent clocks of the Westerners, which were acquiring it too, namely a stationary dial with a moving pointer. This new look is associated with the name of Chan Hsi-Yuan, and there is no reason why one or more of his clocks should not have been carried (as the older water-wheel ones could not have been) on each of the great ships of Ch'eng Ho's fleet. In any case, it is clear that time-keeping by sand-
flow was very much in the minds of the Chinese at that time. It is necessary therefore to re-examine the Western traditions which make the sand-glass begin with Liutprand of Cremona in the +10th century,a and to reconsider the suspicion of Speckhart,b long ignored, that the hour-glass came to Europe from the East.c Liú Ming-Shu (4) mounts an argument of some weight to the effect that since nautical watches (kēng) are mentioned (or implicit) in many descriptions of Chinese navigation from the beginning of the +12th century onwards (cf. Vol. 4, pt. 1, pp. 279 ff.), the measurement of such units must have necessitated the sand-glass, since no form of water clepsydra would be imaginable at sea.6 If Waters (11) is right in the Western nautical sand-glass going back to the Venetian glass industry of the late +12th century, the possibility presents itself that together with the magnetic compass itself and the stern-post rudder it might have formed part of one of those clusters of transmissions from Asia which we find in so many fields of applied science. But against this there is a serious argument and another way out. The sand-glass implies blown glass, and as we have earlier found, the glass-making itself. e Is not the time-keeping joss-stick' the real answer to Liu Ming-Shu (4) mounts in China's Middle Ages, and it would have been very easy to measure time approximately enough with the 'joss-sticks' that were kept alight in the ship's shrine where the compass lay also. In this case the use of combustion clocks at sea for watch-keeping gave a very practical and reliable 'proto-chronometer',f and its exact forms merit even more examination than that which Bedini (5, 6) has already devoted to it in a fascinating monograph. Yet the incense-stick was so characteristic of Chinese religion and culture that it may have been difficult for it to spread to mariners of other cultures even though they might have found it very useful.

Let us now return to the altitude measurements in chih and chiao. The remarkable feature of this system is that it was practically identical with that in use among the Arabic shipmasters of the Indian Ocean, who expressed altitudes in ibis (the fingerbreadth or inch), equalling 1° 56' 25",# and its eighth part, the amsa.## The system was

- a Lombard bishop and ambassador, c. +922 to +972. Thus, at least, I interpret the reference in Feldhaus (1), col. 1222, to 'Luitprand de Chartres, fl. +750', which in itself seems improbable to a degree.
- b In his German translation of Saurin (1), p. 177. The reference is to an earlier author, unspecified, whose evidence Speckhart would like to have checked.
- c There is no lack of Alexandrian antecedents for the sand-flow method—for example Heron's automoble and automatic puppet theatre, in which the motive power was derived from the outflow of sand or cereal grains from a large tank, with the consequent fall of a weighted float. See Needham (38).
- d He makes a dubious exception for the sinking-bowl clepsydra (cf. Vol. 3, p. 315). It appears that coconut shells have been used in South-east Asia for this purpose, but whether or we know not. In the Chilng period mariner's hour-glasses were of pottery or porcelain rather than glass, which may plead for the antiquity of the device in Chinese sea-faring culture. There is a description in the Min Tzu Chin. Hsi 1-Thang (1), p. 273, quotes Marco Polo as saying that there was a sand-glass in the watch-house on every bridge in Hangchow, but the text says only an h'eihsia (Moule & Pelliot ed. p. 732 (ch. 158), cf. Mila (13), p. 84), and we cannot assume that this was anything other than a clepsydra.
- e See Vol. 4, pt. 1, pp. 103, 104.
- h See Ferrand (7), who printed de Sausasure (56). There were 224 iba (the complete circle.

29. Navigation

long known to Europeans mainly from the Muḥī (The Ocean), a compendium of nautical instructions¹ put together by the scholarly Turkish admiral Sīdī 'All Re'īs ibn Husain² when staying at Ahmedabad in India in +1553 on his epic journey home after the destruction of his fleet.³ Later his chief sources became known, the treatise of Sulaimān al-Mahrī (+1511), and especially the Kitāb al-Fusul'd written about +1475 by Shihāb al-Dīn Ahmad ibn Mājid,⁴ the Arab pilot who joined Vaasa d' Gama at Malindi in +1498. We know now that the Portuguese navigators made use of the system for some time afterwards.⁵ It will be seen that the tradition must have been in full vigour in the reign of Ch'eng Ho's flotilla (1405 – 1433). Moreover when the measurements in the Muḥī and its sources are compared with those in the Wu Pei Chih, they are found, generally speaking, in good agreement.⁶ The chief difference between the Arab and the Chinese systems seems to be that when a 'substitute' polar mark-point was desired in equatorial latitudes, the Arabs chose the classical 'Guards' (β and γ Ursae Minoris), which they called al-Farkādān (the 'Calves'),⁷ while the Chinese chose Hua kai; the declinations being very similar, but the right ascensions almost exactly 180° (1 hr. apart).⁸ Both Arabs and Chinese took a pole-star elevation of 1 fingerbreadth as the point at which it was no longer safe to trust to pole-star measurements; they then changed from pole-star to circumpolar mark-point, the Arabs taking 8 finger-breadths of al-Farkādān, and the Chinese 8 finger-breadths of Hua kai as equivalent to 1 finger-breadth of pole-star elevation.⁹ The first Europeans who visited the southern hemisphere found it very strange that the northern pole-star disappeared from sight. Marco Polo lost it in Sumatra on his...
voyage home in +1292 and recovered it at Cape Comorin (lat. 8° N.). Odoric of Pordenone remarked on the same phenomenon some twenty years later. Ye shall understand [wrote Mandeville about +1350] that in this land (Sumatra) and in many other thereabout, men may not see the star that is called Polus Arcutus, which stands even (i.e. due) north and sets never, by which shipmen are led, for it is not seen in the south. But there is another star which is called Antarctic and that is even against (i.e. diametrically opposite) to the other star, and by that star are shipmen led there, as here by Polus Arcutus. Although none of these Western writers recorded the southern stars which the Asian pilots really sighted, they were greatly impressed by this astronomical navigation, so much so indeed that they gave the impression that the magnetic compass was not used in those waters. Nicolò de Conti, who was in the China seas just before +1440, said:

Commonly the Indians say by the guiding of the stars of the Pole Antartique, for seldom time-does they see oure North Starre. They use not the Loademans-stone as wee doe; they do measure their waye, and distance of places, according as their Pole riseth and falleth, and so do they knowe by this means what place they are in. They doe make bigger shippes then we doe... And twenty years afterwards Fra Mauro put the same information in his map. Very near the two clearest sea-going junks a scroll inscription in the middle of the Indian Ocean says:

The ships or junks which navigate these seas carry four masts or more, some of which can be raised or lowered, and they have 40 to 60 cabins for the merchants. They have but one single rudder, and navigate without a compass because they carry an astronomer who stands alone on the high (poop) and commands the navigation with an astrolabe. And Mandeville, though he says nothing on this subject, found posthumously an illustrator (c. +1385) who depicted the instrument on the poop of a ship in the south seas. The words of Fra Mauro have not hitherto been much noticed but their date alone on the high (poop) and commands the navigation with an astrolabe.

The navigation given about the compass in these passages, however, was undoubtedly wrong, and Taylor has plausibly explained how it arose. The Mediterranean pilot of the +14th century never took his eyes off the needle, and gave orders to the helmsman accordingly while working out his course by bearing and distance. For the Asian pilot the needle was only one of his instruments, and the determination of position by star (and possibly even sun) sights was at least equally important. This was no doubt because the region sailed by the seamen of the Arabic tradition was one of relatively scanty, or at least very seasonal, rainfall, and frequent clear skies, so that orientation by the stars was more inviting and capable of more precision. At the same time their oceanic domain included both northern and southern hemispheres, with all that that implied of astronomical challenge. And as the interruption of overcast skies was less, there was not the same reason to wax enthusiastic about the leading of the lodestone. It is true that its only begetters, the more northerly Chinese, had done so, but their words were enclosed in the ideographic language, not to be understood or appreciated by Westerners until comparatively modern times.

The question may be raised as to the mutual influence of the Arabic and Chinese navigators, but at present we hardly know enough to answer it. They had certainly been in contact for many centuries before +1400. Measurements of altitude were particularly prominent in all Arabic astronomy, but on the other hand circumpolar mark-points for invisible stars were rather characteristically Chinese. Again, chih and chiao measurements are not common in early printed Chinese texts, but that does not mean that they were not in widespread use by pilots, whose rutters were generally hand-written. Moreover, we can find possible Chinese mentions of surveyors’ measurements in ‘finger-breadths’ (chih) a good deal earlier than anything similar in Arabic culture. For example, as has already been noted, one of the Wei generals, Têng Ai, was well known about +260 for his interest in military topography—‘whenever he saw a high mountain or a wide moor, he always estimated (heights and distances), measuring by finger-breadths, so as to sketch and plan the best positions for an army camp or fort’. His contemporaries, easily amused, thought this rather pedantic. But of course the system of finger-breadth units for altitudes could easily have arisen independently in the Arabic and Chinese culture-areas.

What instruments were used by the Chinese pilots of the Yuan and Ming for taking star altitudes was long a puzzle, but of those employed among the Arab sailors a good deal was known; they were all forms of the cross-staff or Jacob’s Staff, including one, referred to in Tang and Yuan sources. The Chinese names of these instruments are not common in early printed Chinese texts, but that does not mean that they were not in widespread use by pilots, whose rutters were generally hand-written. Moreover, we can find possible Chinese mentions of surveyors’ measurements in ‘finger-breadths’ (chih) a good deal earlier than anything similar in Arabic culture. For example, as has already been noted, one of the Wei generals, Têng Ai, was well known about +260 for his interest in military topography—‘whenever he saw a high mountain or a wide moor, he always estimated (heights and distances), measuring by finger-breadths, so as to sketch and plan the best positions for an army camp or fort’. His contemporaries, easily amused, thought this rather pedantic. But of course the system of finger-breadth units for altitudes could easily have arisen independently in the Arabic and Chinese culture-areas.

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the tablet or kamal (Fig. 996), in which the stock was represented by a knotted string.\(^a\) Supposedly earlier was the set of nine square boards or plates extended on a string or rod of standard length.\(^b\) These devices measured the angle between the star and the horizon, not that between star and zenith, which was much more difficult on shipboard.\(^c\) At the end of the +17th century the Portuguese pilots used the kamal for some time, calling it the tavoleta, or the balistinha do mouro.\(^d\) The fact that Arab pilots later on called the cross-staff al-bilist\(^e\) must not doubt mean that some of them had received it from the West,\(^f\) but this does not necessarily mean that its origin had been there, or even that their forerathers had not transmitted it in the opposite direction. For as we have already seen, there is evidence of the existence of the cross-staff in China in the +17th century, three hundred years before its traditional invention in Provence.\(^g\) It remains extremely probable, therefore, that the Chinese pilots of the +15th century used some form of cross-staff. That they used a version of the kamal as one sort of cross-staff has now been proved by Yen Tun-Chieh’s brilliant interpretation (19) of a passage which we already gave at an earlier stage without being able to explain it.\(^h\) Here it demands re-translation. Li Hsi\(^i\) (+1455 to +1509), in his Chieh An Lao Jen Man Pi (An Abundance of Jottings by Old Mr Li Chieh-An; printed in 1606),\(^1\) has this to say:

The set of ‘guiding star stretch-boards’ (chhien hing pan\(^1\)) of Ma Hsui-Teh\(^2\) of Suchow has twelve plates in all, made of ebony, ranging gradually from small to large. The largest is more than seven inches square (lit. long). They are labelled ‘one chio’, ‘two chio’ etc., up to ‘twelve chio’, all marked in fine script upon them; and they differ regularly just as a foot is divided into inches. There is also one ivory piece, two inches square (lit. long), and cut off at the corners so that it indicates half a chio (i.e. a chio), half a chio, one chio and three choi. This may be turned on one side or another facing you (in conjunction with one of the larger plates), and these lengths must be the measurements (required for right-angle triangle calculations according to the methods of) the Chou Pei (Suan Ching) (Arithmetical Classic of the Gnomon and the Circular Paths of Heaven).\(^8\)

Evidently we have here a set of standard ebony tablets held at a fixed distance from the eye, not the single one with its knotted string that constituted the typical kamal;\(^b\) plus the interesting addition of a ‘fine adjustment’ in the shape of an ivory tablet with corners truncated to small standard edge lengths, held up at the same time to allow the measurement of fractions of a chio. Yen Tun-Chieh’s calculations showed that the series of tablets described corresponds to a range of from \(1° 36’\) to \(18° 56’\) of altitude, with an average difference of \(1° 34’\) 30’ representing the chio (cf. p. 570). It is equally clear that the Chinese pilots at this time at any rate had 4 chio to a chio, not 8 (cf. pp. 567, 570), though the half-chio was marked on the ivory fine adjustment plate. How long before Li Hsi’s time this system had been in use the text does not say, but the mention of Ma Huai-Teh is intriguing, for a commander of that name was active in the Sung, c. +1064. Since he was a Khai-feng man, however, and our ‘mathematical practitioner’ came from Suchow, it is more probable that he lived at a somewhat later date, but whether it was in the Sung, Yuan or Ming we do not as yet know.\(^a\) We can be sure, at any rate, that the Chinese pilots were using his method in the +15th century, and they may well have been doing so in the +14th or even the +13th.

Evidence indeed seems to be growing that they were taking altitudes by the beginning of the +12th. A text of +1124 has already suggested this (Vol. 4, pt. 1, p. 280), and p. 573 above), and strange confirmation comes from a passage noticed by Lo Jung-Pang in the Sung Hui Yao Kao (Drafts for the History of the Administrative Statutes of the Sung Dynasty).\(^4\) There we read:

In the 3rd year of the Chien-Yen reign-period (+1120) the Supervising Censor Lin Chih-Ping\(^1\) was appointed to take charge of the defences of the (Yangtze) River and the sea, with authorisation to appoint his staff in the region under his command, i.e. from Hangchow to Thai-Phing. . . . (Lin) Chih-Ping spoke of the need for sea-going ships, and requested that they be charted from the coastal ports of Fukuien and Kuantung (and re-fitted). . . . These ships should each be equipped with a ‘Dipper-observer’ (wung tou\(^5\)), bulwarks for protection against arrows (chien ho\(^4\)), iron-shod striking-arms (chiieh chuang\(^6\)), stores of projectiles (ying...\(^d\)\)

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\(^a\) See Vol. 3, pp. 19 ff., for an account of this, the oldest, Chinese mathematical classic.

\(^b\) Yen doubts whether a cord was used with the Chinese set.

\(^c\) Alas, he is listed neither in the Chou fen Chaus nor the Chih Chiang Lu. The Su-Chow Fu Chih would be the only hope, but he is not in the edition of +1691.

\(^d\) Ping sect., ch. 29, pp. 518, 520, 522, tr. Lo Jung-Pang. We are much indebted to De Lo for communicating to us a knowledge of this interesting passage.

\(^e\) Presumably Thai-phing in Anhui, in which case Lin’s bailiwick covered most of the marches between Sung and Chin as well as the open sea.

\(^f\) 李之平

\(^g\) 孤斗

\(^h\) 蒋超

\(^i\) 崔超
29. NAVIGATION

There is hardly any evidence for the taking of star altitudes at sea by instrument, although an astrolabe reached Peking with the scientific mission of the Flemish diplomat, Pierre du Ry. We shall remember in this connection the sighting-tube (wang thung) and quadrant already illustrated in Vol. 3, Fig. 146, drawings taken from a book very close in date to the above document—the Ying Taou Fu Shih (Treatise on Architectural Methods) of +1125. But the 'diaper-observer' might equally well have been a cross-staff or hamul. Perhaps therefore the quantisation of stellar altitudes followed closely upon the quantisation of azimuth directions by the Chinese pilots.8

Summing up the present state of our knowledge about the development of quantitative navigation in the eastern seas, we have to start with the introduction of the mariner's compass on Chinese ships some time before +1050, possibly as early as +830. How soon this spread to the Indian Ocean we still do not know. Before +1300 there is hardly any evidence for the taking of star altitudes at sea by instrument, whether among Arabic or Indian pilots, and only very little for the Chinese navigators.8

But the Shun Feng Hsiang Sung tells us9 that from +1403 'the drawings of the guiding stars were compared and corrected', which suggests a considerable previous development during the +14th century. Broadly speaking, therefore, we may not be far off the truth if we say that when Ibn Mijdid met Vasco da Gama at Malindi, fully quantitative navigation was some two or three centuries old 'East of Suez' but hardly one century old in the West.

The diagrammatic illustration in Fig. 997 shows how star altitude measurements continued to interest Chinese groups concerned with the navigation of traditional craft down to our own times.8 It comes from the T'ing-Hai Thing Chih9 (Local Gazetteer of the Sub-Prefecture of Ting-hai). This place is the chief town of a large island, Chou-shan (Chusan), situated off the coast of Chekiang province just on lat. 30° N., and protecting the straits and estuary leading to Ningpo.8 The only edition of its local history and geography with this title appeared in 1902, but it was doubtless based on

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8 We shall refer again to various items in this list below as occasion offers; cf. pp. 607, 609, 693.
9 It will be remembered that the Little Bear was not seen as a constellate by the Chinese (Vol. 3, p. 261).
11 Lo Jung-Pang (9) recalls the surprise expressed by Hirth & Rockhill (1), p. 29, at the absence of any reference to the use of the seaman's astrolabe by Chinese navigators. Their assumption that it was normally used by Arab navigators was of course ill-founded, and they did not realise, perhaps, that although an astrolabe reached Peking with the scientific mission of +1267, it was not congruent with Chinese astronomy and aroused little interest (cf. Vol. 3, p. 374 ff.). The sea astrolabe was in any case a far simpler thing—the difficulty was, as we have seen, to use it at sea.
12 Here the impressions of Marco Polo, though negative, carry conviction to many. But cf. p. 528 above on the possible use of gnomons by landing parties. Negative evidence must always cede to positive when the latter exists. It would easily be possible to compile an anthology of unfavourable opinions about Chinese navigation (cf. de Navarette (+1637), Cummins ed., p. 111, or Macartney (+1764), Gruner-Bying ed., pp. 81, 275), but the failure of any particular observer to notice something cannot outweigh positive evidence that it was in fact there.
14 This picture was brought to our attention in a curious way. We are indebted for it to Mr P. H. Daniels, technician in the Radiotherapeutics Department at Cambridge. Coming of a family of printers, he had been interested, with his father Mr H. G. F. Daniels, of Harleston, to take somePulls of Chinese wood blocks which had been brought to England early in the present century by the father of Mr A. E. Lambden. These were the diagrams of the T'ing-Hai Ting Chih. We should also like to thank Dr B. E. Holmes for directing Mr Daniels to us.
family of 16 quarter-ellipses, equally spaced, in that part which represents the visible sky. Similar, but much simpler, diagrams were used to demonstrate navigational astronomy in 16th-century England. A complication of this one raise some difficult questions.

There is no problem about the band of declination parallels, for it forms part of a particular astrolabic projection. A few years before Díaz’ exposition it had appeared in a Chinese tractate on a planisphere written by the Jesuit Sabbatino de Ursis (Hsiung San-Pa) in +1611, entitled Chen Fang I Shuo. This band of parallels between the tropics is the same as that of the orthogonal astrolabe projection described in +1550 by Juan de Rojas Sarmiento. Now the ‘ordinary’ astrolabe plate (or tympanum) uses a stereographic projection of the celestial sphere from one of the poles on to the plane of the equator; a practice that stems from Ptolemy’s Plani-sphaerium of the +2nd century, though no instrument earlier than the late +9th century has survived. The disadvantage of this is that for every latitude one must use a different plate under the rotating firework star-map (or rete), so that naturally the demand grew up for a ‘universal’ astrolabe usable without substantial change in any latitude. One of the answers to that was Rojas’ projection, not stereographic but orthogonal (or orthographic). In this the celestial sphere is projected from the vernal point on to the plane of the solstitial colures, with the result that the parallels become straight lines like the equator, and the meridians semi-ellipses. Naturally the intervals between both parallels and meridians become less the further they are away from the centre of the whole. These unequal intervals can clearly be seen in the Jesuit diagrams (cf. Fig. 998) and must have been intended in the Ting-hai one (Fig. 997) though in this respect its meridian hourly spacings within the band are not as well drawn as those of its declination parallels. What any meridian quarter-ellipses with their unequal intervals should look like is seen in the simple diagram of Fig. 999, taken from the +1551 edition of the Cosmographia of Petrus Apianus.

Actually Rojas never claimed the invention of the ‘Rojas projection’. Simpler forms of it had been sketched in antiquity, notably a sundial analemma described by Vitruvius. The textual evidence suggests that Abū al-Raḥmān al-Birūnī thought the same thing about +998, though his explanation has never been properly studied. Further...

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Fig. 998. One origin of the ‘Plan of North Polar Altitudes’: the diagram of declination parallels superimposed on the celestial sphere (with pole altitude 35° instead of 38°) in the Thiên Wên Lăh of Yang Ma-No (Emmanuel Diaz), +1615. The parallels of celestial latitude are crossed by ellipsoidal meridians of celestial longitude.

1 Which had been compiled by Miu Sui and Chhen Yü-Wei as a Hsiên Chîh. The oldest recorded edition is that of +1155.
2 This was a graphical representation of the data contained in the Regiment of the Sun, cf. p. 559.
3 See Vol. 3, p. 405; Table 35.
5 It is a pity that they did not add an altitude scale graduated in chih and chiao.
6 Chen hsiang tien, ch. 3, p. 188.
7 Pp. 48, 50, 52, 57.
9 A cognate diagram entitled ‘Differences in Rising and Setting Positions of the Sun at the Two Solstices’ will be found (strangely for a dynastic history) in Ming Shih, ch. 33, p. 285 (begun +1646, finished +1738, published +1739).
11 In his book Commentarii in Astrolabium libri sex, discussed and elucidated in great detail, by Maddison (2), Rojas was, it seems, much aided by a Dutch assistant, Hugo Helt. Cf. Waters (19), pl. XXVII, p. 165.
12 Cf. Vol. 3, pp. 375 ff. One must remember that the astrolabe was not used at all in traditional Chinese astronomy.

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family of 16 quarter-ellipses, equally spaced, in that part which represents the visible sky. Similar, but much simpler, diagrams were used to demonstrate navigational astronomy in 16th-century England. A complication of this one raise some difficult questions.

There is no problem about the band of declination parallels, for it forms part of a particular astrolabic projection. A few years before Díaz’ exposition it had appeared in a Chinese tractate on a planisphere written by the Jesuit Sabbatino de Ursis (Hsiung San-Pa) in +1611, entitled Chen Fang I Shuo. This band of parallels between the tropics is the same as that of the orthogonal astrolabe projection described in +1550 by Juan de Rojas Sarmiento. Now the ‘ordinary’ astrolabe plate (or tympanum) uses a stereographic projection of the celestial sphere from one of the poles on to the plane of the equator; a practice that stems from Ptolemy’s Plani-sphaerium of the +2nd century, though no instrument earlier than the late +9th century has survived. The disadvantage of this is that for every latitude one must use a different plate under the rotating firework star-map (or rete), so that naturally the demand grew up for a ‘universal’ astrolabe usable without substantial change in any latitude. One of the answers to that was Rojas’ projection, not stereographic but orthogonal (or orthographic). In this the celestial sphere is projected from the vernal point on to the plane of the solstitial colures, with the result that the parallels become straight lines like the equator, and the meridians semi-ellipses. Naturally the intervals between both parallels and meridians become less the further they are away from the centre of the whole. These unequal intervals can clearly be seen in the Jesuit diagrams (cf. Fig. 998) and must have been intended in the Ting-hai one (Fig. 997) though in this respect its meridian hourly spacings within the band are not as well drawn as those of its declination parallels. What any meridian quarter-ellipses with their unequal intervals should look like is seen in the simple diagram of Fig. 999, taken from the +1551 edition of the Cosmographia of Petrus Apianus.

Actually Rojas never claimed the invention of the ‘Rojas projection’. Simpler forms of it had been sketched in antiquity, notably a sundial analemma described by Vitruvius. The textual evidence suggests that Abū al-Raḥmān al-Birūnī thought the same thing about +998, though his explanation has never been properly studied. Further...

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more several instruments have come down to us antedating Rojas but inscribed with the same orthogonal projection, e.g. a splendid astrolabe of Maritime Museum in Greenwich, one of +1480 in the Collegium Maius at Cracow, and a third of +1483 at Florence.

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author of the influential Toledan Tables, improved the design by making a double grid for ecliptic as well as equatorial coordinates; and this is the *saphaea*, *saphaea* that we find illustrated and minutely described in the famous *Libros del Saber de Astronomia* of Alfonso X, King of Castile, produced about +1276.

If the *saphaea* had needed mention only as one of the probable influences upon Rojas (and hence upon de Ursis and Díaz) we could have passed it over in silence, but it has a strange connection with the 16 quarter-ellipses of the Ting-hai diagram. The front of the second instrument described in the relevant part of the *Libros del Saber* is indeed engraved with the *saphaea*, but the back bears a diagram which has not yet been adequately explained. While one quadrant is ruled sexagimally with lines giving the sines of the angles of the scale of degrees, the other three contain a series of semi- or quarter-ellipses, at first sight like those of the orthogonal projection but spaced at equal intervals apart, so that they cannot represent the meridians of that projection. The *Libros del Saber* is far from being alone in giving this construction, for we find it also on earlier astrolabes, one made by Muhammad ibn Fudh al-Khamir in +1212 (with 20 equal divisions), and another by Muhammad ibn Hudhali in +1252 (with 24 equal divisions). Hence the question may be raised whether the equally spaced quarter-ellipses of the Ting-hai diagram do not derive from earlier direct contacts between Chinese and Arabic astronomical navigators rather than from later Jesuit intermediation. Since the spacing of the parallels in Fig. 997 has so clearly been made unequal (as it has to be on the Rojas projection), the equal spacings of the altitude ellipses seem designedly inconsistent with this, and point perhaps to older contacts with the astrolabists and sea-captains of Islam.

Before taking leave of the Chinese pilots it may be of interest to glance at the contents of two or three typical rutters or navigational compendia. The first of these is the *Shun Fêng Hsiang Sung* (Fair Winds for Escort), composed by an anonymous mariner some time about +1430 or at the close of the period of Chêng Ho’s expeditions. The second is the *Tung Hsi Yung Kuo*, compiled by Chang Hâle in +1618, a few years after Emmanuel Díaz had produced his explanation of the celestial sphere, but showing no evidence of any occidental influences. The writer of these *Studies on the Oceans, East and West* was much more scholarly as a historian and geographer than the +15th-century sea-captain, but seems also to have had personal acquaintance with

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*a* Cf. Vol. 6, pt. 6, p. 244.

*b* See Hakluyt (1), p. 186.

*c* See Sauer (1), p. 118.


*e* See Michel (1), p. 184; Suter (1), no. 255.

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*c* Bodelein Library, Oxford, Laud. Orient. MS. no. 145; cf. Duyvendak (1). We have been privileged to consult a draft translation prepared by Mr J. V. Miles (3). The +15th-century dating stems also from Dr R. Hughes, though Hsiang Ta & Hughes (1) placed the MS itself between +1667 and +1619. Some statements in it may be after +1527 for on p. 656 it is said that there are Fo-Lang (Frankish) foreigners established at Nagasaki (priv. comm. from Mr Miles). It is not claimed that the MS. itself is earlier than the last half of the +16th century. The text is now available in Hsiang Ta (5).

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*a* 順風航説

*b* 東西洋考

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the sea. His ninth chapter is entitled Chou Shih Khao, i.e. on the Ship's Master and what he should know.\(^b\)

Part of the introduction of the Shun Feng Hsiang Sung reads as follows:\(^c\)

In bygone days, the Duke of Chou discovered and worked out the principles of the south-pointing needle. Throughout the centuries from ancient times until to-day, these principles have circulated far and wide. Yet if you ignore the increase or decrease in the number of watches, or their divisions, you will be at fault. Thus it was that charts were drawn, and all details of voyages recorded.

Now these old documents get worse worn every year, and it is difficult to judge from them what is the truth of the matter. If later people make copies from these originals, they will, I fear, fall into error. (So) availing myself of leisure, I have made a comparison of the calculated (number of) watches for every day, and have investigated the respective (number of) days for (each) through voyage. And I have collected and written down the number of the watches, the way and manner of making good voyages.

Looking first at what the two texts have in common, they are found to give abundant information on landmarks and general sailing directions (Yang Chen Lu)\(^d\) with compass-bearings, and soundings in fathoms (thao). Chang Hsieh's compendium includes as destinations Indo-China, Malaya, Siam, Java and Sumatra, Borneo, Timor, the Moluccas and the Philippines. The Anonymus goes even further afield—to Aden, Ormus, India, Ceylon and Japan. Both give tables of monthly and seasonal winds (Chu Yüeh Feng)\(^e\) with copious advice on weather-signs (Chan Yen), observing the shapes of clouds, the behaviour of wind and rain, together with other meteorological phenomena such as solar halos.\(^f\) Both give a kind of tide table (Chhao Hsi), adding other signs such as the colour of the water, and any objects likely to be floating on it. Both supply the master with liturgical instructions (Chi Yao), observing the rise and fall of the tides, and the calculation of watches.

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\(^a\) We have again had the benefit of a draft translation (Mills, 4).
\(^b\) Other quotations from these texts will be found in Sect. 261 above. Among later books may be mentioned Yu Chiang-Tu's Yang Hai Chi Yao, ch. 13 of which is devoted to meteorological forecasting and tide-craft.
\(^c\) P. 44; tr. auct. adjuv. Mills (3), Duyvendak (1).
\(^d\) The sea was supposed to be particularly 'choppy' (shai hising)\(^h\) on certain days of the month.
\(^f\) Note the section-heading in the light of p. 560 above. The non-astronomical quality is comparable to what we find in Wm. Bourne (+1581), cf. Taylor (13), pp. 317, 399 ff.
\(^g\) Cf. p. 532 above.
\(^h\) This might also seem at first sight to indicate Arabic influence. But as was shown by Maspero (4), pp. 285 ff., series of azimuth determinations of this kind had been important for the regulation of water-clocks already in Han and Sui times, whence indeed tables survive. Cf. Vol. 3, p. 316.
\(^i\) P. 66; cf. p. 559 above. Also in Min Chu Chi, and Chou Hui Hai Thu Pien, ch. 2, p. 6b.
\(^j\) Bodleian Library, Backhouse Oriental. MS. no. 578, psb 2, 7. We are much indebted to Mr J. V. Mills for telling us of this. The text has since been printed by Hsiing Ts'a (5).
\(^k\) Further investigations may well reveal the Chinese equivalent of the Arabic tidal tables, i.e. the distance required on various compass-bearings to raise or lay an ipha (cf. de Saussure (16) in Ferrand (7), pp. 172 ff.). For Western equivalents using the degree see Waters (15), e.g. p. 127.
\(^l\) Cf. Vol. 3, p. 251 et passim.
\(^m\) See Vol. 3, p. 223 ff.
\(^n\) See Vo!. 3, pp. 229 ff.
therefore that further researches in the literature will bring to light nautical tables correlating *hsia* culminations with the positions of unseen circumpolars, similar to the Arabic lists of the *mandzil* described and analysed by de Saussure.a

Lastly, a word on tide-tables. Since several of the extant Chinese rutters include forms of these, it is worth recalling that the phenomena of sea-tides were carefully studied in China earlier than in Europe.b Authoritative histories still inform us c that the oldest tide-table for a particular port is the early 13th-century *'rød at London bridge*, but in an earlier section of this book it was shown that Yen Su's *Hai Chhao Tsa Lan* of 1026 contained a detailed tide-table for Ningpo. Not much later, in 1132, Liu Chiang-Ming drew up a tide-table for Hangchow which was inscribed on the walls of a pavilion on the banks of the Chih-lien-thang River. The Chinese pilots from the Yuan to the Chhing had thus a great tradition behind them.d

The spirit of these navigators, bent primarily, even under the orders of so great an admiral as Cheng Ho, on peaceful intercourse with the other inhabitants of Asia and Africa, is well seen in the concluding words of Chang Haich's chapter on navigation. According to the writer's opinion (he says), those who make carries build them in workshops, but when they come forth to the open road, they are already adjusted to the ruts. So it is with good sea-captains. The wings of cicadas make no distinction between one place and another, while even the small scale of a bee will measure the vast empty spaces. If you treat the barbarians like harmless seagulls (i.e. without any evil intentions), then the trough-princes and the crest-sirens will let you pass everywhere riding on the wings (of the wind). Verily the Atlas-tortoise with mountain-islands for its hat is no different from (an ant) carrying a grain of corn. Coming into contact with barbarian peoples you have nothing more to fear than touching the left horn of a snail. The only things one should really be anxious about are the means of mastery of the waves of the seas—well, of all dangers, the minds of those avid for profit and greedy of gain.e

(3) **Terrestrial Globes**

If we wanted to find a terrestrial globe at sea on board a modern liner there might be an ornamental one in the reading-room but we should certainly not expect to find one on the bridge. Yet there was a time, in the late 13th and early 14th centuries, when

a (36), in Ferrand (7), pp. 138 ff. b E.g. Taylor (8), p. 156.

d To complete the history of East Asian navigation the traditions of Japan and Korea will have to be investigated. Exactly contemporary with the book of Chang Hais the *Gemma Kōshaku* of Ikeda Kanmō, which includes illustrations of instruments such as a double quadrant. Later on, navigators were taught spherical trigonometry in the *Kōtoku Anken* (Safe Journeys on the High Seas) by Sakkabe Kōchō. Unfortunately neither time nor space permit further study of these works by us. Nor have we been able to see the *Shingeki Chōhosoku* (Guide for Shipmasters) printed in Korea in 1416 (cf. Tamura Senkei's (1), p. 92).

e The allusion is to the story in *Lieh T'ou* (ch. 2, p. 168) about the sailor for whom the seagulls were quite tame when he swam in their midst, until one day after he had promised his father to catch one—knew it, and would not even alight on the water. *Tsa. Wugæ* (7), p. 93; L. Giles (4), p. 49.

Section 9

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such objects figured prominently among navigational instruments—as may be seen from the group of treatises of which Robert Hues' *Tractatus de Globis* of 1554 may be taken as representative. Although we have touched upon terrestrial globes before, this then is the place to conclude the matter.

It is very improbable that such a globe could have been found on a Chinese vessel, even on Cheng Ho's flagship, for representations of this kind were not in the Chinese tradition; or not exactly, for the statement is a half-truth and needs explaining. First let us recall what happened in the West. The usual belief that the first maker of a terrestrial globe was the Stoic Crates of Mallos (c. 160) is authorised by the words of Strabo.b Here the *olkomene* was shown as but one of four great continents separated by oceans—yet another example of those strange parallelisms between the thought of the Far West and the Far East, for Tsou Yen about -390 had been saying that there were nine of such continents sundered in just the same way.c After Strabo little or nothing is heard of terrestrial globes in the West, but the tradition must have been transmitted to the Arabs for in +905 the Persian geographer Ahmad ibn Rustah gave a good description of the terrestrial as well as the celestial sphere.d A few centuries later the *Latin* could do the same, as is shown by the Englishman Sacrobo's *Tractatus de Sphaera* (c. 1333), popular till the Renaissance. e Now it was later in the same century that Jamali al-Din, heading a scientific co-operation mission from the Ikhkan of Persia to the court of China in +1267, took to Peking a terrestrial globe (or at least the design of one): 'a globe to be made of wood', says the *Yuan Shih*, f upon which seven parts of water are represented in green, three parts of land in white, with rivers, lakes, etc. Small squares are marked out so as to make it possible to reckon the sizes of the regions and the distances along roads. g But the idea did not catch on.

Why it did not is very hard to say, for there was much in the Chinese tradition to welcome it. The great cosmologists of the Han repeatedly said that the earth floated in the heavens like the yolk in a hen's egg, or that the earth was 'as round as a crossbow bullet' suspended in space. h When Hsiung Ming-Yü fifteen hundred years later illustrated his treatise on astronomy and geography with a pleasant picture of Chinese terras-cirrups navigauing an upside-down ocean h he significantly made use of exactly the same phraseology. Evidence is accumulating, moreover, that the belief in the sphericity of the earth was much more widespread in medieval Chinese culture than has often been thought. i And in fact the astronomers of China had actually been making terrestrial globes for centuries, but not on the same scale as those celestial ones, rather as quite small earth models held on a pin within their demonstrational


b II, v. 10. On Crates see Sarton (1), vol. 1, p. 185; Stevenson (1), vol. 1, pp. 7 ff.


e Sarton (1), vol. 2, p. 617; Stevenson (1), vol. 1, p. 43.

f Ch. 46, p. 122. On this and the other instruments and plans presented from Persia, see Vol. 3, p. 374, and among other references there given Hartert (1).

g E.g. Chang Hing and Yu Sung about +1200. See Vol. 3, p. 217, etc.

h Reproduced in *Vol. 3, Fig. 103*, p. 499. Parallel Chinese example in Oberhummer (1), p. 108.

i See, e.g., Wang Yung (2), pp. 73 ff; Wei Chua-Hsin (4).
The Rosthorn Globe (Fig. 1002, pl.) is a very different object, especially smaller (just under 1 ft. in diameter) and made of silver sheet metal on which the map and the inscriptions were incised before being covered all over with translucent cloisonné enamel in bright blue, green, violet and other colours. It carries no statement of origin, and internal evidence can only date it as of some time probably between Tasman and Cook, i.e. between +1650 and +1770; but a considerable similarity in place-names shows that it shares a common source with the world-map of Ch'ang Shing-Fu, one edition at least of which was printed as late as 1805. The place-names are meant to be read with the south pole uppermost. Instead of political boundaries, spaces between the meridians and parallels on a single land-mass are picked out rather fancifully in different colours, as for instance in the case of Australia (bottom right in Fig. 1002), which is wrongly joined both to New Guineas and to Tasmania (Fig. 1003, pl.). Here the legend reads: 'The new Western records say that this is New Holland (Hain Wo-a-lang-ti-ya), a great continent all desert with nobody living there.' The East Indies are also badly drawn, for Borneo is placed between Malaya's tip and Java, a feature which suggests the absence of any Jesuit influence on this globe, and makes it more probably a product of some northern Chinese cartographer unfamiliar with the Nan Hai. A large Antarctic continent (wrongly attached to New Zealand) is shown however. The drawing of California as an island might indicate a date around +1700, for Halley's magnetic chart is one of the last to represent it in this way.

A closer look at the map of China (Fig. 1004, pl., with south at the top) shows in the colouring a strange perpetuation of the old division between Cathay in the north (light) and Manzi in the south (dark). The windings of the Yellow River are marked well enough, those of the Yangtze less so, and the Gobi Desert prominently separates China from Mongolia. On the continent many names such as Shantung and Kansu can easily be made out, while in the China Seas Tashihama ('Tai-ma tao') and the Ryukyu (Liu-Chhiu Kuo) with the 'eight mountain isles' (Pa-chhung shan) are the most obvious. Lastly an interesting feature of the Rosthorn Globe is that it bears twelve 30° segments of longitude each stating the time difference between local and Chinese time in double-hours. Thus although some have been inclined to consider it an objet d'art rather than an instrument of precision, it cannot be denied a considerable measure of scientific interest.

* Bought in Peking by Prof. Rosthorn in 1900, it is now in the Österr. Museum f. angew. Kunst at Vienna (I.1. 12796, Go. 1867). The first description was given by Oberhummer (1). For the photographs here reproduced we are greatly indebted to Director V. Griesmenger, Mr J. V. Mills and Dr N. Mihoksky. Furthermore Mr Mills most kindly placed at our disposal the materials for his forthcoming study of Chinese globes with Miss Wallis, which is eagerly awaited, and visited Cambridge to discuss them with us.

** Royal Geogr. Soc., World,251, title Tu Chhing Shu Chh Chih Kung Wun-Kuo Ching Wei Ti-Chih Shih, 43 hand-coloured.

* The prime meridian runs through the Canaries Islands, about 20° W. from Greenwich. On the history of the prime meridian see Hickson (1), p. 9 ff.; Greenwich longitude, though now so familiar, was internationally adopted only very late in the last century.
(g) PROPULSION

(i) SAILS; THE POSITION OF CHINA IN THE DEVELOPMENT OF THE FORE-AND-AFT RIG

Introduction

Sails may be defined as pieces of textile fabric held outstretched upon ships in various ways so that the pressure and flow of the wind can be utilised to drive the vessel upon its course. Sails, and combinations of sails, which exist and have existed at diverse times and places, are of manifold shapes and rigs, almost bewildering in their complexity. If this had been the result of caprice or mere local custom, the subject could hardly interest anyone other than the nautical dilettante; but in fact there runs throughout the series one single creative thread, the desire of man to release himself from natural servitude by sailing, not only with favourable following breezes, but directly into the eye of the wind. Though sails alone were never to permit him to accomplish this feat, there was a maximum efficiency point which could be reached in sailing to windward, and that he ultimately attained. The history of this branch of nautical technology might thus be epigrammatically described as the advance from windward, and that he ultimately attained. The history of this branch of nautical technology might thus be epigrammatically described as the advance from windward, and that he ultimately attained. The history of this branch of nautical technology might thus be epigrammatically described as the advance from windward, and that he ultimately attained.

For the understanding of what follows it is necessary that the reader should bear in mind the chief varieties of what have been called the 'primary' types of sail. These are sketched in Fig. 1005. In these diagrams the masts and spars are shown by a heavy line, while the free edges of the sail are left light. First, there is the square-sail, oldest and simplest, symmetrically hoisted, necessitating always a yard, but at different times and places with or without a boom (A, A'). The square-sail is the only principal sail which always receives the wind upon the same surface. With a wind from behind and to the right of the ship (i.e. aft, from the starboard quarter), the right-hand side of the sail (the starboard side) would be braced forward while the left-hand side (the port side) would be aft of the mast. Then when the wind changed to the other, port, quarter, or when the ship changed course, the position of the sail would be reversed, in other words, the forward or weather yard-arm became the after or lee yard-arm as the sail was trimmed to face the wind. But broadly speaking the limitations of these manoeuvres were soon reached, and sailors of all seas and cultures sought perennially for some escape from the essentially transverse character of the square-sail. Only by devising arrangements which would permit their canvas to be mounted more in line with the long axis of the vessel, i.e. fore-and-aft, could they hope to take advantage of beam or contrary winds.

Fig. 1005. Principal sail types. Masts, yards, booms, sprits, gaffs, etc., in thick lines; sail edges in thin.

A square-sail with boom
A' square-sail without boom (loose-footed)
B Indonesian canted 'square' (rectangular) sail, with boom
C lateen sail with short luff edge
D lateen sail without luff edge
E lug-sail with considerable luff area forward of the mast
D' lug-sail with reduced luff area forward of the mast
F sprit-sail
G gaff- or yacht-sail
H leg-of-mutton sail
I Indian Ocean bi-fold-mast sprit-sail
J Melanesian double-mast sprit-sail
K Pacific boom-lateen sail

For detailed explanations see text.

All these other types of sail, which constituted successive approximations to the ideal fore-and-aft rig, differ fundamentally from the square-sail in being placed assymmetrically with respect to the mast, so that the surface area differs on the two sides. Swivelling thus round the mast as an axis, they receive the wind, as opportunity serves, now offers every inch of its surface to the wind's thrust, the vessel rides comfortably and safely, and the canvas needs a minimum of handling. Moreover, a square-rigged ship can hoist twice the sail area of a fore-and-aft rigged one, which is very valuable in light airs, and chafing does not occur since yards and sails strain away from the masts. These points have often been emphasised to us by Cdr. George Naish in conversation and in correspondence.

* Or very nearly. Prof. Bryan Thwaites, to whom we are much indebted for advice and drafting in the present sub-section, thinks that we may hope to improve even now upon the capacity of yachts to sail into the wind.

b For fuller information: Moore (1); Smyth (1); Anderson & Anderson (1); and many other books, including the nautical dictionaries such as that of Gruss (1); Ansted (1); Adm. Smyth (1).

c The square-sail runs through the whole of nautical history from ancient Egypt to the clippers. It is, as Casson (2) has said, 'without a peer for voyages, especially long ones, made with a following wind. It
on one face and now on the other. The role of the sheets, or ropes which are attached to the outer edge of the sail (its lee-edge or leech) to hold it in and adjust its set, becomes even more important than before. One of the most primitive forms of fore-and-aft sail is the Indonesian canted sail, still rectangular, shown in B. The next stage may be found in the ‘lateen’ sail, so characteristic of Arabic civilisation; it exists in two forms (C, C’), the former retaining a luff (i.e. a short fore or inner edge of the sail, the opposite of the leech), and the latter purely triangular, the head of the sail joining its foot. Mediterranean and Indian Ocean lates and lugs never have a boom, but various South Asian and Pacific peoples use sails of a triangular shape bent to booms as well as yards (K). These ‘Pacific boom-lates’ of Indonesia, Micronesia, Fiji, etc., are believed to derive from a kind of spirit-sail (J) termed ‘Oceanic’ because characteristic of Polynesia, in which the upper sprit performs the office of a more or less aft-raking mast. This in turn originated, it would seem, from a still more ancient form of rig (H) in which the sail, though approximately square, is held aloft by two sprits equivalent to a bifid mast, and can thus be set approximately fore-and-aft. This is the Indian Ocean ‘bifid-mast spirit-sail’ or ‘proto-Oceanic spirit-sail’, and it occupies a central position in the evolution of sailing craft, as we shall presently see (p. 606). It is certainly related to

The following remarks are intended primarily for those who are already familiar with the subject of this section. Bowen (a) has recently challenged accepted conceptions and definitions of the chief classes of sails. He wishes to adopt the narrow definition of Webster’s Dictionary that a fore-and-aft sail is ‘any sail not supported by a yard or yards, usually carried on a gaff, or stay, with or without a boom’. For him, therefore, those only are true fore-and-aft sails in which the luff edge is attached to the mast, and which are not unsightly when without shifting sails, anything but the sheet. The lateen sail (and of course lug-sails) can be, and often are, set fore and aft to the ship, but he emphasises the fact that lateens rarely tack, performing what is for them the safer operation of wearing about. He further says that lateens and lugs are more like square-sails in that they can run before the wind with the sail across the boat without danger of gybing, and also that they will not sail to windward when the sail is backed against the mast. He is brought into difficulty, however, by having to admit that there are certain sails which may be tacked head to wind by shifting only the sheet, yet according to his definition are not fore-and-aft sails because they are set on yards; for example, many lugs.

We are not able to adopt his standpoint here, or to follow him in his criticisms of Anderson, Chatterton, and others. It is surely much better to adhere to the definition of fore-and-aft sails as those which, because of their longitudinal relation to the hull, allow of working to windward. We know this involves classifying the sail of a ‘Hummer keel’, which is rigorously a square-sail, as a fore-and-aft sail when hauled down. But that does not affect the fact that since the example is altogether exceptional, the adaptation of a survival which was made possible by wire stays and mechanical devices unknown in antiquity or the Middle Ages, Bowen’s definitions are all insufficient for the Chinese material; Chinese lug-sails do accomplish tacking by shifting only the sheets, as Ibn Batutah said already in the 14th century, and they do draw well in windward sailing when backed against the mast, because of their stiffness. The Webster definition was derived purely from familiarity with the late occidental full-rigged ship. As Anderson said in his reply to Bowen, it is preferable to retain the older definition according to which fore-and-aft sails are those which receive the wind on either surface and always keep the same edge to windward. ‘The Chinese lug’, writes Hauser (a), ‘is a pure fore-and-aft sail.’

In a later contribution, Bowen (g) maintained his terminology. But his two memoirs contain a mass of information on the evolutionary connections of sails and rigs which compels not only a large measure of assent to his conclusions but also admiration for his services to nautical scholarship.

For Bowen (2), pp. 199 ff., (9), pp. 163, 193, 197, this is a balance lug.

Clearly, the luff of a fore-and-aft sail is always a luff, but the luff of a square-sail changes each time the sail is re-set. When running before the wind it would not be appropriate to call either edge of a square-sail the luff. In the terminology of Bowen (a), pp. 185 ff., (9), pp. 184 ff., form C is a jib-headed slipping lug and of C’ only the true lates.

One of the first illustrations of this rig in a Western book must surely be that in the Herrera’s Nueva Orbits of 1622.
The curvature of the sail is less important than the fact that the wind is blowing at an angle to the boom. Indeed it is not yet generally agreed whether it is better in practice for a fore-and-aft sail to be very tightly bent to the boom so that the whole sail is as flat as possible, or for it to be allowed to set in a distinct curve. The sail is essentially an aerofoil, and many believe that it gives its best results when relatively taut; loose bellying sails lose energy by air turbulence, and perfectly flat ones would not give the differential flow effect.

The action of the wind's force on a sail may be simply described (see Fig. 1006). The wind $W$ strikes the sail—or (for simplicity) the boom $AB$—at a certain angle of incidence. The difference in pressure between the two sides of the sail to which we have already referred produces a lift force $L$ perpendicular to $AB$ and a drag force $D$ along $AB$. It is the conscious purpose of aerodynamic design, and it has been the unconscious aim of ship-builders throughout the centuries, that $L$ should be much larger than $D$. When a boat is making good to windward, $L$ and $D$ may be resolved into two other components, $T$ and $S$, being the force which drives the boat forward on its course into the eye of the wind, and $S$ the force which tends to drive the boat sideways—to make leeway—a force which it is the function of the hull, keel and leeboads to counteract. But if the boat is steered too close to the wind, then the drag $D$ will be so large and the lift $L$ so small that the force $T$ will exert itself backwards (as $T'$) rather than forwards, and the boat will make no headway to windward. One can now see why there was a historical tendency towards ever lofier sails, for the ratio $L/D$ steadily increases as the height of the sail rises in relation to the length of the boom. One can also see why the loose-footed square-sail, even when braced very much forward, could not easily work to windward.

Fig. 1006. Diagram to explain the action of the wind on a vessel under sail. Explanation in text; the case considered is that of an almost beam wind and a fore-and-aft sail.

From the earliest days of sailing it was found that since one could not proceed directly into the wind, one must approach it by a series of passages as near the wind as possible, and as everyone knows, this zigzag movement is termed in general tacking. But the movement of turn has varied with the type of sail. Square-rigged ships could not often tack; they then had to 'wear about' by turning the stern to the wind (see Fig. 1007), and the same is true for lateen-rigged ships, though in these the manoeuvre of tacking is occasionally done. With all the more developed types of fore-and-aft sail, however, the helm has simply to be put over, bringing the bows up into the wind, and the sail 'luffs', hanging loose, until it catches the wind on the other tack. How near these courses could be to the wind is shown on the accompanying diagram (Fig. 1008).

Ancient (e.g. Egyptian) square rig could not even make full use of a beam wind, and post-Renaissance square-sailed ships could come no nearer to the wind than six or seven points (79°), while the fore-and-aft rigs (including the lateen) can sail as near as two or three points (112°), with the exception of the Bermudan spinnaker (110°), which is the rule for much of the north Atlantic trade.

Some of the methods by which modern yachts have increased the efficiency of their sails have been described above. These include (a) the use of headsails of balanced design, (b) the use of taffeta mainsails for windward work, and (c) the use of fore-and-aft sails of symmetrical shape. A more recent development has been the introduction of the asymmetric spinnaker, which is a spinnaker that is deflated and furled when not being used. This allows it to be stowed in a smaller space than a conventional spinnaker, and it can be quickly inflated and unfurled when required. It is useful in close-hauled conditions, where a conventional spinnaker would be inefficient. Another development is the use of leech control to improve sail shape and performance in a variety of conditions. Leech control allows the sailmaker to adjust the shape of the sail's edge, which can improve the sail's performance in various wind directions.

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A striking picture of 'Sovereign' with both set appeared in The Times (22 July 1963). Yet in practice it is a commonplace that the chief use of the one is in beating to windward and that of the other in running before the wind. This information comes from Professor Thwaites. Taut main-sails and bellying spinnakers are now of course habitually combined on many modern racing yachts. A striking picture of 'Sovereign' was not until the middle of the 19th century that the American Gloucester schooners started the move towards the use of taut main-sails. The Schooner 'Humber keel' (Moore (1); White (1), p. 18). Among the first to have battens were the Chinese. "The sails on horizontal bamboos, he wrote, 'have one advantage over the European— they do not belly" (Proudfoot (1), p. 65). Some of the most modern yachts based on scientific principles have adopted Chinese devices such as the battens, and sometimes the multiple sheets (cf. Curry (1), pp. 210, 312; 14, pp. 81, 82 (1), pp. 70, 77, 73, 150, 110, 110; Buckler (1); Wells Coates, etc.). Among the first to have battens were the racing 'clippers' which Linton Hope was designing in the eighteen-nineties (private communication from Cdr. George Naish). An ingenious adaptation was to make the battens of inflatable tyre tubing so that their rigidity could be adjusted by the pressure according to weather conditions (private communication from the late Mr H. E. Tunnicliffe). But they are now generally short lengths holding out the leech rather than continuing across the full breadth of the sail. They can be seen in the picture of 'Sovereign' just mentioned.

The climax of the Chinese battened lug-sail in modern yacht practice was perhaps attained when in the summer of 1960 Lt-Col. H. G. Hasler finished second after a magnificent voyage in the single-handed transatlantic race which he had himself originated. His 'Jester' was equipped with a single unstayed mast and carried a single tall five-battened terylene design, modified in certain ways but retaining the classical multiple sheets, topping lifts, etc. (see Hasler, 1).

The total aerodynamic force on the sail is in a direction which makes an angle only very slightly more by 1° or a degree, certainly not more than 5°, than a right angle with the wind direction. This force then has a large sideways component which the hull, keel, etc., balance out, and a small forward component which drives the boat.
full-rigged ships, using their lateen mizzens, could make good six. With this information in our minds we are in a position to study the historical evidence and the Chinese contribution.

(ii) *The mat-and-batten sail; its aerodynamic qualities*

The most characteristic Chinese sail is the balanced stiffened lug-sail. Fig. 1009a, from Worcester, gives a clear diagram of it. It shows a more or less northern type, for in the

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*a* These are generally accepted estimates.

*b* (2), vol. 1, pp. 46, 97 ff.; vol. 2, pp. 256, 501; also (1), p. 11 ff.; Audemard, pp. 36 ff.; Poujade (1), pp. 159 ff.; Smyth (1), p. 461, gives an excellent description from the point of view of a practical sailor. The drawings of Adm. F. E. Paris (1), pls. 49 to 68, should also be studied.
battens or laths (thiao ¹) of bamboo, the ends of which are secured to bolt-ropes suspended from the yard so as to take the weight of what might be called the ‘sail-frame’, a kind of skeletal ladder. The fabric of the sail is laced to the perimeter of this frame and to each batten (Figs. 1010, 1011, pls.), so that it is kept very flat. The widespread use of bamboo matting sails (li⁵) necessitated this form of frame and led naturally to the balance lug shape. The aerodynamic importance of tautness is, as we have seen, considerable, yet such a design, which doubtless arose because of the easy availability of a material so light and at the same time so strong, never arose in any other culture.² We shall come back to this point. The battens have at least five other uses: they permit of precise and stepwise reefing, they allow immediate furling of sail, which falls into pleats; their setting system obviates the need for cloth or canvas as strong as on other sails, and they act as ratlines giving access for the crew to any desired part. Above all, they are a complete protection against tearing and carrying away; a Chinese sail may have half its surface full of holes, and still draw well.

The multiple sheets (liao su¹) represent a device of great interest. Each batten is connected with all the others by a system of bights and leads, which, gathered up by means of pulley-blocks (hsuan-tieh¹) and euphroes,³ terminate finally in one main sheet on deck, which originates from a fixed point, G in Fig. 1009. Thus the sail is divided into sections (e.g. ABC, DEF). Naturally the variations in the sheeting are legion, but Worcester & Sigaut have given good accounts of many of them.⁴ The greater the number of battens, the greater the number of multiple sheets, the flatter the sail, and the finer the adjustment of its leech (Figs. 1011, 1014, pls.). The halyards (li lan¹), J, K, pass through blocks at masthead (seei thou¹) and yard (fan khang¹). The sail is held to the mast by a parrel, M, for each batten, and there is a hauling parrel, L, arranged as shown, which assists in this and helps to peak the sail when reefed. In a squall only the halyard need be touched, for the sail falls neatly into the lazy lines formed by the double topping-lifts (fan khang sheng¹), the lowest batten-contained sections collapse, the sheets automatically slacken, and can easily be re-set.⁵ The sail never jams. As Audemard thought fit to emphasise, this system ‘avoided the sending of men aloft to take in reefs, always a dangerous operation in bad weather’.

¹ ‘I can speak’, wrote Smyth,⁶ ‘from some experience in handling this form of sail, and south the leeches of the sails are rounded.⁷ As we know from the historical material already discussed, the Chinese sail, in its most typical form, is stiffened by transverse battens or laths (thiao ¹) of bamboo, the ends of which are secured to bolt-ropes suspended from the yard so as to take the weight of what might be called the ‘sail-frame’, a kind of skeletal ladder. The fabric of the sail is laced to the perimeter of this frame and to each batten (Figs. 1010, 1011, pls.), so that it is kept very flat. The widespread use of bamboo matting sails (li⁵) necessitated this form of frame and led naturally to the balance lug shape. The aerodynamic importance of tautness is, as we have seen, considerable, yet such a design, which doubtless arose because of the easy availability of a material so light and at the same time so strong, never arose in any other culture.² We shall come back to this point. The battens have at least five other uses: they permit of precise and stepwise reefing, they allow immediate furling of sail, which falls into pleats; their setting system obviates the need for cloth or canvas as strong as on other sails, and they act as ratlines giving access for the crew to any desired part. Above all, they are a complete protection against tearing and carrying away; a Chinese sail may have half its surface full of holes, and still draw well.

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¹ ‘I can speak’, wrote Smyth,⁶ ‘from some experience in handling this form of sail, and
I may say that once having learned the set and balance of the sails for various points of sailing, nothing can surpass the handiness of the rig. Another expert, Capt. Fitzgerald, called Chinese ships 'the handiest vessels in the world'. Elsewhere Smyth added, in an often quoted statement: 'As an engine for carrying man and his commerce upon the high and stormy seas as well as on vast inland waterways, it is doubtful if any class of vessel is more suited or better adapted to its purpose (than the Chinese junk), and it is certain that for flatness of sail and for handiness, the Chinese rig is unsurpassed.' And Admiral Paris spoke of the rig as 'one of the most ingenious of Chinese inventions'.

The only criticism which he and others have made of it is that it is liable to be rather heavy. Much detail can be made out in the snaps of a Pao-chhing Chhiu-tzu reproduced in Fig. 1012.

As has just been mentioned, the sail-peats and leeches of all Chinese vessels hailing from south of the Yangtze are very rounded, so that the gallant quadrilateral shape (D, D' in Fig. 1005) tends to turn into the softer contour of the quarter disc, giving a quadrantal form. So far does this tendency go that in the fashers and freighters of Yeungkong (Yangchian), a port halfway between the Pearl River and the Leichow peninsula, the battens are gathered at the base of the luff edge so that the sails give the elegant impression of a fan (Fig. 1013). Some noteworthy details of a Yangchian foresail appear in Fig. 1014.

The Chinese balance lug ranks indeed among the foremost achievements in man's use of wind power. Of the circumstances which gave rise to it we know little, but the suggestion has been made that it arose from plaiting together successive palm branches so that the central stem or mid-rib provided a natural built-in batten. As we shall see in a moment, our oldest Chinese text concerning fore-and-aft sailing regards the sprit-sail in China is certainly of great interest, though evidence is still lacking whereby its historical significance may be assessed. It will be understood that this sail is one of those which embody the fullest development of fore-and-aft sailing, since nothing is forward of the mast.

Outside the Chinese culture-area the mat-and-batten sail as such never widely spread. It was of course used from fairly early times in Japan, where copies of 12th-century pictures show it particularly clearly (Fig. 1033a). It spread, too, to the Maldives Islands, where it is habitually used. The Portuguese in the 16th century appreciates it, and rigged their lorchas with it, as we have seen, but there was some obstacle to its diffusion to Europe and other regions, probably the lack of bamboo or other suitable material for the battens. In 1829, however, at least one British steamship working out of Calcutta, the 'Forbes', was rigged with large Chinese batten lug-sails.

An entirely different question concerns the invention and diffusion of the lug-sail considered as a cut, i.e. a shape, and this we shall try to answer shortly.

(iii) Chinese sails in history

What information can we now assemble concerning the history of Chinese sails? Among the ancient characters on the oracle-bones, fan, later meaning 'all, every', and used as an initial particle, 'generally speaking', signified, in its original form (K62), a sail. It is interesting that this graph seems clearly to depict the 'double-mast sprit-sail' now known only in Melanesia (cf. Fig. 1005, I, and Fig. 1016). Probably this was one of the contributions of the south-eastern or oceanic component of ancient Chinese culture, during the second half of the and millennium. It seems a less likely ancestor of Chinese lug-sails than the canted Indonesian square-sail, but the Chinese true sprit-sail could be its direct descendant. The fact is that we have no clear evidence on the origin of the Chinese balance lug, but one cannot help recognising that it was the ideal answer to the problem of making headway against the monsoon winds which blow so regularly up and down the coasts of China, using a material so abundant and cheap as bamboo matting for the sail's surface (cf. Figs. 989a and 1009a, b).

As such, that is to say, for we have just mentioned (p. 593), the adoption of battens and half-battens in the sails of modern racing yachts.

Purvis (I); Elgar (I). The Japanese remained curiously fond of tall square-sails, however, cf. Notebook (1).


1 Hornell (17), p. 181; Bowen (b), p. 155.

2 As the remark of de Rada (+1775) in Boxer (1), p. 394.

3 Worcester (3), vol. 1, p. 69.


5 Purvis (1), Elgar (1).

6 See also Noteboom (1).

7 Pp. 612 ff. below.

8 As we have just mentioned (p. 599), the adoption of battens and half-battens in the sails of modern racing yachts.
The earliest Han mentions seem to be generally to matting, as in the expression *kua hui chihieh li*, blown along by mat-(sails) a thousand li, while the term *fan*, later usual, does not often occur with *pu* as *pu fan* (cloth sails) until the middle of the Later Han. *Archaic* ways of writing the word brought out the connection with the wind, e.g., *fan* in the +2nd-century *Shuo Wen*, and *fan* in the +6th-century *Yu Phien* dictionary. *The Shih Ming* dictionary, compiled by Liu Hsi* about +100, says that a sail is ‘like a curtain, held up to the wind, so that the boat goes lightly and swiftly’. It is at any rate clear that in the last decade of the +4th century cloth sails were reserved for the boats of officials; this we know from a story in the life of the painter Ku Khai-Chih, who was aide-de-camp to a governor at the time. *Cloth sails* became a stock phrase in later poets to indicate an atmosphere of luxury, pomp or buoyancy. Presumably mat-sails were regarded as too rough for the official junks—irrespective of the performance of the two types. Nothing here throws much light on the shape of sail or kind of tackle used.

A +3rd-century text of capital importance does so, however. It occurs in the *Nan Chou I Wu Chih* (Strange Things of the South), written by Wan Chen, and runs as follows:

> The people of foreign parts (nao yu Jen) call chuuan (ships) pa. The large ones are more than 20 chang in length (up to 150 ft.), and stand out of the water 2 or 3 chang (about 15 to 25 ft.). At a distance they look like ‘flying galleries’ (ho tao) and they carry from 600 to 700 persons, with 10,000 bussels (hu) of cargo.

> The people beyond the barriers (naat chiao Jen), according to the sizes of their ships, sometimes rig (as many as) four sails, which they carry in a row from bow to stern. From the leaves a such at least is the impression gained by Dr Chihen Shih-Hsiaing; further research on the point would be profitable. *Cf. CSHK* (Hou Han Sect.), ch. 18, p. 12a; *TPYL*, ch. 771, p. 6a.

> In later centuries there is mention of sails of oiled silk. According to Haü Ming-Hsiaing, the ships of the Chin Tartars cruising off Shantung in +1161 were equipped with these, but they were easily set on fire by the rockets and incendiary arrows of the Sung vessels (Soo Chau Pei Ming Hieh Pien, ch. 237, pp. 12a ff.); noted by Lo Jung-Pang, 2.

> This is a reference to the bridge-corridors or open galleries which appear to have existed in palaces such as that of Chihen Shih Huang Ti.

> Assuming the bundle here is equivalent to the pixel, this would mean about 360 tons.

> This phrase is important. If Wan Chen had wished to refer to foreigners from far away, he would have used the phrase with which the first paragraph begins. But the region which is now Kwangtung was rather loosely attached to the State of Wu in the San Kuo period, and the regions of Annam and Tonking still less so. The probability is, therefore, that the reference is to seafarers of these coast rather than those of Indonesia. This view is strongly supported by the phraseology used in the account of Liu Ta’s conquests in the Indo-Chinese region (+350) in *San Kuo Chih* (Wu Chih), ch. 15, p. 9a.

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The four sails do not face directly forwards, but are set obliquely, and so arranged that they can all be fixed in the same direction, to receive the wind and to spill it (Chih Jen fan pu chhien hsiang, chieh shih liah chieh hsiang chieh, chu hieh nong hieh feng). Those (sails which are) behind (the most windward one) (receiving the) pressure (of the wind), throw it from one to the other, so that they all profit from its force (Hou chieh chieh hsiang chieh, ping liao feng li). If it is violent, they (the sailors) diminish or augment (the surface of the sails) according to the conditions. This oblique (rig), which permits (the sails) to receive from one another the breath of the wind, obviates the anxiety attendant upon having high masts. Thus (these ships) sail without avoiding strong winds and dashing waves, by the aid of which they can make great speed.

This is indeed a striking passage. It establishes without any doubt that in the +3rd century southerners, whether Cantonese or Annamese, were using four-masted ships with matting sails in a fore-and-aft rig of some kind. The Indonesian cantile-square-sail is not absolutely excluded, but it would be unwieldy on a vessel with several masts, and some kind of tall balanced lug-sail seems much more probable. The writer was of the lu-thou1 tree, which have the shape of ‘yang’2,3 and are more than 1 chang (about 75 ft.) long, they weave the sails.

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*Fig. 1017. Sketch of a Lake Thai-Hu trawler (after Audemard, 3). This remarkable craft, though only some 25 ft. long, carries five small masts with lug-sails.*

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1 lu-thou tree
2 yang
3 lu-thou
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perhaps a little confused about the purpose of the rig, but his emphasis on the oblique-
ness of the sails necessitates a cut whereby they would not have got in each other’s way.

Additional contemporary testimony for ships with multiple masts may be derived from the lost book Wu Shi Wai Kuo Chuan (Record of Foreign Countries in the time of the State of Wu) by Khang Thai1 (ff. +260), passages from which are preserved in encyclopaedias. Thus we hear that in the seas off Chia-Na-Tiao-Chou, some country which at present cannot be identified, there were great junks (ta po) with no less than seven sails. These were used by people travelling to and from Syria (Ta-Chhin).

Evidence concerning sails from subsequent centuries has been noted already in passing. There is certainly no reason why the Ajanta artist (+638) should not have been absent-mindedly drawing a Chinese lug-sail, lofty and

602

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Wan Chen and Khang Thai occur again, of course, in Marco (Ta~Chhin).

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passing. There is certainly no reason why the Ajanta artist (+638) should not have been absent-mindedly drawing a Chinese lug-sail, lofty and taut. c At Borobudur (+800)8 and at Angkor Thom (+1188) the absence of a luff forward of the mast might suggest sprit-sails, yet lugs were almost certainly intended. The multiple masts of Wan Chen and Khang Thai occur again, of course, in Marco Polo and Ibn Batštihat, as also in the derivative world-maps. The statement of Chu Yü for +1000 that Chinese ships could use wind from almost any quarter (shih san mien feng) is highly significant.

The Kao-I Thu Ching of approximately +1124 is quite comprehensive in notes on sails and sailing. Speaking of the ‘retainer ships’ (kho chou) which accompanied the larger ships of the diplomatic envoy and carried his staff, Hsi Ching says: 8

When the ship makes land and enters a harbour (khai shou ku hang) she usually does so on the flood tide, and then all the sailors row, singing to keep the time. Those using poles also jump and shout and exert themselves to the utmost, but the ship cannot move nearly so fast as when sailing with a good wind. The main-mast is 100 ft. high, and the foremost 80 ft. When the wind blows favourably, they hoist the cloth sails (for running fast) (fu sa) made of fifty strips of cloth. b But when the wind and blows from the side they use the advantageous mat sails (liang), set to the left or to the right like wings according to the direction of the wind. At the top of the main-mast they may add a small topsail (hsiao fu), made of ten strips of cloth. This is called the ‘wild fox sail’ (yeh hu fan), and is used in light airs, when there is almost no wind. Of all the eight quarters whence the wind may blow, there is only one, the dead ahead quarter, which cannot be used to make the ship sail. a The sailors also attach some bird feathers to the top of an upright pole as a weathercock; this is called the ‘Five Ounces’ (wu hung). b To get a favourable wind is not easy, so that these great cloth sails are not as useful as the mat sails, which, when skilfully employed, will carry men wheresoever they may wish to go.

This important passage clearly shows that the aerodynamic properties of taut mat- and-batten sails were empirically appreciated by a scholar early in the +12th century, and that they were used for beating to windward, while sails of cloth, or of silk, c were hoisted additionally when running before the wind. This combination we have seen already in Fig. 939 and its description (p. 495). The use of topsails (also in Fig. 939) is interesting at this time, but Hsi Ching further describes what may have been something like detachable bonnets on the sails of the Korean ‘official boats’ which came out to welcome the Chinese ambassador. d

Our series of texts may be completed by a passage from the +16th-century historian of the Portuguese conquest of the Indian Seas, de Castanheda. e He spoke of the Chinese junks which had come to Malaca during the previous hundred years and earlier, bringing gold, silver, rhubarb, all kinds of silks, satins, and damasks, porcelains, gilded boxes and fine furniture. They took back with them pepper, Indian cottons, saffron, coral, cinnamon, and mercury, drugs and cereals.

These junks, as the ships of this region are called, are very great and very different from those of all the other countries in the world, for the bow and the stern have the same shape, with one rudder forward and a rudder at the stern. f They have but one mast, e and a sail of ‘Bengal matting’ (made from small reeds) which turns around the mast as if pivoted on a spindle (chukatae). f For this reason the junks never wear around as our ships do. When it is desired to reef (the sails), it is not necessary to fold them, for they fall all in a single piece. Hence the junks sail well; they take much greater burden than our ships; they are much stouter, and they have such great internal beams that a camel could hardly carry one...

Here there can be no doubt that lug-sails were meant, as in the later description of Sung Ying-Hsing, which runs as follows: f


This refers to the sails (embroidered with designs) of the ambassador’s own vessel, the ‘sacred ship’ (shen chou’), cf. p. 440. The actual term is chin fu, which perhaps could also mean embroidered cloth, but less probably.

Ch. 33, p. 30. The passage is curious; it is said that their sails were of more than 20 strips of cloth but that the pieces in the lower part of the sail were not sewn together. Perhaps he was trying to describe some arrangement like that still seen in China (p. 613 below) where a small cantilever square-sail is hoisted like a spinnaker in addition to the main lug-sail.

(1), ch. 112; cf. Fertaud (4); Paris (1).

This Chinese commerce had been notified to the Portuguese King Dom Manuel by Albuquerque in +1512 in an interesting covering letter for a Javanese map which showed all the regular routes and ports of the trading junks (Baiao ed. pp. 76 ff.).

On this, see p. 619 below.

De Castanheda or his informants may have seen the junks only in port, when their fore and main masts were unstopped. For as we know, multiple masts have always been typical of sea-going junks.

Cf. p. 462 above, and p. 611 below.

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Ch. 33, p. 30. The passage is curious; it is said that their sails were of more than 20 strips of cloth but that the pieces in the lower part of the sail were not sewn together. Perhaps he was trying to describe some arrangement like that still seen in China (p. 613 below) where a small cantilever square-sail is hoisted like a spinnaker in addition to the main lug-sail.

(1), ch. 112; cf. Fertaud (4); Paris (1).

This Chinese commerce had been notified to the Portuguese King Dom Manuel by Albuquerque in +1512 in an interesting covering letter for a Javanese map which showed all the regular routes and ports of the trading junks (Baiao ed. pp. 76 ff.).

On this, see p. 619 below.

De Castanheda or his informants may have seen the junks only in port, when their fore and main masts were unstopped. For as we know, multiple masts have always been typical of sea-going junks.

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FIG. 29. Nautics 603

quarter, which cannot be used to make the ship sail. a The sailors also attach some bird feathers to the top of an upright pole as a weathercock; this is called the ‘Five Ounces’ (wu hung). b To get a favourable wind is not easy, so that these great cloth sails are not as useful as the mat sails, which, when skilfully employed, will carry men wheresoever they may wish to go.
29. NAUTICAL TECHNOLOGY

The size of the sail (feng pheng\(^1\)) depends upon the beam of the vessel.\(^8\) If the sail is too large the ship will be endangered; if it is too small it will be ineffective. The sail is made by weaving together thin and narrow strips of the outer parts of the stems of bamboo, and (this matting is) divided into sections grasped by parallel bamboo battens (thiao\(^9\)). Thus the sail folds in tiers (tiek\(^1\)), ready to be (bent to yard and boom and) hoisted. A large main-sail (chang wai pheng\(^1\)) in a grain-ship needs ten men to hoist it, but for the fore-sail (thou pheng\(^1\)) two suffice. In order to get ready to sail, the halyards (pheng so\(^1\)) (have to be passed through) a pulley-block (hsuan-lo\(^1\)) with a one-inch gauge pulley fixed to the top of the mast, and brought down to the halyard winches (on the deck) amidships (yao chien yu n mao\(^1\)). The adjustment of the height of the sail (according to the wind force, etc.) is thus like the variation of the three sides of a triangle (san hu chiao thio erh tu chih\(^9\)). For equal sections (yeh\(^1\)) the upper part of the sail is thrice as effective as the lower.\(^4\) What matters is the adjustment to the conditions. When the wind is favourable the sail is hoisted to its full height and the boat moves at a good speed like a racing horse, but if the wind freshens the sail is reefed (coming down by its own weight) in due order (section by section one after another).\(^7\) (In a squall, the sail may have to be pulled down by long hooks.)\(^6\) In a gale only one or two sections of the sail are hoisted.

Next follows the passage on tacking which Ting & Donnelly omitted. Sung Ying-Hsing explains it clearly enough, having evidently watched the process, but he seems to have confused it a little with the handling of the ship in a current.\(^\text{8}\)

A beam wind is called a ‘tacking wind’ (chiang feng\(^11\)).\(^9\) When a boat is sailing with the current, the sail is hoisted and the vessel wanders about (i.e. takes a zigzag course). Sometimes a difference of an inch in setting the sail when tacking to the east will make all the difference between a safe passage and a setback of several hundred feet. Before she reaches the bank, the rudder is turned (tieh tho\(^12\)) (hard over), and the sail is reset (chuan pheng\(^12\)). The

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\(^1\) Cf. the modules and modular proportions which we saw laid down in the books on architecture (pp. 67ff., 82, 89 above).
\(^2\) See fn. 9 in p. 434 above.
\(^3\) This technical term is now an old friend; cf. the orthographic note on p. 597 above. For a discussion of its many related usages and their origins the reader is referred to Vol. 4, pt. 2, p. 485, as also Needham, Wang & Price (1), pp. 103 ff. On Chinese ships' pulleys and pulley-blocks see Audemard (3), pp. 50 ff.; on the employment of these devices ashore, rarely illustrated, see Vol. 4, pt. 2, p. 96, fn. (b).
\(^4\) I.e. parts of the sail between two battens.
\(^5\) A significant remark in view of the physical theory of sails, cf. p. 593 above.
\(^6\) Sung Ying-Hsing's commentary.
\(^7\) One remembers that he was writing in +1637 or a little before, and that there were no fore-and-aft rigged yachts in England till the end of the century, when some were presented to Charles 11 by the Dutch (Chatterton, 1, 4).
\(^8\) Though Sung Ying-Hsing uses an expression implying right-angle incidence, it is obvious that his nautical informants were referring to winds from port and starboard forward quarters, 'and that their technical term is a precious reference to fore-and-aft sailing. Obviously in tacking, a ship moves to right and left seemingly broadside to the wind.

The term chiang feng, which could be translated as 'stealing the wind', is in fact an ancient one, considered by lexicographers to mean simply 'contrary wind'. The earliest example they give of it occurs in Yu Shen's 4th-century ode Yu Te Fu (1) (cf. p. 86). In view of the evidence presented on p. 600 about the first origin of fore-and-aft sailing in the Chinese culture-area this date might be quite significant, but it must be admitted that the boatmen in the poem lost heart at the contrary wind and let their vessel drift.

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\(^9\) The low Sails are of very thick Matt, trimm'd up with Laths\(^8\) and long Poles, to strengthen 'em, from two foot to two foot, fasten'd to the whole length of the Masts by several little Loops; they are not fasten'd in the Middle, but have three-quarters of their breadth loose,\(^4\) that they may be accommodated to the Wind, and readily tack about as occasion serves. A great many small Cords hanging at the side of the Sail, where they are plac'd at several distances from the Sail-yard to the bottom, are gather'd up, and keep tight the whole length of the Mast, and further the Motion when the Ship's Course is to be changed.\(^8\)

Lastly, a few niceties of terminology. A few pages back, at the opening of the description of Chinese sails, the word \(\text{\textit{d}}\)\(^3\) was mentioned in passing as the technical term for the mat-and-batten type. One may suspect, however, that this properly applies only to canvas sails strengthened with battens, for the character contains the 'cloth', not the 'bamboo', radical. The really correct term would seem to be \(\text{\textit{shuang}}\), in which this radical appears; as its oldest authority the Kiang-Hsi dictionary gives the Nan Yisch Chuhfu! (Records of the South), written by Shen Huai-Yuan\(^4\) in the +4th century. This book also said that the mat-sails were woven from the leaves of the lu-thou cane. Another word, meaning blinds or awnings but constantly used for sails, e.g. in the Kao-Li Thu Ching\(^1\), is of course \(\text{\textit{pheng}}\),\(^1\) and this also has the bamboo radical. Again, an older expression for halyards or sheets, instead of those already noted, was fan chhieh;\(^4\) thus the Than Yuan Thi Hu? (A Delicious Dish of Talk) by Yang Shen\(^8\) (c. +1510) says that these were made of green silk on the imperial ship of one of the Chhi emperors.\(^8\)

(iv) The place of Chinese sails in world nautical development

How do these Chinese inventions compare with parallel progress made elsewhere in solving the problem of windward sailing? We shall try to make our answer as brief as possible, with the aid of the chart in Table 72. Sail types are arranged on it as if against an invisible map of the Old World, and the lines represent the diffusion of forms or the voyaging of stimuli.\(^8\)

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\(^1\) (42), p. 231. Only Donnelly (a) has so far seen the value of Lecomte's nautical descriptions.
\(^2\) Cf. Yebrants Ides (1), p. 56. \(\text{\textit{The parsley}}\).
\(^3\) A clear statement that the sails were lug-sails, not square-sails.
\(^4\) The 'small cords' are of course the multiple sheets.
\(^5\) E.g. ch. 34, pp. 69, 80, b; ch. 39, pp. 24, 45. \(\text{\textit{Quoted in KCCY, ch. 28, p. 154.}}\)
\(^6\) A great deal of patient work has been done since Elliott-Smith (2) first attacked the problem with his heroic obsession, and a great deal more remains to be done, but in this field at least Egyptophilia finds no small justification.

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There is general agreement that the oldest sailing-ships, those of ancient Egypt, were invariably rigged with square-sails. This can be seen on what is perhaps the oldest known record of a sail, a painting of a boat with high stem and stern preserved on a piece of 1st-dynasty pottery and dating from about 3000. Many accept the view that since the prevailing wind in the Nile valley is from north to south, the boats could travel downstream relying on the current, while on the return journey they could run before the wind all the way. Hence the problem of windward sailing did not arise for a long time.

From this focus the square-sail radiated in all directions—to the Mediterranean, where it was universal throughout Greek, Roman and Hellenistic times; to the north, where it was the only automotive device of the ships of the Vikings and Normans, and to all Asia, including India and China. In many parts of the world it still survives, as in the 'Humber keels' of our own country, the barcos rabelos of the Douro, and the freighters of Lake Como, certain Norwegian boats, ships of considerable size on Indian and Burmese rivers, and (as we saw, p. 457, 598, 602) the junks of the Upper Yangtze and the Chilien-thang.

There has been some debate concerning the extent to which square-sailed ships could use quarter or beam winds, or even make headway to windward, and the means whereby they achieved what they did. Chatterton speaks of the 'utter incapacity' of his model ship to all Asia, including India and China. In many parts of the world it still survives, as in the 'Humber keels' of our own country, the barcos rabelos of the Douro, and the freighters of Lake Como, certain Norwegian boats, ships of considerable size on Indian and Burmese rivers, and (as we saw, pp. 457, 598, 602) the junks of the Upper Yangtze and the Chilien-thang.

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Viking ships to do this,\(^a\) and gives some remarkable examples of the dependence of highly developed sailing-ships on favourable winds in recent times. As late as 1800 they sometimes had to wait as long as three months at Hanoose in order to get into Plymouth Sound, and this was long after the introduction of a lateen sail on the mizen-mast. T. R. Holmes maintained that Roman ships could work to windward, but his argument depended largely on complex indirect evidence. An interesting passage in Aristotle's *Mechanica* has been interpreted\(^b\) to mean that Greek and Roman ships managed to get a little nearer to the wind by furling, brailing, or reefing in one way or another, a half of the square-sail, thus giving an approximately triangular character to the other half.\(^c\) What was perhaps another way of doing the same thing may be seen in a Norse carving\(^d\) which shows a number of ropes attached to the foot of a Viking square-sail, which in this way may have been compressed like the drawing of a curtain to one side. Such practices might conceivably be among the origins of the lateen sail. But that sail, which in this way may have been compressed like the drawing of a curtain to one side of the mast (Fig. 1018, pl.\(^f\)) is the typical Indonesian arrangement which we saw in the main Borobudur type (Fig. 973, pl.\(^g\)). Although it is thus attested for the end of the 5th century, we are inclined to think that the invention was very much older there. But it occurs also in the celebrated frameless boats of the Middle Nile, the *naggar* and the *markab*.\(^h\) In all these cases the proportions of the sail (long and narrow) are significantly the same as those of the square-sails of ancient Egyptian ships. The *naggar* may be their direct descendant,\(^i\) or alternatively it may derive from the Javanese invention mediated through the Indonesian cultural influence on East Africa.\(^a\) Such influence is surely also shown by the canted square-sails of the fishing-fleet of Mukalla in the Hadhramaut.\(^b\)

The most prominent Western fore-and-aft sail was the lateen, so characteristic of the Islamic culture-area.\(^a\) This sail exists (Fig. 1005) in two forms, the purely triangular, and the 'quasi-lug' type which retains a small luff edge. The first of these is found only in the Mediterranean, the second throughout the Indian Ocean.\(^a\) Much information exists about the historical appearance of the lateen sail, which is first clearly depicted in a Byzantine manuscript dating approximately from +880.\(^a\) There is thus no doubt that the triangular form was coming into general use in the Mediterranean in the 7th-8th century, but it may be a few centuries older.\(^a\) A determined attempt has recently been made to prove the existence of the lateen sail in Hellenistic times, from an Eleusinian tomb relief of the +2nd or +3rd century, but it has not carried conviction.\(^a\) On general grounds, the 'quasi-lug' form would seem to be more primitive or transitional of the two, and if we are justified in deriving it from the canted square-sail of South-East Asia we may envisage it as generating westwards in its turn the purely triangular form.\(^h\)

An important turning-point occurred when the square-sail of Northern Europe was associated in a combined rig, on vessels of more than one mast, with the lateen. The lateen was hoisted on the mizen. Some think that the process began when ships from Bayonne entered the Mediterranean about +1304,\(^a\) but progress in the adaptation was

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\(^{a}\) Hornell (4), p. 137, (10).  
\(^{b}\) Bowen (4).  
\(^{c}\) There are elaborate descriptions of its use, by Venet (1); Bowen (1), (2); P. Paris (1); and Villiers (1, 4). Drawings in *Adm. Paris*, pl. 5; Smyth (1), pp. 277 ff.; Clossow & Trew (1), p. 111. Discussion in *Jal* (1), vol. 2, pp. 1 ff.; Moore (1), pp. 86 ff.; Poujade (1), p. 142; Hounani (1), pp. 101 ff. The origin of the term *tossa* is obscure. *Hüvel* (1) tries to derive it from *ulla* (unravel), very convincingly.  
\(^{d}\) Smyth (1), pp. 372, 360 ff.; Bowen (2, 9). But this need not mean that the 'quasi-lug' type was never present in Mediterranean waters. If it had never been known there it would be hard to explain why the sails of the peculiar Djeran windmills (see Vol. 6, pt. 2, p. 556) are in fact precisely of this form.  
\(^{e}\) From the Sermons of St Gregory Nazianzen (Bib. Nat. Gk. MS., no. 310) induced by Brindley (6). Good reproductions are given by Hourani (1), pl. 5, 6. There is an earlier picture, a rude drawing on the outer stone wall of a ruined church of the pre-Muslim period at El-Ajas in South Palestine, which might be of the 6th or 7th century A.D. (Procopius, *De Bell. Vandalico*, 1, 1, 3), which says that the ships carrying commanding officers were to have a third of the upper angle of their sails painted red; but critics point out that this may well have meant the small triangular topsails of Roman times, likely still to be in use. These continued even into the eighteenth century, as in the *tossa* rig (Poujade (1), p. 126). Dolley (1) deduces the existence of lateen sails in the Arab fleet at the siege of Thessalonica in +904 from the description of the floating siege towers which were there improvised; this also was subjected to criticism, but the case for it seems to be a better one, and it is intrinsically much more likely.  
\(^{f}\) One wonders whether its westward spread could have been connected with the ship-canal between the Nile and the Red Sea. That ancient waterway was working again between +643 and +796, restored by the second orthodox caliph (cf. pp. 355, 357, 455 above).  
\(^{g}\) Casson (2), with a misleading photograph corrected in Casson (3), pl. 15c, after amplification by the yard. The bay of this stationary ship is certainly canted very high, but it is adjusted to the mast centrally, and as the foot of the sail is not seen, part of it could be lying in folds. A square-sail may therefore have been intended. In any case a triangular lateen can never have been meant, since the luff edge is clearly visible on the relief. I remain unconvinced, even by Casson (4).  
\(^{h}\) Anderson & Anderson (1, 2).
slow, and it was not generally adopted until the latter half of the 15th century, when the impression created by the multiple-masted Chinese junk had borne full fruit. The ships of Columbus (+1492), and all the three-masters of the 15th and 16th centuries, carried a latten aft, so that they could either run with their mainsails or beat with their mizzen. Such a ship, of about +1525, can be seen in the stained-glass windows of King's College Chapel in Cambridge. Cloves has written:

In +1450 northern ships were entirely dependent on a fair wind, and were quite unable, indeed never attempted, to make headways against an adverse one. Before +1500 the European ships had been adequate to make the long ocean voyages which had resulted in Columbus' discovery of America, Dias' doubling of the Cape of Good Hope, and the opening of the Indian trade route by Vasco da Gama. Other scientific advances, such as the introduction of the mariner's compass from China, bore their part in making such voyages possible, but without the far-reaching improvements in masts and sails the great discoverers could never have accomplished their work.

The typically Chinese quadrilateral lug-sail exists in Europe, almost the same in shape, and it became so common there that some have described it as the universal sail of the Atlantic coasts of France. It is also well known in English, Italian, Greek and Turkish waters. But any evidence for it before the late 16th century is difficult to adduce; the earliest representation found by Brindley (+) was +1586, and the name not till a century later. We shall return to its origins in a moment (p. 623).

Strangely enough, a fore-and-aft sail type in the strictest sense, with nothing forward of the mast, is now known to have been in Europe much earlier. This was the square-sail. The first illustration of it was long supposed to be datable at +1416, and practice. We have already seen how the Portuguese barge of about +1450, with its two square-sails, proved unsuitable for beating up and down the west coasts of Africa, so that the caravel of two or three lattes, quite large by +1460, was substituted for it. Well before +1500 the synthesis had been achieved in the equilibrium form of the nau reonda, which had square-sails on fore- and main-masts, keeping a latten only on the mizzen. An alternative, less popular and widespread, was the carraca redonda, with square-sails only on the foremost and great lattes on two or three others. For further details on the Portuguese development see da Fonseca (+).

- Jul (1), vol. 2, pp. 134 ff.; Brindley (2); Chatterton (1), pp. 56, 65, 82; Smyth (1); p. 279; Gibson (4), p. 181; cf. the models of Chatterton (3); pl. 6 of a +16th-century ship with square-sail alone, pl. 8, 9, 10 of ships after +1450 with lattes mizzen.
- Model of the 'Santa Maria' in Chatterton (2), pls. 11, 12; full-scale reconstruction in la Botte & Vivie (1), vol. 1, pp. 238 ff., 246 ff. Clowes & Trew illustrate similarly Drake's 'Golden Hind' of +1577.
- For reservations to which this interpretation is subject, see pp. 589, 932 above. Perhaps the mizen mast was really only a 'hanging' sail, primarily for use in hawse water. Probably the square-sail rig survived until steam because owing to the prohibitive amount of work involved in continually trimming sail, ocean voyagers have always looked for, and waited for, fair winds. Even trading junks work moons. The tea-clippers could have been rigged as multiple-mast fore-and-aft schooners, but they were not, because for running before the wind without change of sail for many days nothing superior to the square-sail was ever developed. Yet this is not to deny that there were solid advantages in the mizen latten, which greatly increased the control of the ship as low a wind. For this note we are indebted to Cdr. George Naish.

- Harrison & Nance (1).
- Brindley (4), Chatterton (1), p. 165. The picture occurs in the Trés Ilustres Heures de Notre Dame, by H. van Eyck. See also Brindley (3); the MS. was lost in a fire at the Turin Library.

- Nance (1) added another example from the late +15th century (MS, Eg. no. 1065, BM). Massa (1) shows one about +1475 in a picture of the St Elizabeth legend at Amsterdam. We have noticed that in the world-map of Fra Mauro, +1459 (p. 472 above).
- Moore (1), p. 168; Moore & Laughton (2); Bowen (9), pp. 161 ff. But others, e.g. Gibson (2), p. 123, point out that the jib-sail came with the gaff-sail, which suggests that both were, in a sense, the component parts of a lateen sail divided vertically into two. See further Clowes (2), p. 165 ff.
- The oldest illustration concerns a siege of Stockholm in +1533 (Nance, 2). Drawings and models of the Stuart Royal Yachts in Chatterton (5), pp. 137; Clowes & Trew (1), p. 137.
- Some warships continued for a long time, however, to carry the long latten yard as a useful spar, with a gaff-sail bent to the aft portion of it; so Nelson's flagship at the Battle of the Nile (+1798).
- If we suppose that the canted sail gave off genetically a kind of lateen sail in each direction, east and west, we can explain the appearance of sails of triangular latten form, but fitted with booms as well as yards, in the Pacific. These were first found among the Ladrone Islands by Magellan (+1521, and as the eastern offspring of the canted sail, they would correspond to the 'quasi-lug' latten of the

Certainly the following decades show several examples, but we know now of a kind of spirt-sail in northern Europe from the previous century, and tomb reliefs take the evidence back to the Hellenistic period. For reasons which will explain themselves as we go on, discussion of this is postponed for a few paragraphs.

There followed eventually the gaff-sail, so familiar in our own time as the typical sail of yachts. Since the gaff was spoken of as a half-sprit, its origin from the spirit-sail is generally considered likely; this took place about the beginning of the +16th century in Holland, and spread to England at the Restoration.

Gradually the more efficient gaff-sail replaced the lateen on the mizen masts of full-rigged ships, a process which, carried further, led to the graceful schooner. Gaff-sails may have been a purely European development, advantageous because easier to handle than spirt-sails; but one cannot be sure, since certain Indo-Chinese and Melanesian boats have something very like them.

It now remains only to add a few keystones into the arches of speculation which we daringly throw across the abysses of our ignorance. Let us look again at the chart (Table 72) which shows the sail forms superimposed upon an imaginary map of the Old World. We see the ancient Egyptian square-sail radiating in all directions, north, northeast and east. We may assume that the canted-sail really is Indonesian (perhaps of the +15th century) and that the Middle Nile nagars are part of a cultural backwash to the African continent. If we suppose that the canted sail gave off genetically a kind of lateen sail in each direction, east and west, we can explain the appearance of sails of triangular latten form, but fitted with booms as well as yards, in the Pacific. These were first found among the Ladrone Islands by Magellan (+1521, and as the eastern offspring of the canted sail, they would correspond to the 'quasi-lug' latten of the

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Erythraean Arabs, which would have been its western offspring. There are, of course, difficulties in thinking of the genesis of the Arab lateen in this way, for it has almost invariably no boom, and it does not seem to occur as a primary cultural trait in those eastern Indian waters which form the intermediate zone between 'Erythraea' and Indonesia. Still, contact could have occurred at least as early as the + century and between Roman Syrian sailors, pre-Muslim Arabs, and Persians, with sailors from regions east of India (Chryse; the Golden Chersonese, etc.).

Support for this belief may be derived from a study of P. Paris (5), which made an interesting analysis of two obscure passages in Strabo and Pliny. About +75 Pliny knew of boats from Taprobane (or points further east) 'with a prow at each end'. These can only have been craft like the yathra dhoni of Ceylon. Pliny's words (about +23) imply a knowledge of boats with double outriggers, and these could only have come from the Indonesian culture-area. The same passage of Pliny contains the description of an ambassador, one Rachiias, from Taprobane (here probably Sumatra), who journeyed to Rome about +45, and spoke of the commerce which his people had with the Seres. There seems really little historical difficulty in believing that all lateens originated from the canted square-sail.

Meanwhile, we must presumably suppose that the Chinese balanced lug-sail was another development from the canted rig. This process was apparently occurring at least as early as the + 3rd century, as we have seen. Here the mechanics of the evolution are a little easier to understand. Besides, several traces of it have survived. For example, some of the junks of the Chhien-thang River carry square-sails, but when wishing to sail to windward, hoist them canting. Roller-reefing, a feature characteristic of the canted sail both in Indonesia and on the Middle Nile, has persisted on some of the square-sailed junks of the Upper Yangtse. And certain Chinese boats carry a vestigial canted sail as a kind of spinnaker additional to their lug (Fig. 1019, pl. 8).

If one cannot spend much time rambling in the Southern Seas oneself, one has only to look at good photographs of the craft of Indonesia and Malaya to see the Indonesian canted rig turning almost visibly into the lug. Thus Hawkins & Gibson-Hill illustrate a boat of Kuala Trengganu which has its square-sail canted so that the lowest corner (the tack) comes in line with the mast (Fig. 1020, pl. 1). Another, the Prahu Buatan barat of Kelantan, has a sail similarly set, but the boom seems no longer quite parallel to the yard, in other words the lengthening process of the leech foot is taking place. Exactly the same thing can be seen happening on Poujade's chart of the sails of Indo-Chinese craft.

A major problem is presented by the European lugger. If it really originated indigenously as late as the end of the + 16th century, its spread around all the coasts of western Europe was astonishingly rapid. The suggestion is at any rate worth entertaining that it came directly from the Chinese junks, losing its battens and multiple sheets on the way. A suspicious circumstance lies in the fact that the Adriatic, Marco Polo's home waters, seems to be the geographical centre of the distribution of the rig in Europe. The trabacco (Fig. 1021) and the braggozzi, both luggers, still predominate in Venetian ports like Chioggia, carrying two standing lugs and a jib. Still more remarkable, they have other Chinese features; they are very flat-bottomed, and they have an enormous rudder which descends some distance below the keel, and which can be tripped up when shallow water is approached. 'These boats', says Smyth, 'are of beautiful lines and great power, constituting one of the finest forms of sea-going lugger.}

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8 Poujade (1), pp. 145 ff., 157 ff., seems to agree more or less with this theory of the origin of the lateen. Bowen, on the other hand, believes that the Arab lateen must have descended, through some kind of lug-sail, from some form of square-sail which had no boom, (a), p. 188. The difficulty here is to find the intermediate forms. Bowen thinks that we may see them in the jib-headed dipping lugs of the western Indian Ocean, (2), p. 187. Bowen also thinks, (2), pp. 101, 110, that the Pacific boom-lateen developed not so much from the canted and boomless Oriental square-sail as from the proto-Oceanic bifid-mast 'spit-sail' of the Indian Ocean, (5), pp. 84 ff., which we shall consider shortly in connection with the origin of all square-sails; transmission occurring through the Polynesian-Micronesian triangular spit-sail, (2), pp. 87 ff., perhaps also through the Melanesian 'double-mast spit-sail', (2), p. 88 ff., 101. But this strange type—one of the putative ancestors, as we have seen, of the Chinese lug-sail—might itself be an 'Indonesian' rectangular sail canted so far as to stand bolt upright. A peculiar standing lug of the Melanesian Bismarck Archipelago, still retaining a short mast as well as the almost vertical boom and yard, has almost reached the 'mastless' (or 'double-mast') stage (cf. (2), p. 205). It is interesting to see how the traditional terminology tends to break down in this field of bewildering but fascinating variety.

9 This, after all, was about the beginning of the Venetian migration to Madagascar (Fernand, 3).

10 Nat. Hist. vi, xxv, 8a, 83.


13 Geogr. xv, t. xv.

14 It will be remembered that Pliny confused them here (v. t, xxiv, 8g ff) with the Yuh-chih, describing them as fair-haired blue-eyed people. As we saw above (p. 449) there were commercial contacts later on between the Yuh-chih and the Malayas, under the Kuchalân empire in India. Cf. Vol. 1, p. 260, on Chinese-Kuchalân diplomatic relations just after Pliny's time.

15 If one prefers the view that the saggur sail was an indigenous Egyptian development, and that all Arab lateens originated from it, one is left with no explanation for the Pacific lateens except independent invention and convergence. Of course this cannot be concluded.

16 This was also the view of P. Paris (3), p. 44. Here Bowen (9), p. 192 ff., too, concurs, turning however to emphasise the direct descent of the Chinese balance lug from ancient tall rectangular square-sails. Elsewhere (p. 197) he traces the descent of Siamese and Indo-Chinese standing lugs from the Indonesian canted square-sail or ancient balance lug. On lug-sail terminology cf. Ansted (1), p. 168.
the world.' And of the Morbihan luggers, he says, 'At a distance their sails (lofty and rectangular) are in outline strangely like those of some of the two-masted Amoy fishing-junks.' Further hints may be gained by the fact that the only instance in Europe of multiple sheeting occurs in Turkish luggers, and there not as sheets at all, but as bowlines, which with batten-sails in China had never been necessary. And on certain Turkish boats, a pair of side-wings or cheeks abaft the stern, just as on sampans, could be seen. Such indications permit us, therefore, to suggest that evidence may later be forthcoming that at some time after the return of Marco Polo to his native city, the Chinese lug-sail was copied in Europe.

Another major problem concerns the origin of the first sprit-sail rig in Europe. Those who have discussed the matter have omitted to notice that rigs of almost exactly the same kind occur in China (Fig. 1015, pl.). That they occur widely there prevents the assumption often made that in Europe they must have derived from the Mediterranean lateen is also unattractive, for on general evolutionary principles the reduction of a square-sail to a triangular one would not be readily reversible. More interesting is the possibility that all sprit-sails derive from the 'bifid-mast' sprit rig of the Indian Ocean which carry a square-sail. Many examples are known—from Ceylon, from Madagascar, from the Pacific also. In this case, the Chinese sprit-sails (information about the earliest date of which is urgently required) would be one derivative, while the European would be another. Here the discovery of Brindley (5) is of exceptional interest; the earliest sprit-sail which he found in Europe, that on the seal of Kiel (+ 1365), seems in fact to be an elongated square-sail carried on a bifid spar, though a normal mast was stepped as well (Fig. 1022). There was apparently neither yard nor boom, just as in the Indian Ocean form. Furthermore, Brindley (6) found that in Tahiti and Hawaii also a conversion of the bifid-mast square-sail to the sprit-sail had occurred, perhaps independently. Again there may be significance in the fact that one of the chief foci of the sprit-sail in Europe is Turkish. The exact means of transmission, however, remain unknown.

If Casson (2) is right in his identifications, as he seems to be, Indian influence on Mediterranean sails may have been exerted a thousand years earlier than the ship in Brindley's seal. For in an important discovery Casson has figured four Hellenistic tomb reliefs of about the +2nd century which do seem to represent sprit-sails of some kind or other, though two of them resemble the sail's arrangement more closely than the true sprit-sail of later times. Still, this seems acceptable in two cases. The lack of any evidence for the long intervening period remains somewhat mysterious, and the hypothesis of two successive introductions cannot as yet be excluded. That is a problem with which we shall encounter other examples of this in Sect. 32. If it is true, it has doubtless Brindley's interpretation; as none of the lines show any sag, he thought that the drawing might have been intended to show a yard, two braces and two sheets.

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\[\text{Fig. 1021. The trabaccolo of Venetian waters, one of the best examples of traditional lug-sail rig in Europe (sketch after Smyth, i). Description in text.}\]
adequate Roman-Indian contacts for the exchange of techniques existed is indubitable; of the trading stations on the Indian coasts much is now known.2 Bowen (2) already saw that the Indian Ocean bi-fold-mast sprit-sail could not possibly have been derived from Europe, for its luff is loose, and by the time that Europeans came again to Indian waters in the +16th century, their sprit-sails had long been laced to the mast. He has now abandoned (9) his former reluctance to believe that these themselves derived from the Indian Ocean form, which is coming to occupy a central position in evolutionary theory. It may well be also, as he thinks, the ancestor of the triangular sprit-sails and boom-latesens of Oceania,3 as well as of the Melanesian ‘double-mast’ sprit-sail which philological evidence connects with the earliest sails of China (p. 599).

One last kind of sail has so far not been mentioned: the triangular peakless fore-and-aft sail (G in the diagram on p. 589). This has a modern air because of its use on racing yachts, where it is called the Bermuda rig or ‘leg-of-mutton’ sail. Its wide application in modern times has come about because of the realisation that most of the work of a sail of optimum rigidity is done by the leading edge, and its aerodynamics have been compared with those of a bird’s wing.6 But sails of this triangular shape are very much older, for it is found in the Chinese culture-area, notably on some of the Indo-Chinese craft described by Adm. Paris and others.4 Here the yard is lashed to the mast and stands upright like a backward-curving antenna, while the boom converges to it with or without a very small luff. It might be regarded as an ‘Arab’ latsen sail shifted horizontally leechwards so far that its yard could become an almost vertical continua­tion of the mast; and since indeed it was almost certainly derived from standing lug-sails of more normal shape,8 this is really what it is. Of course the presence of the boom betrays its origin from the canted Indonesian square-sail. This was at first sight not the only originator of the triangular sail with vertical leading edge, however, for it has at least two other foci, the Lake of Geneva and the West Indies. On the Lake of Geneva the lateen sail reaches the northern limit of its distribution,5 and its conversion there to the leg-of-mutton sail is thought to have been an adaptation to catch light airs in a mountain region.8 The New World (the West Indies and Bermuda) offers more of a problem. The lateen may well have been concerned, for it seems that this was taken to

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the Antilles and to Canada by the French.6 On the other hand a Pacific origin may be invoked, for the earliest drawings of the sea-going balsa sailing-rafts of Peru (cf. pp. 394, 547 above), due to van Spilbergen in +1619, show sails like triangular latesens without masts. Bowen thought at first7 that the artist here inadvertently omitted the booms, in which case the rig would have been essentially the triangular sprit-sail of Polynesia and Micronesia, with more leech divergence of the spits; but subsequently8 admitted that the Peruvians could indeed have abandoned the boom.9 Since the oldest evidence for leg-of-mutton sails in Europe is Dutch and dates from +1623 Bowen is prepared to envisage a direct influence from Peru.6 Thus ultimately the leg-of-mutton sails of Europe and of Indo-China would both have been derived from the canted Indonesian square-sail through the luff convergence of the lug’s yard and boom.6

It would be hard to summarise all the complex facts which we have here been surveying. Yet it seems sure enough that after the first development of canted square-sails, wherever and whenever that may have taken place, the earliest fore-and-aft rigs appeared in the Indian Ocean about the time of Asoka (−3rd century), spreading in different forms both to the Mediterranean area and to the South China seas by the +2nd.8 Seemingly in the West the sprit-sail was forgotten, but in East Asia the tall balanced lug-sail went from strength to strength. Next following were the lateen sails of Arabic culture from about the +7th century onwards. European sailors of medieval times were slow to adopt these more advanced techniques, but the +15th-century Portuguese pioneered nobly in windward sailing. Whether or not the European lug-sail was derived directly from China or South-East Asia remains to be proved, though it seems exceedingly likely. At all events the credit for the oldest decisive inventions which permitted more and more efficient sailing near the wind must go to the peoples of Indian, Indonesian and especially Sino-Thai culture.

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a Poujade (1), p. 156. Pell (1) has published a MS. drawing of lateen sails on galleys on Lake Champ­tain in +1775. Morris (1), pp. 20 ff., maintains that sails of this kind were common enough in North America before this time, and could adduce pictorial evidence for triangular sails with booms in American waters as early as +1629, or at least +1671. Some pictures, such as those of Pell, seem to show in progress the transformation effected by lashing the long lateen yard to a short mast so that it projected vertically far above it. Cf. Laughton (1).

b (5), p. 90.

d E. F. Paris (2), p.c. 1; Piétet (1); Poujade (1), p. 149, 150, 157; P. Paris (1), pp. 43 ff. and figs. 139, 134, 145, 153, 230, etc.

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a See Bowen (9), p. 157, who expounds also the interesting intermediate forms, photographs of which can be seen in P. Paris (1), figs. 201, 202. In order to give these standing lugs and even gaff-sails of a kind, as well as the great Chinese balance lugs, and eventually the extreme form of the leg-of-mutton sail, there had to be a progressive enlargement of the leech area of the sail.

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(v) Leebards and centre-boards

In all fore-and-aft sailing there is likely to be a marked tendency for the ship to drift to leeward. The reason for this was explained at an earlier stage (p. 593) when we discussed the forces acting on a ship so rigged that it can sail near the wind. The tendency can only be counteracted by making the hull of such a shape as to minimise this drift. Here the occidental keeled construction had great potential advantage over the Chinese flat-bottomed box build. But other means of opposing leeward loss may take the form through a trunk along the midship line—these are known as leeboards and centre-boards.

Many types of Chinese river craft are equipped with these devices, for example the Yao-wang chhuan described by Worcester. Such leeboards tend to be about one sixth of the length of the ship, and occur in various fan-like shapes. The Cantonese seagoing trawlers have conspicuous centre-boards. Japanese drawings of the 18th century show leeboards on ships from Nanking. Indeed there is good reason for thinking that the Chinese culture-area is their original home, for as was noted above (p. 393) the Formosan bamboo sailing-raft, perhaps the most ancient existing prototype of all Chinese vessels, has both leeboards and centre-boards. These are essential for its work (it can actually beat to windward with its lug-sail), and though now assisted by steering-oars they are capable of carrying all the burden of the helm, as they still do in its Peruvian counterpart (cf. pp. 394, 548). Then as Chinese shipbuilding developed it would have been most natural to continue the use of leeboards when the flat-bottomed junk construction came to be powered by efficient fore-and-aft rigs.

While medieval Chinese literary references to them are rare, a rather clear one can be seen in the description of one of the warships (Hai-hu) in the Thai Pai Yin Ching of +759. A passage which we shall quote in full presently says that there are attached to the hull on both sides of the ship 'floating-boards' (fou pan) shaped like the wings of the bird (a hawk or gebre) after which this class of vessels was named. These attachments 'help the ships, so that even when wind and wave arise in fury, they are neither driven sideways nor overturned.' The writer, Li Chhiian, may not himself perhaps have been perfectly clear about the function of these devices, but what he says can hardly refer to anything but leeboards. There is no evidence of their existence in Europe before about +1350 at the earliest, and this has led Chatterton (4) to suggest that the device was brought to Europe from Chinese waters in the +16th century. In favour of this view, perhaps, would be the fact that they then appeared first upon Portuguese and Dutch ships.

For writers of the late Ming leeboards were a commonplace. Speaking of river and canal ships Sung Ying-Hsing says:

If the ship is rather long (in relation to the depth of the rudder with which she is fitted), then in a strong cross-wind the power of the rudder will be insufficient (to prevent leeward drift). Then broad boards (phien phet shui pan) are lowered into the water as quickly as possible, and this counteracts the influence (of the wind).

And of sea-going ships:

Amidships there are large horizontal beams set thwartwise and projecting outward several feet; these are for letting down the 'waist rudders' (yao tho). All sorts of ships have them. These 'waist rudders' (i.e. leeboards) do not resemble the proper stern rudders in form, but are fashioned out of broad boards into the shape of knives, and when lowered into the water they do not turn, but help to keep the boat steady. At the top there are handles fitted to the cross-beams. When the ship sails into shallow waters, these 'waist rudders' (leeboards) are raised, just as the rudders themselves are, hence the name.

Curiously relevant here is the quotation given above (p. 603) in another connection, de Castanheda. Referring to the period +1528 to +1538, he spoke of two rudders on junk, one at the stern and another at the bow. P. Paris has suggested that reproduced in Audemard (2, p. 48) showing a bulwarked manless ship towing nine square roughly in the position of oars and each attached by a cable to the edge of the deck. In TSSC, Jung ding chih, ch. 97, p. 58 (his p. 47), the spars, six in number, are apparently pinned to the edge. Evidently the nature of the 'floating-boards' was already misunderstood when the drawings were made.

Another possible mention about this time occurs in the diary of the Japanese monk Ennin. In the early part of the storm which shipwrecked him at his first coming to China in +838, he notes that the translator conjectures iron plates used as reinforcements on the sides of the ship, or, less plausibly, the goings used as ship's bells, but if leeboards of that age were strengthened with iron bands they might well have curved in, and they would fit the description of the monk. On his adventures see further, p. 643 below.

The alternative is, of course, outriggers of some kind, as Dr Lo Jung-Pang (private communication) is inclined to believe. This deserves serious consideration since the few texts we have dwell so much upon the fact that these ships would not capsize. That quite large vessels in medieval South-east Asia had outriggers we know from the Borobudur carvings (already discussed, p. 438 above). The difficulty about such an interpretation is that nothing at all like this survived even vaginally among the multiform Chinese ship designs of modern times. Is it possible that in the Thang some sea-going 'ships had both leeboards and outriggers?}

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what he or his informants had actually seen were certain southern vessels, such as the lang-tangy of Kuantung, and the ghe-sang of Annam, which have a movable board sliding up and down at the bows. This bow centre-board does give, from a distance, the impression of a rudder. Parás also sees significance in the fact that the lee- or centre-board, in any form, is practically unknown in traditional Mediterranean craft.

An alternative method of accomplishing the same end consists in having the rudder relatively large, and lowering it well below the bottom of a flat-bottomed craft. As Poujade has rightly recognised, this was certainly one of the reasons for the widespread Chinese medieval use (which still continues) of rudders deeply slung, and an extreme example from Korea is given in Fig. 1031. But that is no reason for setting East Asian rudders on one side and excluding them from the history of rudders in general.

(a) Oars

(i) Rowing and the handled oar

Since paddles and oars used by rowers go back to prehistoric times, it is quite natural to find that the Chinese language contains a number of terms for them. The exact meaning of these is subject to local variation, and it is hard to identify the significance this has gone far back into the 1st millennium, being found in the Shih Ching and the Shu Ching. Related words, which fluctuate orthographically between the boat and wood radicals, are ching, ch'ao, and cho or (chao). More clearly defined is the steering-oar or stern-sweep, a word which is differentiated from that for the stern of a boat, shao. Originally meant a curved piece of wood, and may therefore have been an early appellation of the curved ‘propeller’ or angle-oar which will shortly be discussed in some detail. The name for this has long been hs, a

word which can be written in an unusually large number of different ways.

Lastly, the punt or prant pole, kwo, has always been clearly distinguished.

Since in Chinese vessels the deckhouses were always placed towards the stern, while the rowers took their places on the deck forwards, the word written in a slightly different manner came to mean the bows. In the Chhien Han Shu, for example, with reference to a 1st century AD: Han Wu Ti had his ships (lit. sterns and bows, cha lu) floating on the River for 1,000 li. Specific study of Han literature, indeed, would throw much light on nautical practices. Thus in the accounts of the fighting which accompanied the restoration of the Han dynasty, about +33, the biography of a general Tshen Peng tells us that ‘There were on the transport ships more than 60,000 rowers working the oars (cho)… Several thousands of boats with lu-jau rushed to the attack.’ The Thang commentator, Li Hien, explains the latter term as meaning that the oars (chiao) were outside the ship while the men were inside. This seeming platitude probably implies that the rowers were invisible from outside because of built-up gunwales for protection against arrows, the oars issuing through ports (cf. the tomb-model in Fig. 961, pl. 6).

Probably in the Han time, as still today, Chinese sailors generally rowed standing and facing forwards. This was a fairly common ancient Egyptian practice, and in China would have arisen naturally from the paddling of the long South-east Asian canoes which gave rise to the dragon boats. Oars are sunk much more deeply in the water at each stroke than is customary in Europe, and often carry a transverse handle at the end of the oar, convenient for this kind of rowing. These T-handled oars go back at least to the Sung, as we know from paintings. Facing rowing has a wide distribution, and though not characteristic of Europe, occurs in connection with Venetian gondolas and the boats of Austrian and Hungarian lakes; a detailed investigation of it might well prove interesting.

During the Sung, Yuan and Ming periods quite large ships were often classified according to the number of oars carried. Thus speaking of the grain-transports called ‘wind-borers’ (Ts'uan-feng), surely in allusion to their quality in beating to windward, the Ming Liang Lu (+1275) divides them into the greater and smaller ‘eight-oared’ types (Ts'au Hsiao pa lu), besides some with six oars only. These were almost certainly not ordinary oars but large sweeps like the yulohs’ next to be described. The Hsiian

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Ho Feng Shih Kao-Li Thu Ching (+1124) reports that each ship of the embassy fleet carried ten oars, continuing:

When making a landfall or entering port, or taking advantage of the tide to negotiate a channel, the ship proceeds with the sound of crashing oars. The sailors throw themselves back and forth, shouting and straining, but the vessel moves much more slowly than when sailing before the wind.a

Sometimes the oars were useful for short bursts of speed under other conditions, as in a flat calm on open waters. There is an account of a sea-fight with pirates ten thousand li from China on one of the Ming expeditions, when a squadron of Chinese ships succeeded in getting away by rowing. Probably this testifies to the efficiency of the 'yuloh'.

(ii) Sculling and the self-feathering "propeller"

Besides the propulsive effect produced by oars worked in the ordinary way, motion forward can also be obtained by mounting an oar approximately in the line of the main axis of the boat, most conveniently at the stern, but also elsewhere, and moving it from side to side of that axis. This technique is used only for small dinghies in the West, but the Chinese elaborated it into an extremely ingenious heavy duty system. Known as the 'yuloh'c (actually a verb yao la, to shake the oar), it has often been described; we have already had occasion to refer to it several times. Its great effect is due to three special modifications: (a) the loom or handle is brought more nearly parallel to the deck by means of a curve or angle inboard of the fulcrum, (b) the fulcrum consists of a thole-pinf or bumkin fitting into a hole in a block attached to the oar, and (c) the loom or handle is attached to a fixed point on the deck by a short length of rope. The cup-and-pin system constitutes an approach to the universal joint.6 It is obvious from a consideration of the parallelogram of forces of such a sculling-oar that the effective work desired is accomplished only during a certain part of the stroke, and for the remainder the oar must be feathered so as to oppose no resistance to the water. The 'yuloh' accomplishes this without any need for work with the wrist; it is simply pushed and pulled to and fro, the handle necessarily describing an arc of a circle, while at the moment required for the

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Notes:

a Ch. 34, p. 56, tr. auct. ad. Lo Jung-Pang, p.c. Cf. p. 60a above.

b The conjecture is obvious that 'sculling,' as it is called, arose from the steering-oar.

c The Cantonese form of the words.

d Searck (1); Maze (1); Worcester (1), p. 6; (3), vol. 1, pp. 57 ff.; Dünmack (1); Ward (2); Worsers (8); Audemard (3), p. 66. Cf. the model in Fig. 913 (pl.).

e Sampson with four yulohs have competed against ships' boats with four oars and won, them only in the fishing-boats of Portugal and Madeira. Since they are apparently unknown in the Mediterranean, it is possible that they may have been a 17th-century Portuguese introduction from the China.

f It is one among several Chinese empirical tentatives towards the contrivance; others have already been encountered in connection with the Carden suspension (Vol. 4, pt. 2, pp. 251 ff., 253) and the compasses (Vol. 4, pt. 1, p. 290).

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feathering, the rope is given a jerk (Fig. 1023, pl.).8 The whole process is difficult to describe, but can be quickly appreciated when it is seen in action.b

How old the yuloh system is cannot be said with certainty but it seems to go back as far as the Han. The word lu itself is Han. The Shih Ming dictionary of Liu Hsi (about +100) says: 'That which is at the side of the boat is called lu.' Now lu is connected with li (the backbone). (Thus) when the strength of (men's) spines is used, then the boat moves (forward). This does not exclude the self-feathering propulsion oar because it has been a practice in China to mount two or more of them near the stern or even near the bows. This is seen in the diagram which Worcester gives of a Chekiang Khui-pang3 boat, and clearly in the famous picture of +1125 which we discuss in several connections (cf. Figs. 826, 976, 1034, pls.).

The lu4 occurs again, for example, in the Tung Ming Chi (Light on Mysterious Things)5 which would be evidence for, perhaps, the +5th century.

One of the first references to the yao-lu, as a phrase, is that in the Fang Yen (Dictionary of Local Expressions) of Yang Hsiung, but as the book may contain some later interpolations we cannot be quite sure that this was in the original text of about +15. However, it would certainly indicate a time not subsequent to the Later Han. The passage says: 'That which sustains an oar (cho) is called a chiang.' Chiang—a small wooden peg (chhi) for the yao-lu.6 The people of Chiangtung also call it the "foreigner" (lu jen).7 That which ties down the oar (cho) is called the chhi.8 Chhi—the rope attached to the head of the oar. A later term for the thole-pin or bumkin was shuai,9 and today the boatmen speak of it as the lu-ni-thou.10 The binome yao-lu11 appears again in the accounts of the battles between the States of the Three Kingdoms period. When Lu Meng12 a general of Wu, was campaigning against Kuan Yu of Shu he employed at one point (+219) a ruse in which he dressed his best soldiers in white like merchants and mounted them on merchant-boats (hau-lu)13 which they sculled back and forth. Since the text dates from before the end of the same century, when many contemporary documents must still have been available, it is rather firm evidence for the dating of the technical phrase.

In the diary of his journey to Szechuan in +1170 Lu Yu said: 'On the twentieth day they unhitched the mast and set up oar-stands (lu chhuan)14, because when

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Notes:

a So at least in the north, but in the south the movement is performed entirely by handling the loom of the sweep. The bare with any pulling on the rope (B. Ward, private communication).

b It looks easier to perform than it really is, however: there is a knack in it. There is nothing to keep the oar on the pivot, which often has but a shallow penetration into the block. As Worcester says, the motion of the yuloh amounts to that of a reversible screw-propeller. Cf. the discussion above (Vol. 4, pt. 2, pp. 35 ff., 202 ff.) on the development of continuous as opposed to alternating rotary motion, and (pp. 119 ff.) on the screw (and even the screw-propeller, p. 125) in Chinese culture.

c Ch. 25, (p. 378), tr. auct.

d (3), vol. 1, p. 152.

e Ch. 1.

f Ch. 9, p. 8a, tr. auct. The echoing sentences are those of Kuo Hsio's early +5th-century commentary.

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92. NAUTICS

Feathering, the rope is given a jerk (Fig. 1023, pl.). The whole process is difficult to describe, but can be quickly appreciated when it is seen in action.

How old the yuloh system is cannot be said with certainty but it seems to go back as far as the Han. The word lu itself is Han. The Shih Ming dictionary of Liu Hsi (about +100) says: 'That which is at the side of the boat is called lu.' Now lu is connected with li (the backbone). (Thus) when the strength of (men's) spines is used, then the boat moves (forward). This does not exclude the self-feathering propulsion oar because it has been a practice in China to mount two or more of them near the stern or even near the bows. This is seen in the diagram which Worcester gives of a Chekiang Khui-pang3 boat, and clearly in the famous picture of +1125 which we discuss in several connections (cf. Figs. 826, 976, 1034, pls.). The lu4 occurs again, for example, in the Tung Ming Chi (Light on Mysterious Things)5 which would be evidence for, perhaps, the +5th century.

One of the first references to the yao-lu, as a phrase, is that in the Fang Yen (Dictionary of Local Expressions) of Yang Hsiung, but as the book may contain some later interpolations we cannot be quite sure that this was in the original text of about +15. However, it would certainly indicate a time not subsequent to the Later Han. The passage says: 'That which sustains an oar (cho) is called a chiang.' Chiang—a small wooden peg (chhi) for the yao-lu. The people of Chiangtung also call it the "foreigner" (lu jen). That which ties down the oar (cho) is called the chhi. Chhi—the rope attached to the head of the oar. A later term for the thole-pin or bumkin was shuai, and today the boatmen speak of it as the lu-ni-thou. The binome yao-lu appears again in the accounts of the battles between the States of the Three Kingdoms period. When Lu Meng, a general of Wu, was campaigning against Kuan Yu of Shu he employed at one point (+219) a ruse in which he dressed his best soldiers in white like merchants and mounted them on merchant-boats (hau-lu) which they sculled back and forth. Since the text dates from before the end of the same century, when many contemporary documents must still have been available, it is rather firm evidence for the dating of the technical phrase.

In the diary of his journey to Szechuan in +1170 Lu Yu said: 'On the twentieth day they unhitched the mast and set up oar-stands (lu chhuan), because when
and rowlocks in general, but probably the former was meant. From the 14th century we have a painting of a fishing-boat by Yen Hui, which clearly depicts the trackers' rope, not sails. The difficulty is to distinguish between the yuloh fulcrum (already quoted, p. 491 above). His description of a dozen or more men working each one has been questioned, but even today on comparatively small river craft it is quite common to see yulohs worked by a team of eight, with two men giving the jerk on the rope, one from each side, which brings them in turn almost flat on their backs. Under yulohs, a speed of 3½ knots is easily maintained.

At the end of the 17th century, the yuloh much impressed Lecomte, whose words may end this brief account:

Notwithstanding these Barks be extraordinary big, and tho' they always be either under Sail, or tugg'd along by Ropes, yet they do by times make use of Oars, when they are upon great Rivers, or cross Lakes. As for ordinary Barks, they do not row them after the European manner; but they fasten a kind of a long Oar to the Poup, nearer one side of the Bark than to the other, and sometimes another like it to the Prow, that they make use of as the Fish does of its Tail, thrusting it out, and pulling it to them again, without ever lifting it above Water. This work produces a continual rolling in the Bark; but it hath this advantage, that the Motion is never interrupted, whereas the Time and Effort that we employ to lift up our Oars is lost, and signifies nothing.

The yuloh also impressed the British Navy, for we learn from Admiralty papers that in 1742 experiments were made in which a sloop was fitted with 'a set of Chinese sculls.' Something rather similar to the yuloh figured among the nautical inventions of the third Earl Stanhope about 1790; it was called the 'Ambi-Navigator or Vibriator.' The intention was to apply steam-power to the device, but it never proved successful.

Then in 1800 Edward Shorter arranged 'a two-bladed screw, at the end of a revolving shaft, set at an angle like an oar in sculling, and having a universal joint connection with a horizontal shaft on the deck.' Two years later, a deeply laden naval transport ship, worked by eight men turning a capstan, made ½ knots with this device. More research is needed regarding the relation of the earliest Western tentative screw- 

The China yuloh is about the same time there is a classical reference to the work of massive yulohs by many men, in the account of Ibn Battūta (already quoted, p. 491 above). The curious story reported by McGregor, that a Chinese screw-propeller was brought to Europe and seen by a Col. Beaufoy in 1780, some thirty years after Bernoulli had first suggested the possible superiority of the screw over the paddle-wheel. It may well turn out that the yuloh played a certain part in the early inspirations of screw-propulsion.

(iii) The human motor in East and West

Students of the writings of naval archaeologists now become familiar with that rather tedious field of controversy which centres upon the construction of the Roman and Greek galley, the interpretation of the technical terms for the banks of oars, and what is to be made of the apparent existence of galleys with forty banks superimposed. The only relevance which this has for us is that it prompts us to ask why such problems never arose in the Chinese culture-area. Apart from the dragon-boats which were used only for racing in folk-festivals, the many-oared galley (though obvious prototypes in the long canoes of the south-east, with their numerous paddlers, were near at hand) remained throughout recorded history absolutely foreign to Chinese civilisation.

The conclusion that this indicates a clear technical superiority of Chinese seamen-ship seems almost unavoidable. Good reasons have already been given (p. 600 above) for believing that South-east Asian waters were the scene of the earliest really successful attempts at sailing into the eye of the wind. If the first lug-sails and sprit-sails were of the + 2nd or + 3rd century, they antedated the lateens by four or five hundred years, and gaff-sails by seven hundred and more. After all, the object of using the human motor on a mass scale was not only to overcome flat calms, but to make headway against strongly adverse winds. The reader has only to imagine what it must have been like for sailors in ancient times when they tried to escape from the proximity of a lee shore in heavy weather with a ship which could make almost no headway to windward. The greater aerodynamic efficiency of the rigid Chinese mat-and-batten sails must at least have reduced the number of occasions when recourse to other motive power was essential. The naval requirements were not so widely different; there is plenty of propulsion with knowledge of the Chinese yuloh. Mention has already been made of the curious story reported by McGregor, that 'a Chinese screw-propeller was brought to Europe and seen by a Col. Beaufoy in 1780', some thirty years after Bernoulli had first suggested the possible superiority of the screw over the paddle-wheel. It may well turn out that the yuloh played a certain part in the early inspirations of screw-propulsion.
combat afloat recorded in the Chinese official histories. And when the Chinese did turn their attention to other motive power, they produced, with that mechanical inventiveness often only grudgingly accorded them by other peoples in modern times, the subtle yuloh (from about the +2nd century), and then the treadmill-operated paddle-wheel boat (at least from the +8th, if not before).²

There is nothing here in contradiction with the fact that human motive power was used on a tremendous scale in ancient and traditional China. All sailors rowed, every seaman could handle the yuloh, but their work was not done under the conditions of organised inhumanity which often prevailed in Europe. There were also the trackers, whose work along the banks of the great rivers was sometimes gruelling, but again in China they were not slaves.³ Elsewhere in this Section we have frequently come across ship types named from the number of their 'oars' (the term includes yulohs).⁴ When obvious, and his critics, especially la Roerie (1), pointed out that while the Athenian (2), p. 66, the drawing of a galleys, which were equipped only with steering-oars, had been rowed by free citizens,⁵ when these were quite large, as some of them certainly were, the gear was carried primarily for manoeuvring in landlocked waters, or when way was urgently required in a flat calm.⁶ Moreover, there were many types of fast official-carrying boats (like admirals' gigs) and patrol boats, which were thus powered.⁷ But put it all together and it adds up to nothing approaching the galley-slave pattern characteristic of Mediterranean Europe for some two thousand years.

Des Noëttes, completing his studies of the history of the axial rudder (2, 4), shortly to be referred to, boldly entitled them, in analogy with his work on the history of the efficient animal harness (cf. Vol. 4, pt. 2, pp. 304, 349), 'Contributions to the Study of the History of Slavery.' In the nautical context the relation was doubtless not so obvious, and his critics, especially la Roerie (1), pointed out that while the Athenian galleys, which were equipped only with steering-oars, had been rowed by free citizens,⁸ the galleys of the +17th century, which all had axial rudders, were propelled by slaves under some of the worst conditions ever recorded in the annals of slavery.⁹ Neverthe-

³ See further on this, p. 562 below, and mem. p. 415 above.
⁵ Cf. the use of steering-oars on large modern sailing-ships, pp. 629, 636 below.
⁶ For example the 'centipede-boat' (Wu-kung chhuan), with several tens of oars on each side, very fast, mentioned in Ming Shih, ch. 92, p. 160 and many other sources. In his Chi Hsiao Hsin Shu (New Treatise on Military and Naval Efficiency), c. +1575, Chih-Chi-Kuang describes the Pa chiang chuan¹ as having 16 oars a side, but the Wu Pa Chih gives it only four a side (ch. 18, p. 217 and 117, p. 14, respectively). We suspect that oars proper were meant in the former text and yulohs in the latter. For the reason the Wu Pa Chih allots the 'centipede-boat' nine 'oars' a side, not twenty or thirty (ch. 117, pp. 123, 134, b). Good sketches from the life will be found in Audemari (4), pls. 65, 66. He reproduces, (a), p. 66, the drawing of a Pa chiang chuan in TSSC, Jung cheng tiem, ch. 97, p. 204a.
⁸ This was in any case only a half-truth. Cook (2) and Mayor (2) have shown that on the Greek and Hellenistic galleys slave labour was frequently employed, and the more so as time went on. According to Turn (1) the Roman galleys first used allied peoples, then more and more frequently slaves. The 'slave's lack of interest in improving the tools he handles' (as Gibson (2), p. 60, put it) can hardly be unconnected with the failure of Graeco-Roman civilization to adopt effective means of sailing into the wind. But this raises questions too large for treatment here.
⁹ French naval historians have studied this in detail; there are dreadful descriptions in Keltzenbach (¹); Garnier (1); la Roerie & Vivieille (1), vol. 1, pp. 150 ff. and in de Loture & Haffner (1), pp. 168 ff. The Renaissance rowed galleys rose and fell like the witch's-mania or the Inquisition; its heyday was from

¹ 魍蚣船
² 附注
³ 菊春
⁴ 雲翰
⁵ 於實
attached to one of the stern quarters, and lastly the stern-post rudder itself, hung on pintle and gudgeon.\(^a\) When a Lincoln MS. of +1265 differentiates tolls between 'navi cum handerather' and 'navi cum helmerother'\(^b\) we can guess pretty well what was meant. But the Chinese terminology is a more difficult matter, since the thing changed with the change of winds, and we did not, as we shall soon see.

A classical monograph was devoted to the invention of the stern-post rudder by des Noëttes\(^c\). He claimed that because of the weakness of the steering-oar a cardinal limiting factor to nautical development existed before the beginning of the +13th century.\(^d\) Until that turning-point the capacity of ships was restricted to about 50 tons.\(^d\) Lack of maneuvrability also kept them slow, and the fact that in heavy weather any kind of steering-oar would inevitably take charge, interfering with the handling of the sails, meant that ships were constrained to keep within reach of shelter and could not venture to any extent on ocean passages. The chief critic of des Noëttes, la Roerie\(^e\) (1, 2), maintained that the stern-post rudder had little or no advantage over the steering-oar, but the consensus of qualified nautical opinion crystallised almost unanimously against him,\(^f\) though des Noëttes, who was admittedly a landsman, often failed to receive the credit which he deserved.\(^g\)

The steering-oar, however, has always remained of value in rapid rivers and narrow landlocked waters, hence its continued use in China today. To respond to the rudder, a boat must have way on her, must, in other words, be moving relatively to the surrounding water, for otherwise there is no streamline flow to be diverted. But when

\(^{a}\) These are the traditional names for the components of the rudder's hinge; cf. p. 632 below.
\(^{b}\) E. B. Brooks, cit. in la Roerie (2).
\(^{c}\) Cf. Fevre (3).
\(^{d}\) See especially des Noëttes (3), pp. 48, 58, 69, (4). This remains as a staked claim, though the figure must certainly be too small (cf. p. 452 above), and there are some demands extreme in the other direction, notably the thousand-ton Roman grain-ships of the +1 century and visualised by Casson (1). Perhaps the most urgent need of naval archaeology today is a systematic, sober and definitive study of estimated tonnages in all historical periods and cultures. Obviously this work cannot be done here.
\(^{e}\) E. g. Poujade (1); Smyth (1); Gilliland (1); Anderson & Anderson (1); de Lutre & Haffner (1), pp. 11, 17, 49. Among la Roerie's supporters Carlini (1) was the most prominent. As Adam & Denoix point out (1), it was rather quixotic to defend the theoretical value of the steering-oar, since in historical fact it was supplanted by the stern-post rudder quite quickly, and this could not have been without good cause. They show by simple calculations, however, that the force required to manage the steering-oar (other things being equal) is considerably less for a steering-oar, with its smaller surface, than for a stern-post rudder. But though more flexibly attached, the former was much more fragile, needed much greater skill on the part of the helmsman, and was limited to relatively small vessels.\(^f\)

\(^{f}\) This may be a convenient point to warn readers that both des Noëttes (1) and \(\ldots\) de Lutre & Haffner (with less excuse) are quite untrustworthy guides in matters of East Asian nautical technology. Des Noëttes was wrong on almost all points; he believed (a) that there were no rudders in China before the coming of the Portuguese, taking at face value an imaginary sketch in van Linschoten, (b) that Chinese iron-working was rudimentary, (c) that Chinese ships made only coasting voyages, and (d) that junk could sail only before the wind. De Lutre & Haffner are even worse (though twenty years later); they said (a) that the magnetic compass had been used by the Chinese in \(-1246\), (b) that in \(-1358\) the eunuch 'Chien-Ho' made voyages and touched at California, (c) that the Chinese junk can only run before the wind, (d) that when the Portuguese arrived the Chinese had only steering-oars, often (e) that junk lazaretts had bottoms so flat that they drifted to leeward, making little headway, (f) that their sails have multiple bowlines (instead of sheets), (g) that northern junks have triangular sails and southern ones rectangular; finally (h) that the Chinese 're-invented', and used, the astrolabe. A more remarkable collection of howlers could hardly be imagined. Yet their book is sound and usable where Europe is concerned.

\(^{g}\) This is what vitiated the argument of des Noëttes (a), p. 43; he assumed that with a steering-oar the shorter arm of the lever was necessarily inboard. But Chinese stern-sweeps are often as long inboard as they are outboard, or nearly so; many examples are illustrated in Worcester (1, 2, 3), some as long overall as 100 ft. Nevertheless des Noëttes was basically right in his dictum that the steering-oar has always been essentially on the human scale, while the axial rudder can be on the scale of the ship, however large.

\(^{h}\) A recent invention accomplishes this by mounting a small auxiliary screw on the blade of a steel balanced rudder (cf. p. 655 below); it is called the 'active rudder'.

another, and from that to a third; if the Pilot, by an address not sufficiently to be admired, does not escape from shipwreck that threatens him every moment.

There are none in all the world besides the Chinese capable of undertaking such like voyages, or so much engaged therein, as not to be discourag'd, and lose all the happiness that befall them, for there passes not a day that is not memorable for shipwrecks; nay, and I wonder all barks do not perish. Sometimes a man is so fortunate as to split in a place not far distant from the shore, as I once found, and then indeed only escapes by swimming, provided one has strength enough to struggle out of the torrent, which is usually very strait. Other times the bark runs aground, and in a moment is upon the rocks, where it remains aground with the passengers; but sometimes it happens, especially in some more rapid torrents, that the vessel is in pieces, and the crew buried, before one has time to know where they are. Sometimes also when one descends the cascade form'd by the river, that altogether runs headlong, the boats by falling all on a sudden, plunge into the water at the prow, without being able to rise again, and disappear in a trice. In a word, these voyages are so dangerous, that in more than twelve thousand leagues that I have sail'd upon the most tempestuous seas in the world, I don't believe I ever ran through so many dangers for ten years, as I have done in ten days upon these torrents.

The barks they make use of are built of a very thin light timber, which makes it more fit to follow all the impressions one had a mind to give them. They divide them into five or six apartments separated by good partitions, so that when they touch at any place, upon any point of a rock, only one part of the boat is full, whilst the other remains dry, and affords time to take up the hole the water has made.

For to moderate the rapidity of the motion, in places where the water is not too deep, six seamen, three on each side, hold a long spriet or pole thrust to the bottom, whereby they resist the current, yet slackening by little and little, by the help of a small rope made fast at one end to the boat, and twin'd at the other round the pole, that slips but very hardly, and by a continual rubbing, slackens the motion of the bark, which, without this caution, would be driven with too much rapidity; insomuch that when the current is even, and uniform, how precipitous soever its course be, you float with the same swiftness, as one does upon the calmest canal; but when it winds in and out, this caution is to no purpose; then indeed they have recourse to a double rudder, made in fashion of an oar, of forty or fifty foot long, one whereof is at the prow, and the other at the poop. In the plying of these two great oars consists all the skill of the sailors, and safety of the bark; the reciprocal jerks and cunning shakes they give it, to drive it on, or to turn it right as they would have it, to fall just into the stream of the water, to shun one rock, without daring another, to cut a current, or pursue the fall of water, without running headlong with it, whirls it about a thousand different ways—It is not a navigation, it is a manege; for there is never a manege'd horse that labours with more fury under the hand of a master of an academy, than these boats do in the hands of these Chinese sailors.

What exactly Chao Yen-Wei was trying to describe here turned largely on his mention of the 'hole' at the stern. Although it is true that numerous pictures of Roman ships show steering-oars coming out through ports in the hull, such an arrangement occurs on no extant type of Chinese boat or ship, nor have we found references to it either


See the illustrations in Daremberg & Saglio referred to below, p. 631 ff.; as also Carlini (1), p. 31.

La Roerie was very sceptical about these ports, however—artist's mistakes, he thought them, for the oft opening of the parados, (2), p. 39 ff.

* See immediately below, p. 631 ff.; as also Carlini (1), p. 31.

W b E. g. Worcester (3), p. 44. and when the captain shouts 'Chhiang-kao! all the punt-poles are immediately (taken) out of the water, while one man hurriedly manipulates a large projecting cudgel-like timber (thang) at the stern. Otherwise they are afraid that the boat will sink (if it strikes a rock)... Between Chhing-thien and Wansen the water rushes around the rocks, so the boat has to be maneuvred in a curving snake-like course; otherwise it will be dashed to pieces and everybody drowned. So the local people have a proverb, saying: 'a boat may be made of paper as long as it has an iron helmsman (thic hsho hshung)'.

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Water-tight compartments; cf. p. 420 above.

The bow-sweep is not uncommon on certain types of river-junk. Examples: Worcester (1), pp. 44, 45, (a), 50, (a), vol. 2, p. 474; Audemard (3), p. 67. Its use is mentioned in a poem by Wang Chou about +540 and one sees it in the Chih-hsing Ming Shang Ho Thu. Moreover the principle was extended in traditional Chinese shipbuilding to rudders, with one at bow and one at stern is figured in LCCC, ch. 2, p. 38a. Possibly this was a paddle-wheel ship, for we have already seen an early nineteenth-century Chinese double-ruddered design of just this kind in Fig. 538 (Vol. 4, pt. 2). Nor is the principle obsolete, for modern special-purpose steamships are not infrequently equipped with bow-rudders conforming to their lines. Cf. Fig. 93a (pl.).
pictorial or literary. Openings for oars or punt-poles would be very improbable in this context. Thus the most likely interpretation would be that the river-boats on which Chao Yen-Wei travelled had axial rudders, as in Li Sung’s painting, and that his ‘projecting cudgel-like timber’ was either the tiller or the rudder-post itself.

The limitations of the steering-oar or stern-sweep became particularly severe at sea, or upon great lakes where rough weather was likely to be met with. A ship of any size required a very considerable spar for this duty, and all the worse the consequences would be when it broke under the impact of heavy seas. Other disadvantages attended upon the attachment of a short but heavy paddle to the aft starboard quarter: it made an inconvenient projection liable to foul other ships or come into collision with quays, and that this was felt is shown by the fact that the Roman vessels were characteristically built with a kind of streamlined shield, an after extension of the parados, to protect the quarter-paddle. The chief value of the quarter-paddle lay in its balanced character, a fiat blade existing on both sides of the axis and not on one side only (cf. p. 653 below), but the universal adoption of the stern-post rudder in the late Middle Ages shows how the weight of advantage lay, and in China, as we shall see, the developed axial rudder retained a balanced form.

Before going further we must pause for a moment to consider what is known of the way in which rudders were attached to Chinese and European ships, and how this is still done in shipbuilding of the traditional kind. In Western antiquity steering-oars and quarter-paddles were slung in various forms of tackle, probably in China also, for China remains the realm of the slung sliding rudder par excellence, and indeed there is no evidence that any Chinese rudders were ever attached by eyes or gudgeons so as to hinge with pintles on the hull. In Western ships and boats the pintle was always erect, standing parallel with the stern-post and pointing upwards if attached thereto, downwards if attached to the rudder itself. Such hooks and eyes were foreign to Chinese usage. Throughout the ages their rudders have been held to the hull by bousing-to tackle which holds it to the ship by bousing-to tackle which holds it by wooden jaws or sockets, and, if large, suspended from above by a tackle pulling on the shoulder so that they can be raised or lowered in the water (cf. Figs. 1026, 1027, pl.).

Sometimes the foot of the largest type of rudder is even connected with the fore-part of the ship by housing-to tackle which holds it in place. The gudgeon-like fittings to which reference has been made may be for this purpose rather than for weighing the anchor, as we naturally tend to assume. If the bearings, as it were, for the main rudder post can be open, half-open, or occasionally altogether closed by outer pieces of shaped timber (cf. Fig. 1028). Thus they have corresponded to the braces (eyes, gudgeons) of occidental ships, though what turned in them was not the pintle but the rudder-post itself, suitable apertures being present in the blade, when necessary, to allow of the helm being put hard over without interference from the socket. The system of open jaws was what permitted the rudder to be raised and lowered.

Though cable and wood thus took the place of iron hinges, it should not be thought that iron was absent from rudders in traditional China, for in fact the larger ones, weighing many tons, were, and are, heavily bound with iron straps and other strengthenings. The Chinese rudder was by no means necessarily located at the aftermost point of the hull or upperworks, but sometimes considerably forward of this, its post construction being facilitated by the transom-and-bulkhead anatomy so typical of the Chinese junk, and we shall see in the denouement how closely the whole conception of the vertical steering mechanism was connected with this. The essential point is that

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*a* See Worcester (3), vol. 1, pp. 106 ff.

*b* The reader will remember the recent recovery of one of the Ming Treasure-ships’ rudder-posts, over 36 ft. in length, by Chou Shih-Tê (1); cf. p. 481 above.

*c* The archetype can be grasped immediately by a glance at Fig. 1028, a drawing by Lovegrove (1) of the manner of attachment of the rudder on a Cantonese Kwailam junk. A similar arrangement is seen in
end that the Rudder, which they shut up as in a Chamber, may be defended on the Sides from the Waves: this Rudder, much longer than ours, is strongly ty'd to the Stern-post by two Cables that pass under the whole length of the Vessel to the fore-part, and two other suchlike Cables hold it up, and facilitate the hoisting or lowering, or as occasion serves. The Bar (i.e. the tiller) is as long as is necessary for the guiding it; the Scamens at the Helm are assisted by Ropes fastened to the Larboard and Starboard, and roll'd upon the extremity of the Bar they hold in their Hand, which they fasten or slacken as they see occasion, to thrust or stop the Helm.

Lecomte thus aids us by showing that some mechanical assistance or advantage was applied to the tiller in large junks in his time.

(2) From Steering-oar to Stern-post Rudder in the West

Jal (1) was the first to notice that the stern-post or axial rudder began to appear in Europe early in the +13th century. All subsequent investigations have established that before that time there was no trace of it in the West." Ancient Egyptian boats are generally shown with steering-paddles at the stern, sometimes as many as five a side, each worked by one man. Or there may be two quarter-paddles connected together by a framework and bar (like that on the Ajanta ship later). The stern-sweep was also known in ancient Egypt; it was fixed to the end of the high stern, supported by a post at its forward end and furnished with a 'tiller' by which it could be rotated by the helmsmen. This blade is firmly fastened to the stern-post or axial rudder; the tiller or steering-oars on each quarter appear also on the double-decked Phoenician or Greek ships of the 7th century shown in the famous Sennacherib reliefs. Single steering-oars are found in Etruscan tomb-paintings and Greek vases, though Greek ships generally had one on each side. Steering-oars were also universal on Roman and Hellenistic ships, sometimes single, sometimes double

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a Here of course he went astray—there was none.
b The point is of some importance, cf. p. 651.
c See on p. 637.
d Moll (1); des Noettes (2), figs. 13, 14. This last is the reconstruction by von Bissing & Borchardt of the 60 ft. wooden ship of the sun-god Ra, built by the 5th-dynasty Memphis kings (Boreux (1), p. 104).

des Noettes (2), figs. 130, 131, Wilkinson (1), vol. 2, p. 144, figs. 400, 401, p. 158, fig. 482; Hornell (1), p. 219; Reinsen (2), no. 4.610, pl. XXIII; Boreux (1), pp. 273, 300. Model paddles exist. Steering-gear of exactly this type is still to be found on some Indian boats, such as those of the Ganges depicted by Creslock (Figs. 1200, pl. 3). It may also be seen in a Gallo-Roman tomb-carving (Bonard (1), fig. 5, opp. p. 146). Adam & Denoix (1), p. 96, suggest that all these steering-paddles could be disengaged from the framework and used as free sweeps when the ship was almost without way on her.

des Noettes (2), figs. 23, 34; Darenberg & Saglio, fig. 3665; Adam & Denoix (1), p. 101.

des Noettes (2), fig. 29; Bartocciini (1), pl. v; Moretti (1); Bloch (2), pl. 48; Lawrence (1), opp. p. 68.

des Noettes (2), figs. 884, 885, 5271.

des Noettes (2), figs. 32, 34; Darenberg & Saglio, fig. 3665; Adam & Denoix (1), p. 101.

des Noettes (2), figs. 23, 24; Darenberg & Saglio, fig. 3665; Adam & Denoix (1), p. 101.

des Noettes (2), figs. 884, 885, 5271.

des Noettes (2), figs. 33, 54, 55; Poujade (1), p. 133; Darenberg & Saglio, figs. 884, 885, 5271, 5874, 1872, 5874, 5900, 5004.
and united by a bar.\textsuperscript{a} Evidence exists that they now began to be slung permanently in position on the quarter by tackle, and the streamlined shield was introduced.\textsuperscript{b} Nothing new was developed by the Byzantine culture, but the Viking long-ships, beginning with the steering-oar, went on to attach it to a pivot,\textsuperscript{c} and ended by converting the paddle to a rudder-shaped form and hinging it on the side of the boat.\textsuperscript{d} Some of these quarter-rudders were also slung.\textsuperscript{e} Norman ships continued the same methods, but the steering-oars on the Bayeux tapestry of c. +1080 are still very primitive in type.\textsuperscript{f} Indeed this remained the case until the end of the +12th century,\textsuperscript{g} and even long afterwards artists and sculptors continued to represent steering-oars instead of rudders,\textsuperscript{h} although the latter were becoming universal.\textsuperscript{i} During this period steering-oars and rudders sometimes co-existed on the same vessel, each being found useful for different purposes.\textsuperscript{j}

The oldest European MS. illustration of a stern-post rudder, with tiller, is in a Latin commentary on the Apocalypse preserved at Breslau, of +1242, as des Noettes (2) recognised.\textsuperscript{k} But Brindley (5) had already pushed the date of introduction somewhat further back by finding a notable iron-bound rudder on the ship depicted in the seal of Ipswich, which came into use in the close neighbourhood of +1200.\textsuperscript{l} A number of other seals of the +13th century (e.g. Elbing, +1242; Wismar, +1256; Snubbihoep-

\footnotesize
\textsuperscript{a} Des Noettes (2), fig. 58.
\textsuperscript{b} Des Noettes (2), fig. 56; Moll (1); la Roerie (1, 2); Darenberg & Saglio, figs. 5289, 5291, 5293, 5294. Seymour (2) figures an ex-voto bronze of +1238 which seems to have been about the size of the ship depicted.\textsuperscript{m}
\textsuperscript{c} As on the Oseberg ship of about +900, see Mercer (3), p. 251; des Noettes (2), fig. 64; Gille (1).
\textsuperscript{d} As on the Rebeck ship; Salver (2).
\textsuperscript{e} On the Nydam and Gokstad ships' steering arrangements see la Roerie (2); la Roerie & Viviale (1), vol. 1, p. 177; Gille (8).
\textsuperscript{f} Des Noettes (2), fig. 65.
\textsuperscript{g} For example, a 14th-century French MS. (des Noettes (2), fig. 65), and a +12th-century Venetian one (fig. 66).
\textsuperscript{h} Seal of Dover, late +13th (des Noettes (2), fig. 67), and Lat. MS., Bib. Nat. no. 8,846 (fig. 68); for the +14th, figs. 69 and 71; for the +15th, fig. 71A.
\textsuperscript{i} At sea, that is to say. Stern-sweeps have persisted on some European river-ships until the present day, notably the interesting barca rabillo of the Douro (cf. Figueraiz, 1), with its high and very 'Chinese' sternman's bridge. Another curious survival of steering-oars to our own day exists in those of the boats used for the traditional water-jousts at Lyons. Cf. Boreux (1), p. 206.
\textsuperscript{j} The steering-oar or stern-sweep can help not only in harbour and estuary manceuvres when the ship had hardly any way on her, but also as a sea if all way is lost on tacking (cf. la Roerie (1), p. 379; Carlini (1), p. 7). Adam & Denoez mention three +13th-century illustrations of ships clearly showing steering-oars as well as rudders; two of these are reproduced in la Roerie (4), figs. 18, 19. The combination, though not very common, has long been known in Chinese practice; la Roerie (2), fig. 20, figured a Thibau fishing-boat using two steering-oars (though equipped with rudder) while attending to nets. Adam & Denoez maintain that the disappearance of the steering-oar was brought about not by the rudder itself, but by the whip-staff and the wheel, which applied mechanical advantage to the control of it. In spite of the illustrations just mentioned, this thesis is at variance with the facts. By about +1500 steering-oars had quite gone out, but the whip-staff did not come in until about +1600, and the wheel not till the neighbourhood of +1700.

\textsuperscript{m} His fig. 75; also reproduced in Alwin Schulte (1), vol. 2, p. 335 (fig. 149), who did not point out its importance. The MS. is Alexander Monasticus Apostolicus Exemplar; it has not been able to trace further details about it; for the matter in Portus or Chevalier. About the same date is the rudder of the ship in one of the stained-glass window medallions in the Lady Chapel of the cathedral at Le Mans.
\textsuperscript{n} See also Hope (1), vol. 2, p. 337. This is just about the time the wheel was first thought of and even carved, according to Lynn White (1), p. 61, the font reliefs mentioned on the opposite page. The hardness of the stone is thought by some to have imposed a ruder, more archaic, style than was by then usual.
\textsuperscript{o} The date +1309 is also that of the earliest mention of the stern-post rudder in the Mediterranean (the Chronicle of Villani; la Roerie, 2). The first use of the word rudder in English is +1530.
\textsuperscript{p} Some of these reliefs seem to show a double rudder, i.e. two rudders placed very far aft on each quarter, or so Brindley thought; but others (e.g. Anderson and la Roerie) do not agree with this view, attributing the effect to imperfections in the dies. Cf. des Noettes (3), figs. 73, 74, 76, 78. Quarter rudders have been re-invented for some Rhône barges (Benoit, 2).
\textsuperscript{q} Descriptions by Swann (1); Eden (1). The story which the Winchester font illustrates is that in the Legenda Aurea, vol. 2, p. 129. Cf. Brindley (3); Anderson & Anderson (1); la Roerie & Viviale (1), vol. 1, p. 193. Some experts still decline to accept the Winchester carving as showing anything more than a quarter-rudder (e.g. Clowes (2), p. 48).
\textsuperscript{r} On terminology see the curious studies of Drapella (1).
\textsuperscript{s} La Roerie (4); Clowes (2), p. 79; Haldin & Weber (1).
\textsuperscript{t} Des Noettes (2), figs. 73, 80. Cf. Anderson & Anderson (1). This was slung. Variable depth rudders lasted on very late on the Rhône at Arles (Benoit, 2).
\textsuperscript{u} Chatterton (1); Anderson & Anderson (1), p. 164; GiIfillan (1), p. 70.
\textsuperscript{v} All attempts to find evidence of it earlier have proved unconvincing (cf. Febvre, 4). Nordmann (1) and Laurand (1) discussed a passage in Lucian which turned out to refer to the double steering-oar connected by a bar. Nothing else emerged from the studies of de St Denis (1) on the vocabulary of ancient Mediterranean sailors. Verwey (1) described earthenware models of boats dug out of a post box amongst +16th-century Saxon pottery; these had an unusual vertical stern-post with a hole in it. But modern archaeologists who discovered the find did not believe that it provided evidence of a stern-post rudder.
\textsuperscript{w} E.g. Smyth (1), p. 373; GiIfillan (1); la Roerie (2); Elliott-Smith (2); Landstrom (1), pp. 218 ff.
\textsuperscript{x} Commenting on Verwey (6). The explanation is on p. 642 below.
\textsuperscript{y} See Sects. 61 in Vol. 4, pt. 1, and on 'transmission clusters', Vol. 4, pt. 3, pp. 544, 584.
alone might arouse one's suspicion that the stern-post rudder was not an auto-
chthonous development either, but made its appearance as the result of long travel
from somewhere else.

(3) China and the Axial Rudder

The problem of the history of the rudder in China presents us with a classical case of the
difficulty which arises when there is reason to believe that one single word has done
duty through the centuries for two or more devices technologically quite distinct. The
word *tho* (or *to*) is certainly meant 'steering-ear' or 'steering-paddle' in the 3rd
century; equally certainly it meant the axial 'stern-post' rudder in the 13th. Since, as
we have just seen, the first appearance of the latter in Europe antedates +1200 by
very little, any investigation of a possible Chinese contribution cannot rely upon names
(d) alone. After that, the word *tho* is employed. The writer says:8 "If the will is there,
people are capable of destroying a boat to make a tho; or melting down a big bell to make a
little one.' After that, the word *tho* takes its place,8 as in the following examples:

Chhien Han Shu,8 referring to -107:

'Han Wu Ti had his boats (chu-la) floating on the water for a thousand li.'

Commentator Li Phei6 of the San Kuo period, +3rd century, says: "The chu is the
after part of the boat where the tho is held (chih); the tho is the forward part of the
boat where the ears (cho) are shipped (tahu)."

Yen T'ien Lun (Discourses on Salt and Iron),2 c. -80, by Huan Khuan:

"The promotion of mediocrities to positions of great responsibility is like setting out to
cross rivers or sea without oars or steering-gear (jw u chieh chu chi chieh hai)l, only to be,
carried away by the first storm encountered, and sunk in the heavy seas full hundred fathom
depth, or blown eastward into the shoreless Ocean.'

(i) Textual evidence

The simplest procedure is to group the relevant texts into separate classes. Let us deal
first, (a) with early mentions, probably mostly referring to the steering-ear, then (b)
consider what verb is used in connection with the tho, (c) what its shape and length,
(d) how it is said to be fixed, and (e) of what material it is made.

One of the oldest references must be in the Huai Nan T'ao, about -120, and
here the archaic word *to* is employed. The writer says:9 'If the will is there, people
are capable of destroying a boat to make a tho; or melting down a big bell to make a little
one.' After that, the word *tho* takes its place,8 as in the following examples:

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9 Ch. 17, p. 115, tr. suct. The reference to the bell is perhaps to be explained by an incident already
related (Vol. 4, pt. 1, pp. 170, 204).
8 Or, still more vaguely, *chu*.
6 Ch. 6, p. 439; cit. TPYL, ch. 768, p. 54a; Tzu Shih Ching Hua, ch. 156, p. 124; cf. Dubs (a), vol. 2,
P. 95.
2 Ch. 21, p. 74, tr. Gale, Boodberg & Lin (1).
1 This last remark is of particular interest in view of the early Chinese explorations of the Pacific
discussed elsewhere, pp. 551 ff.
differing only in radical. The scent grows warm, for here is something 'turning' like an axle at the stern. But the force of this is still insufficient to distinguish between the steering-oar or stern-sweep pivoted on bhumik or rowlock and the rudder held in bearers like those of a rotating shaft or axle. In other words (the language of machinery) we still do not know whether 'point-closure' or 'line-closure' was meant.\footnote{d}

We can perhaps make headway a little further by studying the verbs used to describe the pivoting motion. The word \textit{chuan},\footnote{d} for instance, has the nuance of something swinging round an axis rather than of something pivoting on a single point. And we meet with this already in the +3rd century, in a story about Sun Chhiian,\footnote{Sun Chhiian, when at Wu-chhang, took out a large newly built ship called the 'Chhang-An' on trials at Tiao-thai. There came a strong wind, and Ku Li\footnote{Ku Li} asked the helmsman to steer (the ship) to Fan-khou. But Sun Chhiian said that they ought to go to Lochow. (Ku) Li then drew his dagger and faced the helmsman, saying that if he did not make Fan-khou he would be beheaded. So he immediately turned the helm (\textit{chua ng tho});\footnote{Whatever it was}, and sailed into Fan-khou.}

At any rate, this verb came naturally to a late +13th-century poet, Yü Po-Seng,\footnote{Yü Po-Seng, who used exactly the same expression for what was by then (+1297) undoubtedly an axial bearing or journal at the ends of shafts, often taking the form of spikes rotating in sockets?} who used it naturally in a late +13th-century poem in the +13th century, it cannot be earlier than the Thang, and does not seem to be later than the end of the +9th. In speaking of the proper depth for tombs, which should be neither too deep nor too shallow, the writer says:\footnote{If the hairpin is shorter than it ought to be, its ornamented end will not reach the base of the hair. If the key is shorter than it ought to be, the lock of the box cannot be secured. If the \textit{tho} goes deeper than it ought to, then the end of the boat will not carry its cargo (because it will go aground or strike a rock).}

This gives practical certainty, for the typical Chinese rudder has always been slung adjustedly so that it can hang down well below the level of the ship's bottom, and aid in preventing leeward drift.\footnote{The control of a ship carrying ten thousand bushels of freight is assured by means of a piece of wood no longer than one fathom (\textit{hsian}).} Moreover, in the following century, we have a remark by Than Chhiian\footnote{Than Chhiian, in the \textit{Hua Shu}\footnote{The semantic range of this phonetic (cf. K 1039) is wide, and we do not know the meaning of its archaic graph, but unless some transcription took place, it appears in \textit{chuan}\footnote{This word-component could have been borrowed by the artisans for the bearings or journals at the ends of shafts, often taking the form of spikes rotating in sockets?} as the drawing of a spiked hat or helmet. Is it possible that this word-component could have been borrowed by the artisans for the} in the \textit{Hua Shu}\footnote{The length (8 ft. in Chinese measurement, here just under 8 ft. 2 in. in ours) is clearly much too short for a steering-oar or stern-sweep (often over 50 ft. on comparatively small river boats), but agrees well with an axial rudder.}

The most decisive passage, however, occurs in the \textit{Hiu-an Ho Feng Shih Kao-Lu Thu Ching}\footnote{Illustrated Record of an Embassy to Korea in the Hsian-Ho reign-period, written by Haü Ching\footnote{about the mission of +1124. This must be the text which Han Nouchua had heard of somewhere. It is full of references to Rudders, often to mishaps when they broke,\footnote{or to changing them, but the main sentences are these.} or to changing them, but the main sentences are these:}\footnote{See Vol. 4, pp. 108; Ch. 39, pp. 34, 48.} (Illustrated Record of an Embassy to Korea in the Hsian-Ho reign-period, written by Haü Ching\footnote{about the mission of +1124. This must be the text which Han Nouchua had heard of somewhere. It is full of references to Rudders, often to mishaps when they broke,\footnote{or to changing them, but the main sentences are these:} or to changing them, but the main sentences are these:} about the mission of +1124. This must be the text which Han Nouchua had heard of somewhere. It is full of references to Rudders, often to mishaps when they broke, or to changing them, but the main sentences are these:\footnote{Besides, the Chinese steering-oar or stern-sweep offers only a trailing resistance which would be raised by any submerged object and could not catch on it.}}
At the stern, there is the rudder (ch'eng tho'), of which there are two kinds, the larger and the smaller. According to the differences in the depth of the water, the larger is exchanged for the smaller, or vice versa. Aft amidships, the deckhouse (ch'iao) two oars (cho') are struck down into the water from above, and these are called 'Third-Assistant Rudders' (san fu tho'). They are only used when the ship begins to sail in the ocean.

These passages leave no doubt in the mind that by the beginning of the +12th century, and on Chinese ships, several sizes of axial rudders were carried and used under different conditions, while at the same time steering-oars may have been retained for special purposes. This was sometimes done long afterwards on European vessels, and there are Persian drawings of the +15th century which show ships with two steering-oars as well as a quarter-rudder.

Korean craft of the early +12th century also had axial rudders, for Hsu Ching, describing the coastguard patrol boats (kiin chhuan) which came out to welcome the ambassador's flotilla, says that they were one-masted, with no deckhouse, and that 'they have only a (sculling) oar (la) and a rudder (cho') at the stern.' If the latter had not been something different from an oar, he would hardly have mentioned the axial rudder. This suggests that these 'oars' were really leeboards (cf. p. 618). It is unlikely that additional steering-oars (though sometimes carried as well as rudders, cf. p. 654) would have been used 'in the ocean'. The assistance was in this case against leeward drift.

The ships of the ambassadors were certainly Chinese, and we are told that the Koreans were somewhat surprised at their size. Cf. p. 453 above.

There is nothing in the text which proves that the rudders were axial ones rather than quarter-rudders, but to assume the latter would be gratuitous since no trace of them in China exists, either in what surprised at their size. Cf. p. 463 above.

According to the differences in the depth of the water, the larger axial rudders as well as a quarter-rudder. This was sometimes done long afterwards on European vessels, and on Chinese ships, several sizes of axial rudders were carried and used under different conditions, while at the same time steering-oars may have been retained for special purposes.

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Polo, who is quite specific in what he says (see p. 467 above), but as he wrote a century after the European dateline, it is not relevant to our argument here. We must turn to the remaining types of evidence, how the steering device was fixed and of what material it was made.

The Yü Phin^ (Jade Page Dictionary) of Ku Yeh-Wang,^ compiled in the middle of the + 6th century (about + 543), says of the tha that it is ‘a piece of timber for regulating (the direction of) a ship. It is set (héng) at the stern’. While many of the earlier references mentioned above, as well as others, refer to the stern, the verb used here implies something very permanently established there, more so, perhaps, than would be warranted by the lashings of a steering-oar. However, this is only a hint. The Thang Yü Lin (Miscellanea of the Thang Dynasty) has to be taken more seriously, for referring to about + 750 it speaks of the tho-lou (‘rudder-tower’), i.e. the stern gallery or extension of the poop.^ This is the term always later used for the projecting after-castle in or on which the helmsman stood (and still stands) to work the tiller (tha-kang), and which also contains the winches or other arrangements by which the rudder is raised and lowered (cf. Fig. 1026 above). So far as we know, this is the first appearance of the expression. Its significance cannot well be overlooked, for with steering-oars there is no necessity for a tho-lou, indeed it would be in the way, and among all the hundreds of existing types of Chinese boats and ships there is no instance of a tho-lou co-existing with stern-sweep or steering-oars. These elongated instruments, where present, run some distance forward over the after part of the deck to a kind of light bridge on which the helmsman stands. This, therefore, constitutes strong evidence for axial rudders as early as the + 6th century.

It is tolerably sure that Chinese rudders were never attached to the stern with pintles and gudgeons of iron. But that they were early strengthened with that metal is certain enough. It may be worth quoting a couple of passages from Chou Mi’s Kuei-Hsin Tea Chih (Miscellaneous Information from Kuei-Hsin Street), written about the last decade of the + 11th century. In one place he relates that Li Sheng-Po^- used to say: ‘I always followed (the seamen of) old Chang Wan-Hu when sailing in the sea. Between Chang-chia-ping and Yen-chéng there are eighteen sand-banks. If a sea-going junk should go aground, the cargo of grain must be thrown overboard to lighten her. If the ship still cannot be moved, rafts of timber should be prepared to save the lives (of the crew), for she will go to pieces and give no protection. The (best) wood at the bottom of the rudder (tha shao) is called the “iron corner” (tieh lén). Sometimes the wood called tsu-lan-mu from Chinchow is used. One measure of this costs 500 (ounces of) silver.\(^{14}\)

\(^{a}\) Still, it is interesting to hear him on the raising and lowering of the rudder. His Chinese fleet being somewhere in the East Indies, he says: ‘And in the middle of this land about forty miles, there is but four passes of water, therefore the great Shipspe do take off (take up) their Rudder. . .’ (Penzer ed. p. 193).
\(^{b}\) Ch. 12, p. 170, cit. in Khong-Hsi Tea Tien, art. tha.\(^{19}\)
\(^{c}\) Ch. 8, p. 448, cf. p. 443 above. Master-helmman (the shih)\(^{30}\) above are mentioned in the Thang Waterways Department Ordinances of + 737 (cf. Twickelh (2), p. 55).
\(^{d}\) Hsi Chi, ch. 1, p. 366, tr. acct. On the grain transport service by the sea-route, cf. p. 478 above.

\(^{14}\) Still, of course, some notion of ‘steering’ is implied.

There remains the question of the material of which the tha was made. The use of special wood seems to go far back in history. In the San Fu Huang Thu (Description of the Three Cities of the Metropolitan Area), which is probably of the late + 3rd century, there is the following story.\(^{2}\)

Someone presented a small sampan (tou tshao)\(^{6}\) to the emperor, but he said, ‘Cinnamon wood for oars, pine for hulls, make a boat heavy enough; how could one sail in this? And he ordered that catalpa wood should be used for the boat’s hull, and magnolia wood for the tha. At the other end of history, we may remember the details given by Sung Ying-Hsing fourteen centuries after iron-wood for rudders (p. 416 above). Intermediate in date is an interesting description in the Ling Wai Tai Tu of Chou Chhi-Fei (+ 1178) of special South Chinese woods much sought after for rudders. He says: \(^{5}\)

The Chinchow coastal mountains\(^{7}\) have strange woods, of which there are two particularly kinds. One is the tsu-ching-mu (purple thorn tree)\(^{7}\) as hard as iron and stone, as fine as coral and straight-grained; as large in girth as two men’s reach, and when used for roof beams will last for centuries. The other kind is the tsu-lan-mu\(^{8}\) it is used for the rudders (tha)\(^{9}\) of large ships, for which it is the finest thing in the world. Foreign ships (fan po)\(^{10}\) are as big as a large house. They sail the southern seas for several tens of thousands of li, and tens or hundreds of thousands of lives depend upon one rudder. Other varieties of (timber for) rudders are as not more than 30 ft. in length, and are good enough for junkaus with a capacity of 10,000 bushels, but these foreign ships carry several times this amount, and might break in two if they encountered storms on the deep sea.\(^{11}\) But this Chinchow timber is dense and tough, comes go 50 ft. lengths\(^{12}\) and is not affected by the anger of the winds and waves. It is as .

\(^{3}\) Ch. 4, tr. auct. Cf. p. 414 above.
\(^{4}\) Ch. 6, p. 496, tr. auct. Adjunct. Hirth & Rockhill (1), p. 34.
\(^{5}\) In the farthest west corner of Kuangtung.
\(^{7}\) Hirth & Rockhill confused the passage by translating tha throughout as ‘logs’ or ‘timbers’. One thing at least cannot be doubted, namely that we have to do here with special timber for steering-gear.
\(^{8}\) Just over 350 tons would not ‘several times’ imply some 1,500 tons? Cf. pp. 330 and 304. The ambassador’s ship in + 1124 could carry about 70 tons of grain, but she was primarily a passenger vessel.
\(^{9}\) Probably the lengths in which the timber came to the shipwrights, not those of the finished tha.
\(^{10}\) Naut. 29. 
\(^{11}\) Naut.
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if one could use a single silk thread to hoist a thousand chin⁴ or sustain the weight of a mountain landslide—this (wood) is truly a treasure for those who ride the stormy seas.

A couple of these (logs) for rudders at Chinhchow are worth only a few hundred strings of cash. But at Canton and Chinhchow they are worth ten times as much, for only one or two tenths of the supply of this timber is sent there, its length making transport by sea difficult.

This 'wu-lan-mu' wood⁵ was probably the same as the iron-wood used in later times, but the passage is rather ambiguous about the kind of tho for which it was destined. Ch’ou Chhö-Fëi has just told us, in a passage already quoted,⁶ that the ships which sail south of the Southern Sea, 'like great clouds in the sky when their sails are spread', have tho several tens of feet long. It was unfortunate that he expressed himself just in this way, for if he meant 20 or 30 ft, the length would not be at all excessive for a true axial rudder of substantial size with the rudder-post included (cf. p. 481 above), but if he meant 70 or 80 ft, longer even than the lengths of wood from Chinhchow and elsewhere, he could only have been referring to a great stern-sweep.

The foregoing argument, based solely on the words of ancient and medieval writers, was first sketched out in 1948. It has to be completed by the evidence by pictorial representations which have survived, and finally by the archaeological evidence. The former, though of great interest, proved incapable of taking us much further than the latter, just a decade later, turned out to be quite decisive, settling the matter in a way more radical than anyone had anticipated. It has shown that the other lines of argument were fully justified, and has proved what they could only surmise.

Let us proceed in the same way as before, starting with the earliest times and coming forwards. We may then also work backwards from the most reliable Chinese pictures of ships which date from times later than the European appearance of the stern-post rudder. In this way we shall be focusing, as it were in a microscope, both from below and from above. The epigraphic counterparts of the Han and Chou (wood) is truly a treasure for those who ride the stormy seas. The foregoing argument, based solely on the words of ancient and medieval writers, was first sketched out in 1948. It has to be completed by the evidence by pictorial representations which have survived, and finally by the archaeological evidence. The former, though of great interest, proved incapable of taking us much further than the latter, just a decade later, turned out to be quite decisive, settling the matter in a way more radical than anyone had anticipated. It has shown that the other lines of argument were fully justified, and has proved what they could only surmise.

Let us proceed in the same way as before, starting with the earliest times and coming forwards. We may then also work backwards from the most reliable Chinese pictures of ships which date from times later than the European appearance of the stern-post rudder. In this way we shall be focusing, as it were in a microscope, both from below and from above. The epigraphic counterparts of the Han and San Kuo passages which we have been reading are of course the familiar relief carvings of the tomb-shrines, in which small boats with steering-paddles are frequently seen (cf. Figs. 403-405). There are also the boats, large and small, of the Indo-Chinese bronze drums (cf. Fig. 660), invariably directed with steering-oars. This takes us down to the 3rd century. From then until the end of the Ch’ang we are mainly dependent upon the paintings and carvings of Buddhist iconography, such as the frescoes of the T’ienhuan cave-temples (Fig. 658, pl.1) and the steles of the Lüehch’ao period (Figs. 970, 972, pls.1). In these again the steering-oar uniformly persists, even when the craft are seemingly quite large. One might be inclined to suspect Indian influence here, since bellying square-sails are shown and never the Chinese mat-and-batten sails, yet perhaps we need not seek to deny them Chinese nationality since the stern-sweep persisted so long and so powerfully in China (at least in river craft) until today. In any case no rudders appear in these waters.

What of the other end? Here we are troubled at times by the question of authenticity, for Chinese and Japanese artists did not always faithfully reproduce the technical detail in the paintings which they copied, and the number of authentic examples from the Sung is now relatively small. Nevertheless Yuan paintings of the +13th and +14th centuries always show rudders below the high curving stems of the ships, as for instance a famous one by Wang Chen-Piêng⁷ reproduced by Japanese art historians.⁸ The Sukizaki collection in Japan has a Sung painting dating from before +1180 of two junks with fine balanced rudders (Fig. 1032, pl.3),¹⁹ and another in Chinese possession, entitled Chiang Fan Shan Shih¹ (Sailing Ships making for Market by a Mountain Shore), the work of an anonymous painter, is placed at or before +1200.⁶ Japanese

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* A chin weighs 30 catties (lbs.), cf. p. 415 above.

* Not identifiable. But there are a number of tropical woods known as iron-wood; e.g. Cavanara epiptelophila, Ficus gigas, Insignia borbir, Mala bauhynia, and Mansa ferrae (see Burkill (1), pp. 491, 949, 1243, 1380, 1458 respectively). See above, p. 416.

* P. 486 above. One thinks of his words as referring to Malay vessels of the Borobudur type (cf. Fig. 973, pl.1), but he must have meant Annamese and South Chinese sea-going ships.


* Cf. des Noettes (a), fig. 103.

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29. NUTICS

Fig. 1033. (a) The great warship in the scroll-painting of the Battle of Dan-no-Ura (+1183) preserved in the Akasaka-no-Miya shrine at Shunmonoseki, and copied from an earlier original by Minamotono Ukon-no-Shigen (+1143 to +1153) of the Tosa-706 school of painters, in the first years of the +12th century. The simple (unbalanced) axial rudder is clearly drawn, and the paddles and topping lifts of the large lug-sails inserted with loving care. Note also the prominent anchor windlass at the bows.

(b) Rough sketch of one of the ships depicted in the scroll-painting entitled Meko Shihrei Ekkotsu (Illustrations and Narrative of the Mongol Invasion of Japan, +1281), done in +1281 and preserved in the Imperial Household Museum. The picture occurs in Pl. 3, p. 109, of the 1912-18 coloured reproduction edited by Kubota Benzo. The mastless boats are stowed with Mongol fighting-men, and rowed by two or three sailors on each side standing on outboard projections. In the original the rope or chain (drawn in fact like a rod) of the unbalanced rudder tackle is prominent and noteworthy, though in the small sketch not clearly separated from adjoining parts of the hull. The sketch should also make the bows square and transom-ended.

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* Harada & Komi (1), vol. 2, pl. 111, no. 1 (from Kôka, no. 370, pl. 111). Examples as late as this are not difficult to find; thus a famous scroll illustrating the Mongol invasion of +1281 shows a rudder under the tho-bou at the stern (Fig. 1033 b). Purvis (1), who reproduced this, described also another painting of ships with rudders depicting one of the voyages of the wandering Buddhist monk and preacher Ippen Shinin¹ about +1280, but it is a +18th-century copy by Awa-tatsuki Mmmó Hôgen Takaminsu.

* Harada & Komi (1), vol. 2, pl. 17, no. 1 (from Kôka, no. 373, pl. 1). This is attributed to Ma Kô-Chih. Compare the very similar painting by his contemporary Ma Lin³ in the Lioising Museum collection (Yang Jen-Khai & Tung Yen-Ming (1), vol. 1, pl. 60).

* Anon. (32), no. 4. Here the rudders are of the simple or unbalanced type.
sculpture-scrolls copied from medieval originals depict the Battle of Dan-no-Ura in +1185 where the Minamoto clan defeated the Taira.\footnote{From about this time, the first half of the +12th century, at any rate, we have a painting by Chihao Chung-Chih, done to illustrate Su Tung-Po's second Ode on the Red Cliff, which shows the poet's friends drifting in a boat with a very clear triangular balanced rudder. This work, in the Crawford Collection, was exhibited in London in 1965; see Sickman et al. (1), p. 15.} One of the great war-junks (Fig. 1033) has rectangular lug-sails very clearly drawn, with spars and topping lifts, as well as an axial rudder. But the authenticity of the details is not very sure.\footnote{Reproduced in the Free Gallery of Art at Washington, by the kindness of Dr A. G. Waley.\footnotemark[2] Cf. the study of Waley (30). Reproductions of later copies in Binyon (3), pl. xi. We have already discussed the question of authenticity.}

With the Chinese ship carved so grandly by Cambodian artists on the walls of the royal city of Angkor Thom\footnote{See Yang Jen-Kai & Tung Yen-Ming (1), vol. I, pI.} we are in a better position, for the date, almost exactly the same as that of the Battle of Dan-no-Ura, is not in doubt. Unfortunately this time the details of the relief have been regarded as difficult to interpret. That it shows a Chinese merchant-ship is certain from many features (mat-and-batten sails with multiple sheets, grapnel anchor, etc.), but at the after part of the hull there is seen (Fig. 975, pl. iv) what appears at first sight to be an axial 'stern-post' rudder turned round so that it is facing forward along the quarter. As such it has been accepted by many,\footnote{Some doubts could be set at rest. For in the previous years excavations undertaken by the Kuantung Provincial Museum and Academia Sinica in the city of Canton, in connection with rebuilding operations, brought to light from a tomb of Dutch boats also have spars of this kind.} but others have been uncertain; P. Paris (2) for instance pointed out that the post seems to have been carved with nodes in it as if it were a piece of bamboo, suggesting rather that it was meant to be the mast of the small fishing-sampan alongside, yet with this it has no connection and the stones show no sign of damage.\footnote{See Yang Jen-Kai & Tung Yen-Ming (1), vol. I, pp. 114, 115 above.} It could not be a quarter rudder since it would not then extend lower than the ship's bottom, and no evidence exists for the employment of this at any time in East Asia.\footnote{See Yang Jen-Kai & Tung Yen-Ming (1), vol. I, p. 10, and Waley (19), pp. 59 f. We reproduce the copy in the Free Gallery of Art at Washington, by the kindness of Dr A. G. Waley. Cf. Sullivan (3), p. 428.} In support of its interpretation as a true median rudder is the fact that it projects well below the hull, acting as a centre-board in the usual way, and that the stern-gallery (from which it would be hoisted and lowered) juts out above it—these are features highly characteristic of the Chinese slung rudder. One can even see the head of the helmsman inside a kho-lou at deck level. The sails are set and the vessel is weighing anchor to leave a deep-water harbour. We therefore accept the carving without hesitation as evidence for the median rudder, remembering always that the Cambodian stone-carver was not a nautical expert,\footnote{If the small upright piece of timber at the stern is not the bumbkin of the yuloh or stern-sweep, it might be the post of the rudder. If the spar is not a yuloh or a stern-sweep, it might conceivably have been inspired by a slanting strut such as those which will exist on Hakkas boats in the neighbourhood of Melsham. This gives added strength by connecting directly the after part of the rudder with the middle of the tiller (G. R. G. Worcester, unpublished material, nos. 86, 88, 170). Some Dutch boats also have spars of this kind.} and lacked perhaps a very clear idea of what exactly there was down there under the water at the stern of a Chinese merchantman.\footnote{See p. 539 above.}

Then as our next document we have the celebrated scroll-painting by Chang Tse-Tuan finished just before +125 and entitled Chhing-Ming Shang Ho Thu (Coming up the River to the capital, Khaifeng, after the Spring Festival), with all its wonderful wealth of detail on the daily life of the people and their techniques. Here many slung and balanced rudders are depicted with the utmost clarity (Fig. 1034, pl. iv). Since the date corresponds almost exactly with the literary evidence of the embassy to Korea we have once again the mutual confirmation of painting and text.\footnote{Reproduced in the Free Gallery of Art at Washington, by the kindness of Dr A. G. Waley. Cf. Sullivan (3), p. 428.}

Lastly, if the existing Sung copies are to be trusted, we can find balanced rudders in the paintings of the famous Wu Tai artist Kuo Chung-Shu.\footnote{Reproduced in the Free Gallery of Art at Washington, by the kindness of Dr A. G. Waley. Cf. Sullivan (3), p. 428.} In his Hsieh Chi Chang Hsing Thu (Sailing on the River while the Sky is clearing after Snow), painted in +951, there are two large junk with well-drawn balanced rudders.

Between +950 and +100 only one other piece of iconographic evidence presents itself, a painting of a ship by Ku Khai-Chih, the famous artist of the second half of the +4th century. It illustrates the Lo Shen Fu (Rhapsodic Ode on the Nymph of the Lo River), written by Tsiao Chih\footnote{Reproduced in the Free Gallery of Art at Washington, by the kindness of Dr A. G. Waley. Cf. Sullivan (3), p. 428.} a hundred and fifty years earlier.\footnote{Reproduced in the Free Gallery of Art at Washington, by the kindness of Dr A. G. Waley. Cf. Sullivan (3), p. 428.} While this painting (Fig. 1035, pl. iv) seems to embody certain archaic ideas of perspective characteristic of the draughtsmanship of Ku Khai-Chih's time,\footnote{Reproduced in the Free Gallery of Art at Washington, by the kindness of Dr A. G. Waley. Cf. Sullivan (3), p. 428.} the earliest extant version of it is probably a Sung copy of the +11th or +12th century. It is therefore impossible to be sure that the rudder-like object shown was really in the original, for it might have been introduced in one of the Thang copies through which no doubt the famous picture was handed down. Besides, what is it? At the stern of the ship we see a curious trapeziform structure which looks quite like an axial rudder hoisted inboard to a position high out of the water, and beside it there is a backward and downward pointing spar which might be a 'yuloh' (a sculling-oar), or perhaps a stern-sweep quite appropriate for a river ship. But one remains rather at a loss, and few were willing to take Ku Khai-Chih's picture as evidence for the 'stern-post' rudder in the +4th century, the time of Kuo Pho and Sun Fang.\footnote{Reproduced in the Free Gallery of Art at Washington, by the kindness of Dr A. G. Waley. Cf. Sullivan (3), p. 428.}
Hou Han date (+1st and +2nd centuries) a magnificent pottery ship model which demonstrated the existence of the axial rudder already at that time. Before these discoveries the tomb ship models recovered in modern archaeological research had all been of the Warring States or Early Han period (-4th to -1st centuries), and all had evidence of steering oars (cf. p. 447 and Fig. 961, pl.). Now however the pottery model, nearly two feet long, was found to be equipped in very modern style. We need not recapitulate the description already given (p. 448), suffice it to say that, as Fig. 965 (pl.) shows, deckhouses cover most of the beam, which is surrounded on both sides by a pair of poling galleries. The stern extends at a considerable distance beyond the last transom-bulkhead in the form of an after-gallery (in fact a tho-loa), the floor of which is formed by a criss-cross of timbers through which the rudder-post descends into the water. This is seen particularly well in Fig. 1036 (pl.), a photograph taken from astern. The true rudder is indeed present, trapeziform as would be expected, and having no resemblance to a steering-oar, but most clearly exemplifying the remark about 'eight foot of timber' which Than Chhiao was to make nearly a thousand years later. Most gratifyingly, its shoulder is pierced by a hole exactly where the suspending tackle should be attached to it. Possibly the original state of the model, made no doubt for some wealthy merchant-venturer and ship-owner of Han Canton, incorporated all the tackle by which the rudder was secured, but the little cables long ago rotted away and we can only guess now how it was done. A second hole is present at the top of the rudder-post.

It has not as yet, we think, been pointed out that a curious similarity exists between the lines of this ship (in particular the position and shape of the rudder) and those to be seen in a representation of the ship of the famous Japanese minister Sugawara no Michizane (+945 to +993), Ennin's younger but more exalted contemporary (Fig. 1038, pl.). According to Purves (5) this many times copied scroll still exists at the Shinto temple of the minister at Kyoto, the Kitanon Tenmangū, where he is deified as the god of learning. The same applies to another fine Japanese ship painting, that in the Kitanon at Kyoto dated c. +1120 and classed as a national treasure (see Anon. (56), pl. 37). This work, perhaps from the brush of Enchō Jonin (a disciple of the famous abbot Myōe, +1173 to +1233), depicts the taking of the Kegon School formulae to Silla by Gishō and Gengyo. The general shape of hull and sails recalls the Bayon ship (cf. p. 461) and there is a Tunhuang-like pagodesque deckhouse at the poop (cf. p. 455), but the rudder is singularly like that of the Canton model. The vessel is guided by a dragon—the spirit of a Chinese girl of high birth who fell in love with Gishō unavailingy and threw herself into the sea. So also we may be led to find prototypes of these hulls and rudders in paintings of the Tang—I think particularly of Li Chao-Tao's boats on the poling gallery. The stern extends aft a considerable distance beyond the last transom-bulkhead in the form of an after-gallery (in fact a tho-loa), the floor of which is formed by a criss-cross of timbers through which the rudder-post descends into the water. This is seen particularly well in Fig. 1036 (pl.), a photograph taken from astern. The true rudder is indeed present, trapeziform as would be expected, and having no resemblance to a steering-oar, but most clearly exemplifying the remark about 'eight foot of timber' which Than Chhiao was to make nearly a thousand years later. Most gratifyingly, its shoulder is pierced by a hole exactly where the suspending tackle should be attached to it. Possibly the original state of the model, made no doubt for some wealthy merchant-venturer and ship-owner of Han Canton, incorporated all the tackle by which the rudder was secured, but the little cables long ago rotted away and we can only guess now how it was done. A second hole is present at the top of the rudder-post.

Pao Tuan-Phêng (a, 2) takes Watson (1) rightly to task for having missed the significance of the axial rudder, but he himself accepts Watson's statement that a steering-oar was mounted on the port side of the Kegon scroll. This strange idea is certainly due to misrepresentation of a long-gowned human figure which stands on the poling gallery at the port forward corner of the helmsman's deckhouse. Of course neither Pao nor Watson had the opportunity of studying the model at first hand, or adequate photographic documentation even, but the point is not unimportant as we know that the combination of rudder and steering-oar did, and does, sometimes exist (pp. 616, 618), and the record needs keeping straight.

The exact shape of the rudder, and the manner of its attachment within the after-gallery, are shown in my drawings made in the Museum at Canton in 1958 (Fig. 1074a, b, pl.). The handiwork in Chinese museums have since then frequently assembled the model wrongly. Thus the otherwise beautiful photograph in Anon. (25), pl. 444a, has the rudder reversed in the after-forward direction, and in the National Historical Museum at Peking in 1964 the rudder was placed pointing out of the open after end of the after-gallery instead of through its floor.

About the transmission of the technique (and surely such there was) very little can be said. It seems overwhelmingly likely a priori that an invention of this kind would have come round by way of mariners' contacts in the South Asian seas, though it is not impossible that a Chinese artisan who had built ships for the Liao dynasty handed on certain ideas to Russian merchant-shipwrights trading to Sinkiang in the realm of the Western Liao (Qar-t'Khitil) between +1120 and +1160. This might explain the region in which the rudder first manifests itself in European culture, but support from Russian sources is so far lacking. At the same time the Islamic world offers more light (though not very much) for the travels of the rudder than it does for the mariner's compass. A famous illustration in a Baghdad MS. of +1237 shows an axial rudder on a sewn ship (Fig. 1039, pl.) it comes from the Maqāmīt (Historical Anecdotes in Rhymed Prose) of Abi Muhammad al-Qasim al-Harīfī (+1054 to +1122). The tiller arrangement is not very clear, but medieval Asian seamen certainly used various kinds of relieving-tackle to secure it. A description of a related device has already been noticed in the quotation from Lecomte (p. 635 above), and a contemporary Chinese example of a tiller held firmly by adjustable ropes is well seen in a port bow view of the Maze

We repeat mention of our warmly felt indebtedness to Dr Wang Tsai-Hsin and his colleagues of the Canton Museum for their kind help in these studies, pursued in 1958 with the collaboration of Dr Lu Cew-Dyen.

The story has been told in Vol. 4, pt. 1, Sect. 261.

La Rosière (4), p. 31, was prepared to admit that the axial rudder was used in the Far East at least a century before it appeared in Europe—'mais tout en de a) d'ailleurs qu'on m'inconscrit de curiosité'. As Western naval historians and archaeologists become more aware of Chinese priorities, an increased disposition to deny their relevance may be expected. Thus already Adam & Denoix (1), while acknowledging fully the antiquity of the Chinese axial rudder, urge that it should be regarded as something sui generis, a 'rudder-centreboard', and implicitly deny that it had any influence on the stern-post rudders of the West. Needless to say, we have no sympathy with this view. It belongs, we feel, to the Department of Face-Saving Redefinitions, on which see Vol. 4, pt. 2, p. 545, and also p. 564 above.

On the attention paid to the opposition of the Western Liao State in +12th-century East-West contacts also in connection with the magnetic compass (Vol. 4, pt. 1, p. 332).

Bib. Nat. MS. Arabe no. 5,847, Cf. Blochet (1); Hourani (1), p. 98; des Noettes (3), fig. 90.

Collection model of a South Chinese freighter (cf. Fig. 1040, pl.). Now for the past century and a half European observers have described elaborate tackle-controlled rudders on many types of Arabic sailing-ship. Hence considerable interest attaches to a passage in the Ahsan al-Taqâsîm fi Ma'rifat al-Aqâlim (The best Divisions for the Knowledge of the Climates) written by Abû Bakr al-Bannâ' al-Bâshârî al-Muqaddasî in +985. Describing a difficult passage in the Red Sea, he says:

From al-Qâzîm to as far down as al-Jâr, the bottom is overspread with huge rocks which render navigation in this part of the sea most difficult. On this account, the passage is made only by day. The shipmaster takes his stand on the top and steadily looks into the sea. Two boys are likewise posted on his right hand and on his left. On espying a rock he at once calls to either of the boys to give notice of it to the helmsman by a loud cry. The latter, on hearing the call, pulls one or other of two ropes which he holds in his hand to the right or the left, according to the directions. If these precautions are not taken, the ship stands in danger of being wrecked against the rocks.

It seems almost impossible that this description could refer to lanyards attached to steering-oars, but on the contrary it would closely agree with the tackle-controlled axial rudders which have lasted in use in Arab waters to the present day. In this case we have to conclude that the Chinese invention had already been introduced in the Arabic culture-area before the end of the +10th century. From all that we know of Arab trade in the eastern seas, this would not be at all extraordinary. But the transition from the Muslims to northern Europe remains at first sight more difficult to understand. Perhaps some sea-captain from northern Europe was more observant and alert during the Second Crusade (+1145 to +1149) than any of his colleagues from the Mediterranean.

In spite of all controversies, the stern-post rudder, no less than the mariner’s compass, was an essential pre-requisite for the oceanic navigation of large ships. Without it, the developments of the second and third periods of quantitative and mathematical piloting (see pp. 554 ff. above) would have been long delayed if not completely inhibited. The historical implications of the stern-post rudder in the West are only now beginning to be understood, but some will be obvious from our account of the +15th-century voyages (pp. 511 ff. above).

The Portuguese success in these maritime undertakings [wrote Trend] was due to science; and the science of the day, however rudimentary, had led to a series of technical improvements.

Of course the stern-post rudder did not solve all the problems of steering ships — it would be astonishing if it had. (Western) ship tonnages did not rise suddenly, but between the +15th and the middle of the +16th centuries Portuguese average burthens doubled at the least. The decisive role of the stern-post rudder was really rather different; owing to its position on the median line and pivoting there, it became possible to stand a course in heavy weather, maintaining a constant angle between the median line of the ship and the wind direction. Hence it became possible to outflank the regions of the trade-winds far from the sight of any coasts. What was at stake was nothing less than the mastery of ocean navigation itself.

Elaborating the words of Godinho (like Trend, a scholar rather than a practical sailor) one might add that by standing a course in heavy weather he meant beating to windward or making efficient use of a beam wind for days at a time without exhausting the crew; this was what the stern-post rudder permitted, the complete circuit of the trade-wind areas (cf. Fig. 989a, map), neither desperately fighting them nor merely running before them. Thus an invention of the China Seas found its supreme application in the roaring Atlantic.

Now comes what we have called the dénouement. The invention of the stern-post rudder involves a remarkable constructional paradox — it was developed by a people whose ships had characteristically no stern-posts. If we look again at pictures of the ships of ancient Egypt, of the Greeks, or of the Norsemen, we see invariably that the stern sloped gradually upwards in a curve from the water-line. The slanting stern-post was in fact, to use astronomical terminology, a ‘posterior sternum’ corresponding to the ‘anterior sternum’ of the stem, and a direct prolongation, like the latter, of the keel. But the junk had never any keel. Its bottom, relatively flat, was joined to the sides, as we have seen (p. 391), by a series of bulkheads forming a set of watertight compartments, and instead of stern and stem posts there were transom ends. Now the bulkhead build provided the Chinese shipwrights with the essential vertical members to which the post of the axial rudder could conveniently be attached, not necessarily the aftermost transom but perhaps one or two bulkheads forward of it. This principle held good from the smallest to the largest sailing-ships. It might be called that of the ‘invisible stern-post’. Of course, in later times, rudders were fashioned in curving shape so as to fit various kinds of curving stern-posts, but our argument suggests that
29. NAUTICAL TECHNOLOGY

(4) Balanced and Fenestrated Rudders

The civilisation (so often miscalled 'static') which initiated axial rudders also gave them a far-reaching development. From time to time we have had occasion to mention the 'balancing' of rudders. People generally think of the rudder as an object in which the whole of the blade or flat part is abaft the post itself. But many large modern ships, on the contrary, have rudders in which there is a flat portion forward of the post as well, and this construction is termed 'balanced'. Such an arrangement not only balances the weight on the bearings but also facilitates the work of the helmsman and the steering-power which may assist him, since the water exerts pressure in his favour on the forward portion. The value of this balanced structure was a leading point in the reasoning of Carlini and la Roerie, who admired the steering-oars of antiquity for exhibiting it, and reproached the medieval Western stern-post rudders for failing to conserve it. These writers, who were not very interested in what they called 'exotic pirogues', did not know that balanced rudders are common on many types of Chinese river-junk (Fig. 1043, pl.), though in their simple forms they are unsuitable for seagoing vessels. Although we have not been able to find any specific literary references to them there is now no room for doubt that they go back to the earliest stages of the invention in China. Indeed it seems quite likely that the balanced axial rudder was the first to evolve, for the placing of a steering-paddle in a median upright position against or near the aftermost bulkhead would lead directly to it.

Europeans were very slow, generally speaking, to adopt the principle, perhaps because they were mainly interested in sea-going ships, and until iron construction afforded ways of securing balanced rudders thoroughly (e.g. by pivoting the base of the post) they were not very feasible. An 'Equippollent Rudder', however, was among the inventions of Lord Stanhope about +1799. Shuldham pressed the matter forward in 1819. One of the earliest ships with a modern balanced rudder was the 'Great Britain' of 1843. The strangest aspect of the situation is that one of the two oldest representations of rudders of any kind in Europe, that on the Winchester font, shows what looks like a balanced rudder. Could this conceivably have any significance with regard to the transmission?

The balanced rudder is also traditionally at home in India, especially on the Ganges, where certain classes of boats, the ulakh, the patela, etc., are equipped with striking triangular forms. These seem more primitive than the Chinese ones however, because the difficulty of doing this was one of the chief factors which inhibited any earlier development of the invention in the West. The bulkhead-attached rudder posts can be seen clearly in many Sung pictures (Figs. 1035, 1034, pls.), as well as in drawings of contemporary Chinese craft. The Cantonese ship model of the Han does not show the vertical nature of the attachment so well, but this may be partly because we do not know exactly how it slung its rudder—in any case the shape of the latter speaks for itself. Alternatively we may be seeing the axial rudder here in statu nascendi, after it had acquired its very particular shape and just before it had found its home on the vertical bulkhead timbers. For it is noteworthy that although the Canton ship model has bulkheads its lines are rather like those of a punt, sloping gradually to the water-line at bow and stern; and only when more upright and blunt-ended sea-going forms developed from this would the invitation to verticality really have asserted itself— with the additional advantage of the centre-board function in the lowered rudder position. To sum up the matter, we can not only feel sure that the 'stern-post' rudder originated in the Chinese culture-area at the beginning of our era, but we can form a pretty good idea of just why it did so.

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Footnotes:

a Even la Roerie saw this, (a), p. 35; in the sense that he commented on the tendency of the sternposts of European ships to become straighter as soon as the axial rudder was adopted. 'The convex stern-post', he said, 'lent itself but poorly to the fixing of a line of hinges.'
b This is true also of the Japanese ship shown in Fig. 1038 (pl.).
entirely symmetrical fore and aft, and therefore less efficient. One hesitates whether to look to China or to ancient Egypt as the main source of influence on the rudders of these vessels. But perhaps they are best regarded as very exaggerated ancient Egyptian steering-paddles, all the more so because, though vertical, they are generally fixed to the counter as quarter-rudders and not to the stern-post at all.\(^2\)

Perhaps the most remarkable of all these inventions was the fenestrated rudder. When European sailors first frequented Chinese waters, they were surprised to see some junk rudders which were riddled with holes. No doubt they found it difficult to believe that this had been designedly done. Such fenestrations, generally diamond-shaped and cut out at the edges of the planks, ease the steering by reducing the pressure against which the tiller has to act, and minimise the drag on the ship caused by turbulence in the hydrodynamic flow past the rudder.\(^3\) But as the water is a viscous medium the efficiency of the rudder is very little impaired. The practice was remarked by Admiral Paris, though he did not fully appreciate its value. Fig. 1044 (pl.) shows the stern of a Hongkong fishing-junk in dry dock with a fenestrated rudder.\(^6\) The device was probably quite empirical in origin, based upon knotty wood or damaged gear, but it is not at all too fanciful to suppose that some medieval Taoist sailor, finding that his work was eased and that his ship sailed better, was fully content to follow the principle of wu wei,\(^d\) and letting well alone, recommended the arrangement to his friends.\(^e\) The fenestrated rudder has been widely adopted in modern iron ships during the present century, having been brought to the attention of European marine engineers by Winterbotham in 1901. Indeed, it may even have helped to stimulate the important invention of anti-stalling slots in the wings of aircraft.\(^g\)

(i) **TECHNIQUES OF PEACE AND WAR AFLOAT**

(i) **ANCHORS, MOORINGS, DOCKS AND LIGHTS**

Much has been written on the history of the anchor, an essential device which goes back to prehistoric times. The ancient Egyptians used heavy stones combined with hooked branches to form grapnels,\(^h\) but metal hooks were coming into use already in

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\(^a\) Exact replicas of the ancient Egyptian quarter steering-paddles with tillers occur on other Ganges boats (cf. p. 653 above; Hornell (1), figs. 45, 46). Yet a Chinese flavour asserts itself, for though the patela rudder is vertical it is not at all firmly fixed and it does not look at home on the craft that carry it. One senses the application of an extraneous idea to a vessel not really adapted for the purpose.

\(^b\) Cf. Poujade (1), p. 258.

\(^c\) Cf. Finch (1); des Noettes (2), fig. 111; Waters (4); Anon. (17), no. 3.

\(^d\) Cf. Vol. 2, pp. 68 ff.

\(^e\) Ultimately the principle was extended to gripes and keels; cf. the Hainan junk model in the Maze Collection, Anon. (17), no. 9.

\(^f\) The holes, he said, ‘reduce the labour of “putting hard over” to a minimum while not much affecting efficiency in steering; the stream lines, owing to the viscosity of the water, being deflected almost as well as though the small holes were non-existent’. Mr Hubert Scott described to me in 1959 the trial run in 1901 of one of the first coal-fired Parsons turbine torpedo-boat destroyers. So powerful was the streamline flow that when the helm was put hard over at 30 knots, the balanced rudder could not be reversed, the vessel continuing to speed round in circles. A fenestrated rudder was the answer.

\(^g\) We have discussed this already (Vol. 4, pt. 2, p. 592).

\(^h\) Boreux (1), p. 416; van Nouhuys (2), an article much preferable to those of Moll (2); Reisner (1), is the best authority. On the simplest and oldest anchors, holed stones, see Frost (1, 2).
Fig. 928. The sea-going sailing-raft of Thaïwan and the south-eastern Chinese culture-area (photo. Ling Shun-Sheng, i). Note the curved wooden bar at the bow, one of those which gives the bamboo platform its concave profile; the centre-boards, some of which are sticking up in position; the bamboo bulwark rail on each side of the craft; and the characteristically Chinese lug-sail with battens.

Fig. 930. Two of the large rafts of the Ya River in Szechuan (photo. Spencer, 2).

Fig. 931. A flotilla of bamboo rafts used in cormorant fishing, on the Hsin-chiang R. near Huang-chin-pu, south-east of the Poyang Lake in Northern Chiangsi (orig. photo., 1964).

Fig. 933. Model of a Ma-yang-tru (Maze Collection, Science Museum, Kensington). Anon. (17), no. 3. The powerful bow-sweep, generally carried, is shown. See p. 630.
Fig. 936. Bow view of a Fuchow pole-junk or timber freighter (Hua-phi-ku), from the Waters Collection (National Maritime Museum, Greenwich), to show the complex construction of the forward part of the hull. The horns of the two wings at the bow rise some 10 ft. above the deck. Though rarely with more than three masts, these ships also attain lengths of nearly 200 ft. (note the two crew figures visible at the bows). Scale drawings of such a ship will be found in Worcester (3), vol. 1, pl. 50.

Fig. 937. Bow view of a Hangchow Bay freighter (Shao-hsing chhuan) in port, from the Waters Collection (National Maritime Museum, Greenwich), showing the build of the forward part of the hull. The blunt transom bow looms forward, and its thwartship planking rests on and slightly behind the rounded extremity of the ascending fore-and-aft bottom planking. The bow is usually decorated with a face in bright colours, and the counters bear paintings of the pa-hua and Yin-Yang symbols (cf. Vol. 2, pp. 273, 312) instead of oculi. Note the grapnel anchor and the furled batten foresail. These ships never exceed 90 ft. in length and are usually three-masted; they also carry leeboards (cf. p. 618), not here seen. Scale drawings in Worcester (3), vol. 1, pl. 48.
Fig. 938. Deck of a Swatow freighter (from the Waters Collection, National Maritime Museum, Greenwich). The mainmast strut, which transfers part of the thrust of the wind on the sail to the hull and bulkheads forward, is prominent. One of the usual iron bands and wedges on the mast can also be seen, and the halyard winches (one dismounted) on each side to port and starboard.

Fig. 940. A small three-masted freighter on the Chhi-en-chang River near Hangchow (orig. photo, 1964). The crew are hoisting the mainsail by means of the transverse halyard winch so characteristic of Chinese ships (cf. Fig. 939). Grapnel anchor, oculus and steerman’s shelter are noticeable. The identification-plate reads Ché Hang fan 23, i.e. ‘Sailing-ship no. 23 of Hangchow in Chekiang Province’.

Fig. 946. A page from the Matthew Baker manuscript of 1586 in the Pepysian Library at Magdalene College, Cambridge. The shape of a fish is superimposed upon the drawing of a hull, to illustrate the famous shipwright’s maxim of those times: ‘a cod’s head and a mackerel’s tail.’
Fig. 947. A revealing photograph of the port quarter of a South Chinese freighter or 'trawler' under repair in the shipyards of Hongkong (from the Waters Collection, National Maritime Museum, Greenwich). Four or five bulkheads are seen, the aftermost one especially clearly, because of the removal of the strakes of the hull. Within the upcurving stern itself, an additional five ribs or frames are seen, and these also occur in various combinations between pairs of bulkheads further forwards. A Fuzhou freighter such as that in Fig. 936 (pl.) would have some fifteen bulkheads and about 37 rib frames. In the present picture the slot for the slung rudder can just be made out under the overhang of the stern gallery. Figures give the scale.

Fig. 948. A picture to illustrate Marco Polo's encomium upon the extraordinary abundance of Chinese shipping; some of the salt transport boats awaiting cargo at Tsou'hui-ching in Szechuan (cf. Vol. 4, pt. 2, p. 129). The temple on the ridge to the right, and that on the projection of the city-wall, with the 'half-timbered' houses (cf. Fig. 796), are very characteristically Szechuanese (photo, Jukes Hughes, from the Salt Commissioner's house, 1920).

Fig. 953. Model of a Wai-phi-ku (Maze Collection, Science Museum, Kensington). See p. 430.
Fig. 956. Ancient Egyptian tomb-model of a Horian ship from the VIth Dynasty (Poujade, 3). The resemblance to characteristic Chinese builds is striking.

Fig. 957. River-junks starting downstream from Kweilin on the Li-chiang (R.) in the early morning mists (photo. Groff & Lau, 1). The bipod masts so typical of this region recall those of ancient Egypt.

Fig. 958. Dragon-boat (Lung chhuan) races at Hongkong.

Fig. 959. Wooden tomb-model of a Former Han river-ship excavated from a princely burial of the — 1st century at Chhangsha (Anon. (11), pl. 103). Length, 4 ft. 3 in. There is some uncertainty as to how the component pieces should be put together. The arrangement shown here is about the same as that adopted at the National Historical Museum in Peking (1964), but to the nautical eye it cannot be right, as it leaves no room either for helmsman or rowers (the black object amidships is the smallest of three deckhouses). There is some uncertainty as to how the component pieces should be put together. The arrangement shown here is about the same as that adopted at the National Historical Museum in Peking (1964), but to the nautical eye it cannot be right, as it leaves no room either for helmsman or rowers (the black object amidships is the smallest of three deckhouses). The arrangement of Hsia Nai (1) is preferable. The U-shaped piece, here enclosing the after deckhouse, ought to project astern as a gallery, and a central notch in this indicates that the stern-sweep or steering-oar was intended to turn on it, though one would have expected it rather to work through it on the terminal hull transom bar. The two larger deckhouses ought perhaps to be superimposed, and the smallest one should be moved either aft or forward. Lastly the bulwarks are upside down, for the oarports must be along their lower not their upper edges; and this is proved because those along the line of ports are flat while the other edges are slightly convex. Other components of the tomb-model have not been incorporated in any reassembly we have seen—notably part of a fourth cabin or deckhouse, oval objects like shields, U-shaped objects, miscellaneous unidentified boards, and an extraordinary piece of carved and fretted woodwork that might have been a figurehead (cf. Fig. 960), or a 'prow-oke' (cf. Fig. 964, pl.) . There are no obvious bulkheads.
Fig. 962. Tomb-model ship in red pottery of the Later Han period (+1st century), in the Canton Museum (orig. photo. 1964). Length, 1 ft. 4 in. Four human figures (young) are shown as crew. Description in text, p. 448.

Fig. 963. Tomb-model ship in grey pottery of the Later Han period (+1st century), excavated, like the preceding, from a burial under the city of Kuangchow (photo. Canton Museum). Length just under 1 ft. 10 in. This is a document of singular importance for the history of shipbuilding, cf. Fig. 1036. View from the starboard side, showing slung rudder under the overhanging poop or ‘false stern’ (cf. p. 390), steersman’s cabin, several roofed or matting-covered deckhouses, a long poling gallery (cf. Fig. 966), bollards or yuloh male-pins, and a projecting bow with an anchor (cf. p. 657) hanging from it. The mast was probably stepped just forward of the deckhouses.

Fig. 964. Bow view of the model in the preceding illustration (photo. Canton Museum). The anchor is seen attached to its bollard, and just behind this an ornamental screen which recalls the ‘prow-yokes’ of Indo-Chinese craft. Lateral projections support narrow outboard decking and bitts or bummkins. The transom stern is well seen.

Fig. 965. View of the model in the preceding illustrations from above, bow at bottom (photo. Canton Museum). The removable roofing shows the cabins or holds, but no bulkheads are visible. The wide poling galleries break off only in one place, the probable position of the mast, but no tabernacling is provided.
Fig. 966. The use of the poling gallery, a picture of a Cantonese river-ship at Kukong (Chihli-chiang) on the Pei-chiang (R.), taken from a passing sampan (orig. photo., 1944). Grubbing labour upstream on windless days.

Fig. 968. The largest of the ships in the Tunhuang cave-temple frescoes; from cave no. 55 at Chhien-fotung (photo. Pelliot Collection, Musée Guimet, Paris). Description in text (p. 455). The Buddhist Ship of Faith sails from the shores of illusory in the foreground (the upright oblongs are inscription-bearing cartouches) to the Paradise of Amida.
Fig. 970. Carving of a ship on a Buddhist stone stela of the Liu Sung or Liang dynasties (+5th or +6th century) from the Wan-Fu Ssu temple at Chêngtu (photo: Historical Museum, Szechuan University).

Fig. 971. A timber freighter of the Chhien-thang River, often used for transporting flood-protection fascines (cf. p. 341); one of the relatively few Chinese craft which make use of square-sails. Note also the sprit-sail on the small foremast (photo: Fitch (1), 1927).
Fig. 972. A ship in stormy seas depicted on the back of a bronze mirror of Thang, Wu Tsai or Sung date, i.e., 9th to 12th century (photo. of rubbing, Shensi Provincial Museum, Sian). The inscription on the bellying square-sail reads: "The Inspector of Thien-hsing city in Feng-hsiang prefecture... (name illegible)." Note the very uncharacteristic shrouds. Description in text, p. 457.

Fig. 973. Typical Indonesian ship from the reliefs of the great temple of Borobodur in Java, c. +800 (photo. Krom & van Erp). Sewn hull, prominent stern- and stern-posts, large outrigger, bipod masts, and an artemon sail as well as the characteristic Indonesian canted square-sails. Further discussion in text, p. 458.

Fig. 974. A craft of a different type in the reliefs of Borobodur, c. +800 (photo. Krom & van Erp). Reasons are given in the text for regarding it as Chinese. The sail, for instance, appears to be a mat-and-batten lug-sail, and the hull has a square-ended look.
Fig. 975. The Chinese merchant-ship carved on the Bayon at Angkor Thom in Cambodia about +1185 under Jayavarman VII (photo. Claeys & Huet). A document of importance in the history of naval architecture, this is discussed in the text at several points, notably pp. 460 ff. and p. 648. The mat-and-batten sails, with their multiple sheets, the axial rudder slung below the level of the ship's bottom, the anchor with its winch, and the characteristic 'oriflamme' flag, are all to be noted. Many other vessels are depicted on the monument, but they are invariably of the paddled canoe type, even if substantial in size.

Fig. 976. One of the passenger-carrying river-junks in the painting Chhing-Ming Shung Ho Thu, a work by Chung Tse-Tuan of about +1125 (from the reproduction of Chung Chen-Tu, 3). The scene is one of the waterways near Khausting, perhaps the Pien Canal (cf. p. 311) itself. Judging by the figures on board, the length of the vessel from stem to stern would be about 63 ft. It is being tracked upstream by five men (out of the frame on the left), the bipod mast being supported by numerous stays. The large rudder, slung and balanced, is especially noteworthy. The poling gallery is in use at the port bow and to starboard while the master and his mates, interrupted at their lunch on the upper deck, are shouting instructions and warnings to the crew of a large boat (out of the frame on the left) which seems likely to collide with the junk negotiating, with lowered mast, the great bridge shown in Fig. 826.
Fig. 979. The government patrol-ship of +1377, recovered from the mud near Liang-shan Hsien and now preserved in the Shantung Provincial Museum at Chian (photo. Liu Kuei-Fang, 1). Description in text (p. 479).

Fig. 982. A few examples of the massive quantity of sherds of Chinese porcelain along the coast of East Africa (Kirkman (4), pl. 6). Celadon pieces of the +14th century or earlier from a Muslim tomb of +1399 at Gedi on the Kenya coast:

1, 2 brown 3 light grey
4, 9 dark green, crackled, lotus bowl
5 sage grey 6 dark grey 7 blue-green
8, 10 basic tint 11 dull sea-green

White and blue-and-white porcelain was also found in the later strata.

Fig. 983. Some Chinese coins from the East African coasts, a collection identified by Huberé (3). Nos. 5, 20, 21, 29 and 31 from the neighbourhood of Brava, no. 16 from near Merca, and the rest in or near Mogadishu:

1, 8 Sung Hai-Ning reign-period +1668 to +1707 (cast +1701)
3 Nan Thang (Pan-Ta, Chung-Hsing or Chiao-Thai r.p.) +941 to +981
4, 5 Sung Shun-Yu r.p. +1241 to +1253 (cast +1249)
6 Shao-Hsing r.p. +1131 to +1162 (cast +1145)
7, 8 Sung Ching-Ho r.p. +1211 to +1217
9, 10 Sung Yuan-Yu r.p. +1086 to +1093
11, 17 Sung Yuan-Feng r.p. +1078 to +1085
13, 14 Ming Yung-Lo r.p. +1403 to +1424 (cast after +1408)
20 Ching Shun-Chih r.p. +1644 to +1661
22, 26 Sung (Chien-Chung-Ching-Kuo or Chung-Ning r.p.) +1101 to +1106 (cast in +1101 or +1105)
28 Sung Thien-Hsi r.p. +1017 to +1021
30 Ching Hsien-Feng r.p. +851 to +861
21, 27, 29, 31 Annamese nineteenth-century coins of four reign-periods
23, 32, 34, 35 Ceylonese +19th- and +20th-century coins (+1113 to +1299)
12, 15, 16, 18, 19, 23, 24, 25 Illegible or undatable.
Hon. Kiln. described and reproduced by Lowell (I); by this time of course it incorporateis ideas and nomenclature and the other, also Korean and traditionally a gift to Hideyoshi in Countries in Successive Ages), first prepared in Tenri University copy.

Displayed in the Catalan map of Jesuit origin, but it is quite clearly based on the map of Yi Hoe in Japan, one (undated, but probably done in Korea soon after +1688) at the Tenri University Library; and the other, also Korean and traditionally a gift to Hideyoshi in 1692, in the Honynori Temple at Kusamato in Kyushu. On these see Unno (1).

In 1964 we had the opportunity of studying closely the Tenri University copies.

Besides these major codices there are many derivative maps of later date springing from the same tradition, including printed versions. One of these, dated +1683, and entitled Theun-Hiss Chin-Poe Wan-Kun Ten-Chi Lo-Ching Chhiian Thu, has been discussed and illustrated by Unno (4). Another, Yi Chai Chhiian Thu, published in Korea at least as late as the end of the +18th century, has been described and reproduced by Lowell (17); by this time of course it incorporates ideas and nomenclature of Jesuit origin, but it is quite clearly based on the map of Yi Hoe & Kwén Kün. Moreover, their work was so much admired that its name got attached mistakenly to maps of related traditions, e.g. to a Korean copy of Yang Tsu-Chhi's +1256 map of China and Korea (properly called Ta Ming Yi Chii Thu) now kept in the Myōshinji Temple at Kyoto (see Miyazaki, 1).

At the first glance one is astonished to see a very recognisable outline of the Mediterranean, with the Italian and Greek peninsulas, Sicily, Sardina, the coasts of Palestine and Spain, and a pagoda marking the position of the Pharos of Alexandria (A-la-sai-i) in the land of al-Miz (MI-su, Egypt). The copyist, however, was not quite sure that the Mediterranean was a sea, so he drew its outlines as if they were rivers, even though this meant giving some of the 'rivers' a circular moat-like course. The same is true of the Tenri version, but in the late Lowell version the Mediterranean is labelled Ti Chun Hae (the Sea in the Middle of the Land), and drawn accordingly, though with an outline more distorted than here. Yi Hoe & Kwén Kün must have had it right in +1492, for no one could have invented that outline for rivers, but river-trips during the ensuing centuries had, I think, misgivings, and so went another way.

For the rest, the northern part of the continent of Africa is drawn here so that it fits conveniently on to the southern part shown in Fig. 984, for in this respect there are no great differences between the Hon-il Kangni. and the Kings Yi Thu; but our cartographer was at fault in making the long river flow into the top of the Red Sea and not into the Mediterranean. This at least is assuming that it was intended for the Nile. If on the other hand the Nile is the shorter one flowing towards Alexandria out of the great central lake, it would be tempting to see the parallel river accompanying it as Joseph's arm (cf. p. 365), and indeed this does send off a side-branch to a lake on the left—thus the Arabs may have told the Koreans and Chinese about the Fayum and Lake Moeris. The long peninsula pointing to the south, beside Africa is of course Arabia, and of it the rivers of Mesopotamia are seen flowing into a very truncated Persian Gulf, while a large round island in the middle of the Indian Ocean is marked Hai Tao (Sea Isle).

A wealth of place-names, mostly in cartouches, can be seen, but no adequate study has yet interpreted them. One can make out transliterated forms of Hispania (I-us-pun-ta-na), Barchena (Pa-li-hau-na) and Tarragona (Ti-li-khu-na) on the Spanish peninsula; while in the Tenri version France is labelled Fa-li-hau-na (= al-Afraniysh) and Germany A-lei-man-i-a (= al-Lamantiysh). In the Byōkyoku version, here reproduced, one finds satisfyingly Mu-li-bai-lu-na where Marseille should be. There is nothing easily identifiable in Italy, unless Mu-li is Milan. England does not figure in the Byōkyoku version, but the Tenri one has a large island off France and Germany labelled Khun-lun Tao, no doubt the British Isles. It retains the same position in the late Lowell version (which does some justice to the Baltic), now becoming, many may be glad to learn, two islands, not only Ying-chii-li Kus but also I-erh-lang-tu. What the Byōkyoku version does, however, is even more extraordinary, namely the Aures Is. (Chi Shan) off the northwest coast of Spain, unknown to al-Hidrict (cf. Fig. 230) and Ibn Khalidin, and not re-discovered by the Portuguese till after +1594. It is interesting to find that the late Lowell version, absorbing old Western legends, Jesuit-transmitted, adds Fu Tao, the Fortunato Isles, off a modern northwest bulge given to Africa.

The chief object of interest in the northern part of the European zone is a mysterious great city shown as a dark crumbled disc, equivalent in importance (according to the symbols used) to Seoul, and marked...
fairly clearly Hsi-kho-na; this has been thought to be Budapest, but from its position suggests Moscow or, more probably for that date, Novgorod. The Caspian (Chiu-li-wan) is shown but the Black Sea omitted—unless it is represented by the blank space with the wiggly upper border north of Italy and Greece. Only two cities of the second class (dark discs without crenellations) are indicated along the tract of the Old Silk Road, Pah-shih-pa-li (Bishbalig) in Sinkiang, and Tu-a-pu-ni (Derbend) on the west coast of the Caspian. Both can be seen in the portion of the map reproduced. Between them come Pu-tu-la (Bokhara), not even in a cartouche, and Pu-ru-erh (Balikh), shown as an island in a lake.

For the interpretation of Hsi-kho-na it is necessary to remember that the map was made just at the end of the career of Timur Lang (+1336 to +1405), who with other Mongol leaders used to assemble armies in the seventies at a town called Sighnaq, near the Jaxartes R. (Syr Dar'ya) in Turkestan or Kazakhstan, and on one of the western loops of the Old Silk Road (cf. Hodkham (1), pp. 99, 125 ff.). If this were the explanation, Hsi-kho-na should have been placed between Bishbalig and Derbend rather than west of them, but of course none of the cartographers concerned had ever been, so far as we know, within two thousand miles of the Aral Sea. The question remains open.

Strangely, there is no obvious mention of Byzantium. Other places such as Damascus (Tu-mi-shih), Hama (Ha-mi) on the Orontes in Syria, Mosul (Ma-shih-li), Aflaq (A-fa) in Mesopotamia, Mecca (Ma-ho), and Medina (Mo-te Kuo) in another version, are recognisable enough, and usually in just about their right positions.

We have no means of knowing exactly what the place-names on the original map of +1402 were, because changes were introduced as one version succeeded another. This was especially the case with the East Asian names since dynastic alterations were so common, but later on growth of knowledge about Europe also led to revision. It would be very desirable to have a systematic catalogue of identifications of all those on the versions that still exist, but this work has not yet been done. A tenacious tradition will certainly be revealed. The general conclusion is that largely as the result of friendly intercourse between the sea-going East and West Asian peoples, China and Korea knew far more about Europe in Ch'eng Ho's time than Europe knew about them.

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**Fig. 987.** A moderate-sized five-masted Tu-pu-thou freighter (from Chiao-chow Bay near Tsingtao) at Wei-hai-wei, under sail in light breezes (photo. Waters Collection, National Maritime Museum, Greenwich). This again may give some idea of the probable type of build of the much larger Treasure-ships of the Grand Fleet of the +15th century. See also Figs. 935, 936, 938, 939, 986, 1010, 1027, 1042. In this ship the foremost is stepped to starboard so that from this angle only the luff edge of the foresail can be seen.
Fig. 991. The Chinese Taoist statuette, c. 4 in. high, found in 1879 at Port Darwin in Australia among the roots of a banyan tree at least 200 years old (photo. Fitzgerald). See p. 537.

Fig. 995. A 'seaman's doll' or sand-glass (po-li lou) in Chinese use, the illustration in the Liu-Chih-Kuo Chih Lüeh of +1777. Whether or not Chinese mariners had the sand-glass before the middle or end of the +16th century remains doubtful, and it is surely more probable that what they used for their watch-keeping in Thang, Sung, Yuan and Ming times was the pyro-chronometer or combustion clock constituted by the carefully made incense-stick (cf. Bedini, 5, 6). This was very common in temples, yamen and homes ashore, and would have been highly convenient at sea. Cf. Vol. 3, p. 330, Vol. 4, pt. 2, pp. 127, 46, 528.
Fig. 1000. Part of a register of navigational constellations contained in an anonymous MS. MS., cutter entitled Chih Nan Chhing Fa (General Compass-Bearing Sailing Directions) and appended to a military and naval encyclopaedia, the P’o-chhien (Key of Martial Art), by Lü Phan & Lu Chhîng-En (+1660).

From left to right:
1. Nan tou (Southern dipper) = Tou hu, six stars in Sagittarius.
3. Hsin hsiu (Imperial baldachin), sixteen stars in Cassiopeia and Camelpardus.
4. Pei tou cheng hsiung (Star in the midst of the Northern dipper). A sailor’s name; possibly Thai yang shou (Bright guardian) = y Ursae Majoris.
5. Niu lang hsiung (Herd-boy) Altair in Aquila, and two neighbouring stars.
6. Chih nǐ (Weaving girl), Vega in Lyra, and two neighbouring stars.
7. Têng lung (Lantern), the Southern Cross, four stars in Crux Australis.

All but three of these entries (nos. 2, 5 and 6) include rising and setting azimuth points, though not altitudes. Photo. Bodleian Library.

Fig. 1001. Chinese terrestrial globes; the David Globe (now in the British Museum), made in +1633 under the guidance of the Jesuits Emmanuel Diaz (Yang Ma-No) and Nicholas Longobardi (Lung Hua-Min), whose names appear as signatures of the inscription in the cartouche on the globe’s under surface.

A partial translation of this is given in Wallis & Grinstead (i). Looking at China as the centre we can see the outlines of Korea and Japan, Indo-China, Malaya, Sumatra, Java, Borneo and New Guinea, but not Australia. Far on the left the outlines of the Red Sea, Arabia, the Persian Gulf and the Caspian can also be made out. Far on the right at the bottom can be seen a group of islands which represents the Solomon, discovered by Mendels in +1568, and the New Hebrides, Quiros’ ‘Australia del Espiritu Santo’ of +1606.

The geography of the globe embodies notable improvements upon the world maps made in China by Matteo Ricci (Li Ma-Tou) between +1584 and +1603. Among other things it registers a very early record of the discovery of the Torres Strait, which as late as +1770 remained unknown to all but a few European cartographers, and it recognises the archipelagic nature of the land east of New Guinea. Now that this too was known to be an island, Diaz and Longobardi and their Chinese colleagues were probably very uncertain about the existence of a southern continent, the presumed ‘Magellania’, so they found it convenient to use the space for their inscription. Dutch exploration of the Australian coasts had in fact been going on in +1606 and from +1616 onwards, but of this they did not know. Yet they placed the Antarctic continent well south of South America, so they may have heard of the Dutch discovery of Cape Horn in +1616.

The globe, 1 ft. 11 in. in diameter, is made of painted lacquer on wood, to a scale of 1:21,000,000. The mounting shown is Copernican (inclined) but the globe has now been remounted in its original Ptolemaic (vertical) manner.
Fig. 1002. Chinese terrestrial globes; the Rosthorn Globe (in the Österreichisches Museum für angewandte Kunst at Vienna), undated but attributable by internal evidence to the period +1650 to +1770. Just under 1 ft. in diameter, it is made of silver sheet metal on which the outlines and inscriptions were incised before being covered all over with translucent cloisonné enamel in bright colours. Around the South Pole the times in different parts of the world are given in Chinese double-hour signs (cf. Vol. 4, pt. 2, pp. 439, 461; Needham, Wang & Price (3), p. 200). Instead of political boundaries, the ‘rectangles’ formed by the meridians and parallels are depicted in different colours, e.g. on Australia, and Russia (O-I0-ssu Ikuo).

The place-names are meant to be read with the south pole uppermost, but here and in the following two illustrations we present the photographs in the usual orientation. China, central in this picture, is portrayed in two colours, light for ‘Cathay’ north of the Yangtze, and dark for ‘Manzi’ south of it. Indo-China lies well enough below, but the East Indies are badly drawn, Sumatra being placed too far west and Borneo intervening between Malaysia and Java, with New Guinea joined to Australia. The Indian peninsula is clear, the words Pang-ko-Ia Hai (Bay of Bengal) prominently appearing east of it, and on the far left one can make out the mouth of the Indus (Yin-tu Ho), the Persian Gulf, Arabia and the Red Sea.

Fig. 1003. A closer look at Australasia on the Rosthorn Globe. On the continent itself there are three chief inscriptions; in the north-west Wei-té-ssu (de Witt’s Land), and in the north-east Tieh-mén-ssu-an (van Diemen’s Land) surrounded by conventional drawings of rocks or mountains—and in fact Australia is joined to Tasmania. In the south we read ‘The new Western records say that this is New Holland (Hsin Wu-a-lang-ti-yu); a great continent all desert with nobody living there’; To the north Timor and the Celebes are roughly inserted, with a bloated Groote Eylandt in the Gulf of Carpentaria. Off Exmouth Gulf and the North-west Cape a large sausage-shaped island is shown, conceivably intended for the Cocos-Keeling Islands, discovered in +1609, or even for Christmas Island, first marked in +1666. Off Perth there is another, which might be meant for Rottnest Island, enormously magnified. North of the equator, which runs correctly through the middle of Borneo, the Philippines are shown as a too scattered conglomerate, while at the bottom on the right are the Solomons, etc., all individually much too large.
Fig. 1004. A closer look at China on the Rotthorn Globe. As mentioned already, the provinces south of the Yangtze are done in dark colour, those north of the River in light, and since north is here at the top, the Chinese place-names are all upside down. The Gobi desert is represented by the broad scaly-patterned band running north-east-south-west and labelled Sha-mo. To the left, at the edge of the light-coloured square, is marked Thu-lu-fan (Turfan in Sinkiang). In Manchuria we can see, among other names, Heilungjiang, Kirin, and Tou-erh-po-nd, i.e. the land of the Durbet Mongols, one of the four tribes or groups of banners of Inner Mongolia (cf. Gilbert (1), p. 907). The Korean peninsula, in light colour, is adequate, but Japan is badly drawn, having Kyushu hooked to the north; moreover Sakhalin, instead of being an island, appears as a fat black peninsula. Between Japan and Korea, Tsushima Island (Tui-ma Tao) is prominently marked, and Quelpart (Cheju) Island also appears among several that are unmarked. Further south the Lia-Chih island chain appears as a light-coloured lump just to the left of the 130° meridian, with a landmark, Pe-chhung Shan (the eight mountain idea) clearly incised on the billowing sea.

In China itself the Yellow River is following course and discharging through the mouth of the Huai, though the old northern course is partly shown. A row of scale-like dots similar to those used for the Gobi desert traces the course of the Great Wall, with Peking (Ching Shih) just south of it. The light-coloured country north of the Yangtze bears provincial names such as Shantung, Shanxi, Shensi and Kansu, clearly visible, but the southern provinces are so dark that no names can be read; the country between the Huai and the Yangtze is of an intermediate colour but has no inscription. South of Kuangtung, however, some places are marked in the sea, notably Ao-men (Macao), the Thousand-mile Shoal (cf. Vol. 4, pt. 1, p. 284), and an island called Pheng which should stand for the Pheng-Hu or Pesadarees Is. between Thaivan and southern Fukien, but seems here to include Thaivan itself. Hainan I. is also shown. All these are just outside the frame of this picture, but faintly visible in Figs. 1002 and 1003.

Fig. 1010. The mainsail of a Ta-pu-thou freighter (cf. Fig. 987) drawing nicely on a wet and windy day off the coast of Shantung (from the Waters Collection, National Maritime Museum, Greenwich). The details of the rig come clearly out. In the foreground there are the multiple sheets, with two of their euphroes visible, all attached to the leech ends of the battens, where the bolt-ropes can be seen along the sail edge. Behind them to port and starboard we see three ropes of the topping lift system (1, 1 in Fig. 1009a), and further away to port the feed of this, which includes a twofold purchase. The halyards (J, J in Fig. 1009a) are on the other side of the mainsail, but the four main sheets of the foresail (and even the crowfoot convergence to the lower euphore) can be seen descending to their baying-cleats on the port side of the deck (cf. Fig. 987). Three figures near by give the scale. The halyards of one of the mizen masts run up on the extreme left of the picture. On the starboard side an old-fashioned lantern appears.
Fig. 1011. Details of the sail leech edge of an Antung freighter visiting Wei-hai-wei (from the Waters Collection, National Maritime Museum, Greenwich). The attachments of the multiple sheets to the batten ends, the auxiliary bamboo batters, the bolt-ropes (N, N in Fig. 1009a), and the patched canvas can all clearly be seen.

Fig. 1012a, b. A Pao-chhing Chhiu-tzu freighter under sail, seen from the great bridge over the Hsiang Chiang (R.) at Hsiang-chun south of Chbangsha in Hunan (orig. phot., 1964). A description and scale drawing of this smart and well-appointed type of river-ship, c. 75 ft. long, and named after a city (now Shao-yang) on a tributary, the Tsu R., is given by Worcester (3), vol. 2, p. 431, pl. 156. Here one can see many things, the prominent balanced rudder, the multiple sheets, the parrels securing the sail to the mast, halyards and secondary halyards, the ropes of the topping lift, some of the hauling parrels (cf. Fig. 1014), the lumber irons that bridge the mat-roofed cargo deckhouse, and the old-style capstan amidships forward, worked with rough handspikes and used both for hoisting sail and weighing the anchor. The large empty pottery jars which form part of the freight are similar to those universally used for the complicated preparation of 'soya-bean sauce' (chiang yu), on which see Sect. 40.
Fig. 1013. A Yangchiang fishing-junk becalmed, showing the extreme rounding of the sail leeches which is characteristic of the southern Chinese coast (from the Waters Collection, National Maritime Museum, Greenwich). The yard, battens and boom are all gathered towards the base of the luff edge, so that the lug-sails look at first sight like radial fans. The multiple sheets, which in the case of the mizen sail are attached some way short of the leech edge, are clearly seen, and topping lifts, parrels and hauling parrels can also be made out. An unusual feature of these ships is the prominent masts stays, perhaps adopted from European practice (cf. p. 401), in any case useful on the edge of a typhoon. In build, the stern recalls that of Hongkong junks (cf. Fig. 1044), the strakes being gathered by scarf joints so that the aftermost transom is relatively small, but this is hidden by a false aft transom under the projecting stern gallery. A great slot is left for the slung rudder, which here is deep in the water.

Fig. 1014. The foresail of a Yangchiang fishing-junk, just set, to show more clearly the nature of the rig (from the Waters Collection, National Maritime Museum, Greenwich). The sail shapes and mast stays are as expected from Fig. 1013, but one can now see better that the battens are connected by a number of radial ropes which help to keep them just the right distance apart. The topping lift system is well seen, but also the four heavy wire parrels, preventing the natural tendency of fore-and-aft sails to move forwards, as does the heavy strop from the boom which is taken several turns round the mast. Further to be made out is the complicated reeving of the hauling parrels (cf. Worcester (3), p. 71), which assist in holding back the sail and preserve its balance; the system seems close to variant C in Worcester’s pl. 15. The multiple sheets are of course hidden, but the purchase block of their feed can be seen behind the figure in shadow. A second is sitting at the beakside beside the two anchors, a one-sided side anchor and a Chinese non-fouling anchor with the stock at the crown (cf. p. 557). Behind, the mainsail is just being hoisted, coming up grandly out of its pleats.

Fig. 1015. A Chiangsha sprit-sail sampan on the Hsiang River (orig. photo. 1964). Description and scale drawing in Worcester (3), vol. 2, p. 442, pl. 167. Even so small a sail as this has multiple sheets, as can be seen.
Fig. 1018. An Indonesian pra-o-mayang, showing the characteristic canted square-sail rig (drawing of Adm. Paris). The steering-oar is also to be noted. In this picture the vessel is seen sailing as near the wind as possible, but by the direction of the flag the angle can hardly be much better than 70°. Nevertheless the canted square-sail is to be regarded as the first step in the development towards fore-and-aft sails.

Fig. 1019. A fishing-junk from Tolo Harbour (Thu-lu-wan, the great eastern inlet in the Hongkong New Territories) using a canted square-sail as a kind of spinnaker in addition to the two usual lug-sails (from the Waters Collection, National Maritime Museum, Greenwich).

Fig. 1020. A small boat of the Kuala Trengganu fishing fleet (North-eastern Malaya) running for port before the afternoon wind from the sea (photo. Hawkins & Gibson-Hill). The foot of the canted square-sail is here placed so far to starboard, or at least amidships, that it almost approximates to a lug.

Fig. 1023. Working a small lighter (probably at Canton) by the use of the self-feathering scull oar (photo. Fitch, 1927). The motion of this yuloh, which pivots on a fulcrum and is attached to the deck by a short length of rope, amounts to that of a reversible screw propeller. See pp. 622 ff.
Fig. 1024. A boat being tracked upstream in one of the rapids in the Yangtze gorges near Chungking (photo. Potts, c. 1938).

Fig. 1025. Pa Chhuan Hoa Hsia Thu (Boats descending the Gorges out of Szechuan), a painting by Li Sung, c. 1525 (Ming copy). The sling rudder and the outboard thole-pins for the yulaha are noteworthy.
Fig. 1027. The deck of a Swatow freighter, looking forward (from the Waters Collection, National Maritime Museum, Greenwich). In the foreground the massive iron-bound slung rudder can be seen entirely out of the water and stowed on the poop, since the vessel is at rest in harbour.

Fig. 1029. A stern-sweep with tiller, of ancient Egyptian type, still in use on the Ganges in India today (photo. Crebick, t).

Fig. 1030. One of the two oldest depictions of an axial or stern-post rudder in Europe, the carving on the font at Zedelgem in Belgium, dating from c. 1180. It illustrates some legend of the saints, just as do the story-pictures in the Tunhuang frescoes.
Fig. 1032. Two passenger-carrying river-junks with stayed biped masts moored side by side in the mists of evening outside a city wall; a fan painting attributed to Ma Ho-Chih, c. +1170 (in the Suzuki Collection, reproduction from Harada & Komai). Both ships show balanced rudders, but that on the left more clearly, than the right being obscured to some extent by a bundle of poles, perhaps a fender, hanging over the side.

Fig. 1034. Details of the slung and balanced rudder system of one of the cargo-boats in the Chhing-Ming Shang Ho Thu (Coming up the River to the Capital after the Spring Festival), painted by Chang Tsé-Tuan c. +1125.
Fig. 1035. Ku Khai-Chih's painting of a ship, done about +380 to illustrate the poem of Tshao Chih 'Diaspodic Ode on the Nymph of the Lo River', written c. +230. None of the early copies, nor the original, survive, so the illustration is of a Sung (+12th-century) copy preserved in the Freer Gallery of Art at Washington. There has been much speculation about the structures at the stern, which may or may not be evidence for an axial rudder as Ku Khai-Chih saw it, or as his copyists misinterpreted it. Archaeological evidence now strongly indicates that he was trying to depict one (see text, p. 649).

Fig. 1036. Stern view of the grey pottery tomb-model ship of the +1st century excavated at Kuangchow (photo. Canton Museum, cf. Figs. 963, 964, 965). The attachment of the axial rudder, with its eye for the slinging tackle, between the timbers of the floor of the after-gallery, is well seen.

Fig. 1037. Pages from my notebook with sketches of the shape and mode of attachment of the rudder of the +1st-century tomb-model ship, made in the Canton Museum, 1958.

a Shape and relative dimensions taken from photographs.

b Manner in which the shung rudder was secured within the after-gallery.
Fig. 1038. The ship of the great minister Sugawara no Michizane taking him into exile c. +902; a scroll-painting preserved in the Ueno Museum and said to be a copy of an older painting by Fujiwara no Nobuie (d. +1264 or +1265) still in the Tenmangū at Kyoto (the Shinto temple dedicated to Sugawara as god of learning). In general build, and particularly in the shape and position of the rudder, this vessel distinctly recalls the Canton model ship of the 11th century. As in the ship sketched in Fig. 1033 (b) the sailors are rowing backwards on outboard projections, not forwards as in China. Reproduction from Purvis (i).

Fig. 1039. Ship in a +1237 MS. of the Maqamat of al-Hariri (Bibliotheque Nat., Paris, Ar. 5847). The axial, presumably stern-post, rudder seems to be provided with some kind of lateral control. It is natural to think of the Arabs as having been the transmitters of the invention of the axial or median rudder to the Europeans, but no illustrative material of the required time, the +12th century, has so far come to light.

Fig. 1040. A freighter or grain-carrier of Hongkong and other ports of South China (model in the Mate Collection, Science Museum, Kensington). Anon. (17), no. 3. The relieving tackle for the tiller is well seen at the stern. Ships of this kind are intermediate between the Chinese and European traditions, for they have hulls with keels and sternpost, as here shown, while rig and rudder follow Chinese practice. The stern view of a ship such as this would be similar to those seen in Figs. 1013 and 1044. On hybrid types cf. pp. 433 ff.
Fig. 1042. The massive slung rudder of a Fuchow timber freighter stowed in the after-castle when in port (from the Waters Collection, National Maritime Museum, Greenwich). Cf. Fig. 936 and the drawing in Fig. 1041.

Fig. 1043. The rudder of a Mau-yang-teu (cf. Figs. 932, 933 and Worcester (1), pl. 1) seen in a shipyard on the Upper Yangtze (photo. Spencer, A). This beautiful shape, fitted on the right to the curve of the hull, is the Chinese balanced rudder _par excellence._
Fig. 1044. The stern of a Hongkong fishing vessel in dry dock, showing the fenestrated rudder characteristic of many types of Chinese ship (from the Waters Collection, National Maritime Museum, Greenwich). The figures of workmen give the scale, and another fenestrated rudder being re-bladed is seen on the right.

Fig. 1050. A reconstruction of one of the armoured 'Turtle ships' used by the Korean naval forces under the admiral Yi Sunsin against the Japanese in the last decade of the 16th century. The model is in the National Historical Museum at Peking (orig. photo. 1964). Cf. Underwood (1), figs. 46-9. It is believed that at least two masts were used, but lowered before battle through a central fore-and-aft slot in the armoured roof (not shown in this model) by some method of striking such as that described in Worcester (3), vol. 1, p. 79.
29. NAUTICS

the Tène age. Brindley (10) has studied a bronze-age anchor which would be about contemporary with the Homeric mentions, and from about -500 onwards the anchor of the Mediterranean peoples had attained approximately the familiar form, as is known from many coins on which it appears. The stock, however, was absent in the earlier periods. That a parallel evolution of forms occurred in China can be deduced from the names employed. The earliest expression for casting anchor was *hsia shih,* and the stone-weighted grapnel was called *ting,* sometimes written *ting.* It was simply made by binding from one to four forked branches together with a piece of stone, and this lasted long in use; we saw it above on the Bayon junk of +1185 (Fig. 975, pl.). When the use of metal hooks was introduced, these words were replaced by *mao* (or *miao*), combining the idea of the shoots of plants or the claw of a cat with the metal radical, but the sound was perpetuated in *ting,* though the original and still more general meaning of this is an ingot. The Yü Phien dictionary of +543 seems to be the first in which the word *mao* appears, and if this may be taken as evidence that metal anchors were not used much earlier, their introduction in China would have occurred later than in the West.

Nevertheless the Chinese made a contribution of some importance to the development of the anchor. The most characteristic of their forms is the adze anchor, i.e. an anchor made in such a way that the arms form an acute angle with the shaft (about 40° or less) at the crown instead of diverging from it at a right angle or in an arc. Such forms were not unknown in Europe (the Roman temple-ships or barges on the Lake of Nemi had them), but the Chinese passed the stock across the shaft not at the ring end but near the crown end (also of course at right angles to the plane of the arms). This serves the purpose of canting the anchor and ensuring that the arms bite, but it has also the great advantage of being almost non-fouling. The efficiency of this device was often

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*a* Feldhaus (7), col. 930. A stone and metal anchor from the Swiss lake-dwelling culture is in the museum at Biel.

*b* But Odys. xiii, 77, refers to a stone with a hole in it. On this kind see Frost (1), pp. 29 ff.

*c* This still occurs in the travel account of Fa-Hsien, c. +444; cf. the discussion between Brindley (11) and van Nouhuys (1), to which the intervention of a distinguished sinologist, Giles (10), brought little enlightenment; indeed he quite misled Moll.

*d* An early mention of the stone-weighted grapnel or killick is associated with the name of Huang Tsu,* a commander of the San Kuo period (early 3rd century), but Worcester (3), vol. I, p. 97, failed to give the exact reference, and we have not found it.

*e* It is mentioned also in the Kao-Li Tzu Ching (ch. 34, p. 4b) earlier in the same century. The contemporary Norman ships depicted on the Bayeux tapestry are said to show the earliest flakes of modern type on their iron anchors (des Noettes (2), fig. 65).

*f* Van Nouhuys (4), p. 37; Moretti (1). The dating of these ships to the reign of the emperor Caligula (+37 to +41) has been confirmed by radiocarbon analyses (Godwin & Willis; Godwin, Walker & Willis).
praised by European nautical writers, and during the nineteenth century it was several times 're-invented', with addition of hinged stocks (Hawkins, 1821; Piper, 1822; Porter, 1838), so that some of the most modern 'stockless' types, such as the Danforth anchor, derive originally from the Chinese rather than the Graeco-Roman form. We can trace the Chinese adze anchor back through the Fukienese Shipbuilding MS. (Fig. 1045) not only to the +17th-century Wu Pei Chih (Fig. 1046) but to the +1st century in the Cantonese tomb-model ship of Fig. 964 (pl.).

Anchor windlasses (i.e. vertically mounted drums) are mentioned several times in the Kao-Li Thu Ching and those on the larger Chinese 'retainer ships' which carried the personnel of the embassy he speaks of as shen lun. The rope which was wound on the drum (phai ting) is called 'ship's-self' (phai ting). The crew holds the hawser by a stock (ting) when danger is imminent; its hawser is called 'water-eye' (shui yen).

A very different form of mooring is commonly found in use by the smaller river-junks and sampans; it consists of a trunk or tube built into one or more of the compartments of the vessel. Through this a weighted pole is driven down into the mud of the lake or river bottom. Known as the 'watchdoug' (khan chi goo) it is operated as follows: The heaviest weighs about 500 catties and is the 'water-eye' (shui yen), it is used in stormy weather at sea. In fact, they must then have been what they are now, large bamboo baskets, in the use of which no sailors are more skilled than the Chinese.

Sung Ying-Hsing has this to say of the anchors of the inland grain-transport freighters:

Anchors of iron are dropped into the water to moor the ships; a grain-boat usually has five or six. The heaviest weighs about 500 catties and is called the 'watchdoug' (khan chi goo). In addition, two small ones are slung both at bow and stern. When a ship in midstream meets with too strong an adverse breeze, so that she cannot go forward, and also cannot tie up anywhere, the river-bed near shore is rocky instead of sandy, and one cannot approach the shore, then one must anchor in deep water letting go the hook so that it sinks (quickly) to the bottom. The hawser (hai yu) of the anchor is wound round the bollards (chiao chia mu) on the deck (and made fast to them). When the flukes (choo) or the anchor the mud and sand of the bottom they dig in and hold securely. The 'watchdoug' is resorted to only when danger is imminent; its hawser is called 'ship's-self' (phai ting) in order to indicate its importance. Or again, when the boat is under way in company and seems likely to collide with another vessel ahead which has had to slow down, the stern anchors are simply lowered into the water to check the speed. As soon as the wind abates, the anchors are hoisted by means of a winch (yin chhe)
29. NAUTICAL TECHNOLOGY

'stick-in-the-mud anchor' is at least as old as the Sung, for paintings of that period show it, but it is ancient in many parts of the world from New Guinea to 6th-century Holland. The principle is still used in modern dredgers.

To study the construction and layout of harbours and docks in Chinese history would require a whole chapter to itself, all the more difficult to write in that we have come across no studies of the subject either by Chinese or Western scholars. One question of marked technical interest may however be raised, namely the development of dry docks for building and repair. The European aspect is a little obscure. For Darmstätder (t) the first dry dock in England, and probably, he thought, in the Western world, was that made at Portsmouth for Henry VII in +1495; it had no gates but was closed by piling filled in as required. Straub, on the other hand, puts the first dry docks in de Bélidor’s time (c. +1710). Neuberger & Forbes, as well as others, have claimed Alexandrian credit, even to the 3rd century, but the more recent survey of Goodchild & Forbes brings nothing to substantiate this. In any case, we have excellent evidence for the invention in the Sung period, with a circumstantial account from the pen of Shen Kua:

At the beginning of the dynasty (c. +962) the two Chê provinces (now Chekiang and southern Chiangchou) presented (to the throne) two dragon ships1 each more than 200 ft. in length. The upper works included several decks with palatial cabins and saloons, containing thrones and couches all ready for imperial tours of inspection. After many years, their hulls decayed and needed repairs, but the work was impossible as long as they were afloat. So in the Hsi-Ning reign-period (+1068 to +1077) a palace official Huang Huai-Hsin suggested a plan. A large basin was excavated at the north end of the Chin-ming Lake capable of containing the dragon ships, and in it heavy crosswise beams were laid down upon a foundation of pillars. Then (a breach was made) so that the basin quickly filled with water, after which the ships were towed in above the beams. The (breach now being closed) the water was pumped out by wheels and pumps. The upper works included four square towers, the fronts of which were all that was still standing. Though otherwise and inside lights must have been used on a small scale in China, literary references generally speak of them in connection with foreign ports. Thus Chia Tan2 the geographer, writing between +785 and +805, says, in his description of the sea route between Canton and the Persian Gulf, referring to some place near the latter’s mouth, that the people of the Lo-Ho-I country have set up ornamental pillars (hua piao) in the sea, on which at night they place torches (chü) so that people travelling on board ships shall not go astray.

Independent confirmation of lighthouses in the Persian Gulf for a century later is available in Arabic authors such as al-Masudi,3 and al-Muqaddasi.4 It is perhaps of interest to read what a Chinese writer said of the Alexandrian Phars in +1225:

The country of O-Kên-Tho5 (Alexandria) belongs to Egypt (Wu-Ssu-Lí). According to tradition, in olden times a stranger (t jen), Chhu-Ko-Ní6 by name,7 built on the shore of the sea a great pagoda, underneath which the earth was excavated to make two rooms, well connected and thoroughly hidden. In one vault was stored grain, and in the other arms. The tower was 200 ft. high,8 four horses abreast could ascend (by a winding ramp) to two-thirds of its height. Below the tower, in the middle, there was a well of great size connected by a tunnel with the great river. To protect this pagoda from foreign soldiers, the whole country guarded it against all enemies. In the upper and lower parts of it twenty thousand men could readily be stationed as a guard or to make sorties. At the summit there was an immense mirror, and if

E.g. TP Yü, ch. 333, pp. 54 ff. But when the forts were on a coast or waterside there was a gain to shipping because the universal practice was to keep one light burning perpetually in time of peace. The Thai Pui Yo Ching (+795) says: ‘Every night when all is well one light is lit. If there is an alert the watchmen light two, when smoke or dust (etc.) give warning of an enemy’s approach they light three, until six times, when a great alarm is given. When the light is not seen, the watchmen must have been captured by the enemy’ (ch. 46. p. 24). Similar beacons announced the arrival of the Chinese embassy to Korea in +1124 (Hidam-Ho-Feng Shih Kao-Li Thu Ching, ch. 55, p. 26). By +1563 there were no less than 711 beacon stations along the coasts from western Korea to northern Chiangchou (Chhau Hai Thu Pien, chs. 3-6). Gandas (i), pp. 18 ff., describes the watch-towers on artificial mounds (tung) still used in northern Chiangchou in the late tenth century for giving warning of tidal waves as well as pirates. For Chinese material we have unfortunately nothing comparable with Rosani’s monograph (1) on maritime lights and signals. But information on naval formations, signals and combat positions is contained in Yu Chhia-Hsi’s Fang Hui Chi Yuan, ch. 14 (1823).

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2 See Forster (t); Neuberger (t), p. 245; Feldhaus (1), col. 6424; de Camp (2), etc. 3 Hsin Thang Shu, ch. 438, p. 188, tr. Hirth & Rockhill (t), p. 13. The location seems to be the coast of Baluchistan (Mehran). 4 Ty, de Meynard & de Courteille (t), vol. 1, p. 230. 5 Ty, Rocking & Azos (t), p. 17. 6 Chau Ju-Kua in Chhau Fan Chih, p. 356, tr. Hirth & Rockhill (t), p. 146, mod. auct. Cf. Fig. 985. 7 Ta Chung, 3. Col. 5. (b) The ‘be of the horns’. 8 Tr. de Meynard.

a Amending chang (10 ft.) to chüh (1 ft.).
warships of other countries tried to make an attack, the mirror detected them beforehand, and the troops were ready to repel it. But in recent years there came (to Alexandria) a foreigner, who asked to be given work in the guardhouse below the tower, and he was employed to sprinkle and to sweep. For years no one entertained any suspicion of him, but suddenly one day he found an opportunity to steal the mirror and throw it into the sea, after which he made off.

With this background it is rather interesting that one of the most famous Chinese lighthouses was the minaret of a mosque in Canton. This was the Kuang Tha of the Huai Sheng Sau, and we have already come across it, with its golden cock at the top of the tower, in connection with parachutes. A detailed account of the buildings was given by Chihou Chih-Shih at the beginning of the nineteenth century, in words based partly on a much older description, that of Fang Hsin-Ju in his Nan Hai P'ai Yang (A Hundred Chants of the Southern Seas), written about +1200. Rising to a height of 165 ft., it was called the 'Light Tower' apparently because a light was kept burning at the top to guide shipping. It was first built in the Thang by foreigners, our authorities say, and had a spiral staircase inside it. Each year in the fifth and sixth months the Arab foreigners used to assemble to scan the estuary for their sea-going barques, and then at the fifth drum they ascended the tower to shout prayers for favourable winds. In +1468 the Imperial Censor Han Yung caused the minaret to be repaired, and arranged it for sending official messages, presumably by lights. However, Buddhist pagodas also served occasionally as lighthouses. The Hung-chou Pu Chih says that the Liu-Ho Tha on the Chhien-thang River was equipped with a permanent light from the early Sung onwards to guide ships seeking their anchorages at night. Thus two at least of China's religions contributed something as the equivalent of the Brethren of Trinity House.

(a) Towing and Tracking

Mention has often been made above of the tracking of junks up rivers in China. For anyone who has lived near one of the great Szechuanese rivers, the Chialing at Chungking for example, the cries of the trackers, and the sound of the drums which give them the time, remain among unforgettable memories. No natural difficulties defeated the Chinese boatmen, as can be seen from Fig. 88o (pl.) which shows one of the towing galleries along the gorges of the Yangtze. Teams of as many as a hundred men may be employed in the most difficult places. Fig. 1047 shows salt boats being tracked upstream in Szechuan. The paintings of Haia Kuei (+1180 to +1230) are often cited as evidence of tracking before the time of Marco Polo's description (p. 466 above), but we have much earlier representations, such as those among the Tunhuang frescoes (Fig. 547, Vol. 4, pp. 311 in Vol. 4, pt. 2). A possible relation between the trackers' cloth-band harness and the development of the efficient harness for draught animals has already been suggested at the same place (p. 312). In tracking (la chhien), the cable (jo) is secured to a cross-beam aft, whence it passes to the mast and runs through a cast-iron snatch-block. This can be raised or lowered by halyards; normally it hangs at about one third of the height of the mast, but when overtaking another boat it is hoisted above.
to the masthead. The bamboo cable used for tracking has already been mentioned in other connections; one of its remarkable qualities is that while hemp ropes lose some 35% of their strength when wet, this plaited bamboo undergoes on saturation with water an increase of tensile strength of about 20%. Tests by Fugl-Meyer showed that a cable of 14 in. diam. would take a load of nearly 5 tons when dry and about 6 tons when wet. 

(3) Caulking, Hull-sheathing and Pumps

The means used by traditional Chinese shipwrights and sailors to render hulls watertight have been referred to from time to time in foregoing sub-sections—generally speaking the classical mixture for caulking was essentially the same as that used by the brine-works engineers of Szechuan for the conservation of wood in ships and buildings; from this and other purposes long before their employment for the latter. Moll (3) has attempted to write the history of the conservation of wood in ships and buildings; from this and other connections we know that the Romans tried sheathing ship bottoms with lead, as in the galley of Trajan on Lake Riccio (described by Alberti), and in the temple-ships of Lake Nemi. This, however, was only exceptional; and no examples of sheathing are known from the Middle Ages. Lead was tried again in Europe about 1525, but soon abandoned in favour of sheathing with a layer of boards (cf. p. 468) often with horsehair packing; then from +1758 copper plates began to be widely employed. 

Attention a On all details, see Worcester (1), pp. 13 ff., (2), vol. 1, pp. 42, 62 ff., vol. 2, p. 296. Tracking by men along the river-sides lasted in France till 1830, so it is not surprising to find Gallo-Roman bas-reliefs which show it, but one does feel some surprise in finding that they also attached their cables to the mast (Benoit (2); Bonnard (1), fig. 18, opp. p. 240; Pobé & Roubier (1), pl. 210).

b Ontp. 191, 248, 249.


e Described in the book of techniques written by the monk Lu Tsang-Nien about +580, the Wu Lei Hsiang Kam Koi (On the Mutual Responses of Things according to their Categories), (p. 31). Quoted recently by Li Chiang-Nien (1), p. 76, no. 94.

f See Lane (1).

g Neuburger (1), p. 428, referring to Athenaeus, Deipnosophists, v. 40.

h Moretti (1); Ucelli di Nemi (1, 2).

i Or so it used to be thought, but the -3rd-century Greek merchant-ship sunk off Marseille which has been investigated by divers had its hull and (apparently part of its deck) completely covered with 60 tons of lead plating secured with lead-coated copper nails (Cousteau, 1).

j Charnock (1), vol. 1, p. 101; vol. 3, p. 201; de Lortue & Hafliner (1), p. 103; Clowes (2), pp. 93, 104. As also frequently on Chinese sea-going junks of the +18th century, if not rather earlier (see Chao Chchia-Chieng, 1). There was always much trouble with electrolysis where the copper came in contact with the iron of the nails.

1 水 池
2 柳 棨
3 伽蓝相和志

29. NAUTICAL TECHNOLOGY was drawn by Julien (4) to the fact that Chinese writings of the early +4th century refer to the covering of junk bottoms with copper. Thus the Shih I Chi, by Wang Chia, referring to an embassy from the Ch‘en-Chhiu kingdom in the legendary reign of Ch‘heng Wang, says: "Floating on the seething seas, the ambassadors came on a boat which had copper (or bronze) (plates) attached to its bottom, so that the crocodiles and dragons could not come near it." Here the defence against organic life is clearly mentioned, and the passage would seem to prove that the idea, at least, existed in Wang Chia's time. Another Chin book, the Chiao-chou Chi\, by Liu Hsin-Chi, says that at Anting a copper or bronze boat which had been built for the King of Yüeh lay for a long time buried in the sand, where it could be seen at low tide. It has now been shown that stories of metal boats occur abundantly in the early Chinese literature of folklore and legend. They are particularly common in South China and Annam, where they often form part of the epic exploits of the Han general, Ma Yuan, who restored the far south to Chinese allegiance in the campaign of +42 to +44. The bronze or copper boats of which people see the vestiges are thus associated with the setting up of bronze columns to mark the southern limits of the empire, the casting of bronze oxen as landmarks, and the building of canals to shorten sea voyages or make them more safe. The evidential texts date from all periods between the +3rd and the +4th centuries, but the only one which specifically mentions the bottom of a ship is the early +4th-century Shih I Chi. Although it is quite possible, as sinologists tend to think, that the idea of using metal in the construction of boats was purely magical and imaginary in origin, it is at any rate equally possible that some southern group of shipwrights in those ages had the services of smiths who beat metal into plates fit for nailing to the hulls of their craft to protect the timbers. If so, the copper-bottomed junks of the +18th century derived from an indigenous tradition, and not from the Lake of Nemi in the Far West. We even hear of iron boats. In or before the Sung, a book of unknown authorship, the Hua Shan Chi, speaks of a derelict iron boat beside a mountain lake. This was doubtless a further echo of the same legend, or the same technique. But iron armour for warships was no legend, as we shall see (p. 628).
The machines used to keep the hulls of ships dry when afloat have been little studied. The large ship built about –225 by Hieron of Syracuse was said to have been fitted with an Archimedean screw or *cochlea*, worked by a single man, for pumping out the bilges, but the account of Athenaeus seems somewhat fabulous.

After the end of the +16th century the Chinese used piston pumps (*chhou thai chhi*), as Europeans did earlier. But under estecnic conditions such machines were probably much less effective than chain pumps, and indeed we find that Westerners who came in contact with Chinese shipping at this time greatly admired the methods employed. Our earliest statement is that of Gaspar da Cruz, a Portuguese Dominican who was in China for a few months in +1556. After explaining that the Chinese ‘do use in all things more sleight than force’, he goes on to say:

A ship be it never so big, and have it never so great a leak, the pumps are made by such sleight that one man sitting alone moving his feet as one that goeth up a staircase, in very little space he pumps it out. These pumps are of many pieces made in the manner of water-wheels, laid alongside the side of the ship, between rib and rib, every piece having a piece of wood of half a yard (a) little more or less, one quarter well wrought; in the midst of this piece of wood is a square little board, almost of a hand’s breadth, and they join one piece to another in such a manner as it may double well. The joints, which are all very close, whereby this manner of pump doth run, are within of the breadth of the little boards of every one of the pieces, for they are all equal; and this manner of pump bringeth so much water as may be contained between the two little boards.

The same appreciation was manifested by de Mendoza in +1585:

The pumps which they have in their shippes are much differing from ours, and are farre better; they make them of many pieces, with a wheel to draw water, which wheel is set along the shippes side within, wherewith they doe easily close their shippes—for that one man alone going in the wheel, doth in a quarter of an hour cleanse a great shippe, although she leake verie much...

And later it was popularised by Isaac Vossius, and still thought noteworthy at the beginning of the nineteenth century. As we lack clear Chinese descriptions, it is a little difficult to be sure about the type of chain-pump used. At first sight a vertical *sígyah* might seem the most suitable for shipboard, but the description of da Cruz, though (as his editor says) rather incoherent, points unmistakably to an inclined square-pallet chain-pump of true Chinese type (see *Vol. 4*, *pt. 2*, p. 339). Before the middle of the +16th century, then, in this connection at any rate, the Chinese had not been much inhibited by the absence of the piston-pump.

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2. It will be remembered from Sect. 27 that, with certain interesting exceptions, piston-pumps for liquids were not in the Chinese engineering tradition.
5. (*ii*), vol. I, p. 136
6. Bui quopque (Lusitani) observandum in navibus Sinicis quod quaesivi ruinosae fiant et multas admiserint aquas, non tamen mergantur; cum ad uno homine sedente, et tympanum costis navium appositi calcante, spatium unius horae plus aquae extraudit, quam in nostris navibus etiam complures aquae extraudiant (Vol. 4, *pt. 2*).
7. Davis (*i*), vol. 3, p. 82.
8. *The Vessans*.
At one or two points already there has been mention of submersible craft, of course a late development in any civilisation. Here it may not be out of place to refer to the efforts of earlier times to enable human divers to remain under water at considerable depths and for as long as possible. China comes into the story in connection with pearling. In one of the later chapters of the Thien Kung Khi Wu (+ 1637), Sung Ying-Hsing describes the pearl fisheries, which in his time (apart from foreign countries of the south seas) were concentrated near Leichow and Lienchow in southern Kuangtung, north and north-west of Hainan Island. He tells us that the divers (mu jen), who belonged to the Tan, an ancient southern people, worked over special shallow depths, but possibly Chinese divers in the early Ch'ing may have used paired ones with inlet and outlet valves, and a double-acting piston-bellows working in the boat.

But certain jellyfishes, sea-urchins and clams are also greatly feared by Asian pearl-divers; cf. Thomazi (1); Frost (1). Free divers with oxygen can work down to 100 ft. but below 100 ft. deep-water narcosis is to be feared, leading to dangerous errors of judgement. Attached divers with pumping machinery have rarely worked below 300 ft. A single air-pipe would not be much use except at shallow depths, but possibly Chinese divers in the early Ch'ing may have used paired ones with inlet and outlet valves, and a double-acting piston-bellows working in the boat.

The danger from sharks must have been very real indeed. It is emphasised in many of the Chinese literary references, as e.g. most vividly in Shih huo, which was not on the cards.

Sometimes, for tens of years at a time, there was a sort of close season, to allow the pearls to grow.

The history of pearling on the coasts of Kuangtung has been sketched in an interesting paper by Schafer (10), from which we may glean some indications about the techniques employed at different periods. The centre of the industry lay in the Lienchow region, the old name of which was Ho-phu commandery, and here on the coast among islands there were 'pearl lagoons' or indentations of the sea (chu chih) so famous that at one time the whole district was known by that name. This wealth had been exploited at least as far back as — 111, when the armies of Han Wu Ti annexed the islands there were 'pearl lagoons' or indentations of the sea (chu chih) so famous that at one time the whole district was known by that name. This wealth had been exploited at least as far back as — 111, when the armies of Han Wu Ti annexed the

Fig. 1048. Pearl divers in the Thien Kung Khi Wu, ch. 18, pp. 88, 92. The caption says: 'The ship which carries the divers who go down into the sea to collect the pearls.' Breathing-tubes and some kind of masks are in use, but in the corresponding picture of the Ming edition, only the latter are seen.
The province did not produce grain or fruit, but the sea gave forth treasure of pearls. As it bordered on Chiao-chih, there was constant coming and going of merchants and dealers who brought in cereals. Formerly, all the governors had been in general avaricious or corrupt, requiring the people to gather and search (for pearls) without regard for any limit. Consequently the pearl-oysters gradually migrated to the confines of Chiao-chih province. The travellers therefore ceased to come, people were without resources, and the destitute died of starvation in the streets. But when (Meng) Chhang1 took up his office he radically altered the former evil practices, and sought out what would restore the well-being of the community. Before a year was out, the departed pearl-oysters returned again, the people resumed their normal work, and commerce circulated. This was regarded as quite a miracle.

Thus Meng Chhang (perhaps appreciating the true cause of the disappearance of the pearls rather better than the historian) decreed a temporary cessation of pearl-fishing, and stood out as a successful exponent of nature-protection and fisheries conservancy.2 In characteristic Chinese fashion he became later on the tutelary deity of the industry, and long afterwards Thao Pi2 (+1017 to +1050) wrote an inscription for his temple:3

In bygone times good Governor Meng,
Loyal and honest, walked by this distant shore.
He did not rob the wombs of the oysters,
And the waters' depths abounded with returning pearls.

In the +3rd century, after the end of the Han, the pearling districts became part of Wu State, and from this time dates what may be the earliest account of the divers' work. In his Nan Chou I Wu Chih,4 Wan Chen5 wrote:

There are people in Ho-phu who excel in swimming to search for pearls. When a boy is ten or more years of age he is instructed in pearl-diving. The officials forbid the folk to gather pearls (except for the government). But certain skilful robbers, crouching on the sea-bottom, split open the oysters and get fine pearls, whereupon they swallow them and so come forth.

Smuggling was thus keeping pace with government control. And indeed from +228 the whole district had been renamed for a while Chu-kuan,5 i.e. (the domain of the) Director of Pearl-fishing. This official title, persisting centuries afterwards, struck the +9th-century poet Lu Kuei-Meng6 as a peculiar piece of local colour, and he described the far south as a place

Where most of the men are herbalists, and practise mad sorcery,
And the bureaucracy includes a Director of Pearl-fishing, who disburse the salary cash.7

Over the ages the industry was troubled from time to time by waves of Confucian austerity at court which injured all such luxury trades, and during the Thang pearling

a.1 Ch. 28b, pp. 126, 392. Cf. Yen Thien Lu, ch. 2, p. 75.
2. After - 30 the wife and children of an official, Wang Chang, migrated to Ho-phu after his death, where, helped by a local assistant governor, Wang Shou, they amassed great quantities of pearls in a short time (Chhien Han Shu, ch. 76, p. 31a; ch. also TPYL, ch. 80a, pp. 86, 94; tr. Pfizmaier (94), p. 642).
3. Ch. 106, p. 136; parallel passage from another Later Han history in TPYL, ch. 80a, p. 98; tr. Schaefer (10b), mod. auct.
4. Wang Ch.
5. Wang Sh.
6. Wang Ch.
7. Wang Ch.
was stopped several times. No such inhibitions weighed upon Liu Chhang, however, the last of the emperors of the Nan Han dynasty in the Wu Tai period, who stationed a whole division of soldiers near Lienchow and had them instructed in pearl-diving. The texts concerning these men say that they weighted themselves with stones and dived below 300 ft. (which must be an exaggeration), so that one after another died of drowning or sharks. But as soon as the Sung armies took Canton in +971, this use of troops was abolished.

One of the earliest texts which attributes to the Tan people the greatest role in the pearl diving industry is the Thien Wei Shan T'hung Tham. (Collected Conversations at Iron-Fence Mountain) written about +1115 by Tchai Thao. In a long and interesting passage he tells us that the fishermen arrange ten or more of their boats (hat thing) over the pearl beds in a ring, and let down on both sides mooring-cables attached to rocks which lie as anchors on the bottom. Then the Tan diver, having attached a small rope to his waist, takes a deep breath and plunges straight down from 10 to 100 ft., after which he leaves the mooring-cable and feels his way to collect the pearl-oysters (lit. pearl-mothers, chu mu). After what seems only a few moments he urgently needs air, so he gives a big jerk to the waistrope, and the sailors on the boat, seeing the signal, wind this rope in, while at the same time the diver climbs up along the mooring-cable (as fast as he can). From this it would seem that windlasses were employed, and that the waist-rope probably remained attached to the main cable by a smooth loose ring, so that the diver was rapidly brought back to his way of escape when the winding-in began. Tchai Thao continues with a graphic account of the agonies of divers who overstepped by accident the narrow limits of safety, and the means taken to revive them, saying that among those who see and admire pearls in ordinary society, very few have any conception of what it costs to get them. The same emphasis, especially concerning the dangers from sharks and other evil beasts of the sea, is found in the long account of Chou Chhu-Fei in his Ling Wai Tai Ta sixty years later. He adds little to the technicalities however, except to say that baskets are also let down on long cords with the divers themselves, a further precaution since these could be wound in at leisure. One begins to get a picture of slow but continuous improvements in diving technique through the centuries, leading to the inventions of the Ming with which we started.

There is nothing improbable in the techniques described in the Thien Kung Khi Wu. Indeed, they may be quite ancient. A passage from Pao Phu Tsau (c. +320) includes, among magical recipes, the following: "Take a real rhinoceros horn more than 1 ft. long and carve on it the shape of a fish, then put one end in the mouth and enter the water—the water will open out 3 ft. on all sides, and you will be able to breathe in the water." Perhaps this is a concealed reference, in the alchemical manner, to a diver's tube. In any case both breathing-tubes and diving-bells of a kind are alluded to by Aristotle and other ancient writers such as Vegetius. A German ballad of +1190 (i.e. about Li Chao-Thao's time) mentions the breathing-tube of a diver, and the first European illustration occurs in the work of the anonymous Husite engineer about +1430. It is of much interest that between this time and that of Sung Ying-Hsing, Leonardo sketched, in the Codex Atlanticus, a breathing-tube such as was used by Indian Ocean pearl-divers; and this, besides having spikes to keep off fishes, is strengthened against collapse under pressure by just such metal rings as those referred to in the Thien Kung Khi Wu. But the pressure of the water on the diver's lungs must always have been the great limiting factor for the attempt to use atmospheric air. It is therefore interesting that bellows for pumping it down the tube are mentioned in an Arabic work on hydraulic engineering of about +1000, and it would be interesting to know whether the Chinese of the Sung period also used them. The first European mention of a double pipe for breathing in and out occurs in the works of Borelli (+1679), and Huyghens in +1716 combined such pipes with a diving-bell. We have not
so far found any references to the latter in Chinese literature, but the idea was current in Europe much earlier than is generally supposed, and remarkable pictures of ‘diving-bells’, some with breathing-tubes, are to be found in +14th- and +15th-century MSS of the Alexander-Romance. The adventurous king was supposed to have descended into the depths of the sea in a sphere or barrel of glass, emerging safe and sound in the presence of the treachery of his queen Roxana, who let go the cables. The pearl-field of Asia, that continent which Alexander aspired to rule, especially those of India and China, may well have been the original home of all diving techniques, and their early history may have to be discovered from there. Indeed, it has been plausibly suggested that the breathing exercises so prominently associated with Hindu, Buddhist and Taoist meditational, mystical and thaumaturgical disciplines, had a close connection with the practices of the divers who earned a hard living, from antiquity onwards, by ravishing the treasures of an element not natural to man. At any rate, the Buddhist matyra-dharma (law of the fishes) caused pathetic dismay to Alexander, according to one of the legends of his descent:  

Seigneurs, Barons, fait-il, bien je me suis aperçu
Que le monde entier est damné et perdu,
Les violents grands poissons devorent les menus. 

So far we have been thinking only of those natural pearls which were sought at such risk by the Cantonese divers century after century. But there are also cultivated pearls and artificial pearls, the former made by the bivalves under adventitious stimulus, the latter made entirely by man. The invention of cultured or artificial pearls, formed by the implantation of a small foreign body which the oyster then coats with nacre,  

a With the exception of the curious story in the Shih I Chi (Memoirs on Neglected Matters), a book of wonders written by Wang Chih about +370. Here we find (ch. 4, p. 60) the following: ‘Chhin Shih Hung II was fond of matters concerning spirits and immortals. (In his time) people from Yuan-Chhi arrived in “conch-boats” (lo chou). These had the form of spiral conch-shells and made their way on the sea-bottom, no water being able to enter them although submerged (ohem hung hui i, erh shou pu chin fu). Another name for these craft was “under-ows-waves boats” (sun po chou).’ The passage also occurs in collections, e.g. Le Shuo, ch. 5, p. 192. It is hard to know now whether we should treat this kind of report as pure legend and ‘wish-fulfilment’ thinking, or whether it had any basis in diving-bell experiments. Perhaps further evidence will emerge from the texts. Attention was drawn to this passage long ago by items in the Journal des DeBats and the Antiquitatem Rundach; we owe our knowledge of it to the notes of the late Prof. Fritz Jäger, kindly placed at our disposal by Prof. W. Franke. 

The history of the diving-ball has been sketched by D. W. Thomson (1). 

b Reproductions are given by Feldhaus (a), pl. ix and figs. 295, 296, 297, and by Cary (1), pl. vii. On the Alexander Romance see Cary (1); Thomsenk (1), vol. I, pp. 531 ff.; Tarl (1), p. 249. The legendary corpus concerning Alexander the Great is of course quite post-classical; it seems to have started in Alexandria in the +3rd or +4th century, and the early versions are known as pseudo-Callisthenes, since some of them were attributed to the real historian of that name (d. 328), who accompanied Alexander on his Asian campaigns. The corpus passed, with continual accretions, into many Latinizing and European languages. On the descent into the sea in particular, see Cary (1), p. 237, 341. Dr D. J. A. Ross has promised us a literary and iconographic study of Alexander’s bathyscape. Cf. pl. 56 above. 

c On the Persian Gulf industry see Bowen (5, 6); Molker (1). 

d Diot (1), p. 264. See also Vol. 2, pp. 143 ff. 

e Meyer (1); the +15th-century Alexandriade, cit. front. (1). 


g Nacre or mother-of-pearl is a deposit of crystalline calcium carbonate laid down upon a network of protein (conchiolin); cf. Gregoire (1).  

\[ \text{Nacre or mother-of-pearl} \]

\[ \text{Conchiolin} \]

\[ \text{Calcium carbonate} \]

\[ \text{Protein} \]

\[ \text{Crystaline} \]

\[ \text{Network} \]
This makes it clear that in the +18th century, for the great botanist Linnaeus took advantage of it, and acknowledged the origin of it. When a young man he saw fresh-water mussel pearlizing going on at Purkijau on Lake Lulid in Lapland. Twenty years later (+1751) he wrote that he had read of a Chinese method of producing cultured or induced pearls, and in another ten years he had been able to demonstrate the feasibility of the method on the freshwater mussels of Sweden, using small pieces of silver wire together with tiny balls of plaster or limestone. Eventually he sold the process for a substantial sum. The details are related by Gourlie (1), pp. 87, Ch. 18, p. 19b, tr. Schafer (1). The word here used for the oyster came afterwards to signify the tapeworm, but the origin of it is not known. When a young man he saw fresh-water mussel pearlizing going on at Purkijau on Lake Lulid in Lapland. Twenty years later (+1751) he wrote that he had read of a Chinese method of producing cultured or induced pearls, and in another ten years he had been able to demonstrate the feasibility of the method on the freshwater mussels of Sweden, using small pieces of silver wire together with tiny balls of plaster or limestone. Eventually he sold the process for a substantial sum. The details are related by Gourlie (1), pp. 87, Ch. 18, p. 19b, tr. Schafer (1). The word here used for the oyster came afterwards to signify the tapeworm, but the origin of it is not known. The crucial sentence depended on its back armour 'patterned with pearls' (Ch. 1, (p. 3)). The essential secret of the technique had probably always been to implant small pieces of the nacre-secreting epithelium of the mantle along with the inorganic nucleus so that a closed cyst was formed within the parenchymatous tissue. Naturally this was not revealed to the Chhan-Ling people in modern times. Finally, as far back as the +2nd century, we have a remark-
29. NAUTICAL TECHNOLOGY

While oyster pearls are in the belly, shark pearls are in the skin. Abundance of texts describe the shark people (chiao jen), who live at the bottom of the sea, give lodging to pearl-divers, and sometimes come ashore to wander about and sell their pongee silk. On departing they pay their bills by weeping tears which turn to pearls.

In tactics of land and sea, and him about naval preparedness. Tzu-Hsii held the dominating position that it had in the ancient Mediterranean. There is no evidence that these were in fact used. Nevertheless the under-water line was perfectly possible, and indeed there is a certain amount of evidence that this would seem unlikely on account of the basic blunt-ended and flat-bottomed build of Yiieh Chiieh Shu (Lost Records of the State of Yiieh) now preserved only in collections such as the Yuan Chien Lei Han encyclopedia.

Ho Lu (king of Wu, r. -514 to -496) had an interview with (Wu) Tzu-Hsii and asked him about naval preparedness. (Tzu-Hsii) answered: "The (classes of) ships are named Ta-i (Great wing), Hsiao-i (Little wing), Thu-wei (Stomach-strikers), and Lou chhuan (Bridge ship). Nowadays in training naval forces we use the tactics of land forces for the best effect. Thus Great-wing ships correspond to the army's heavy chariots, Little-wing ships to light chariots, Stomach-strikers to battering-rams (chhang chhê), Castled ships to mobile assault towers (kang lou chhê) and Bridge ships to the light cavalry."

There remains still something to be said about naval techniques as opposed to the peaceful practices of the sea. On various occasions above (pp. 442, 625) we have touched upon the question of whether or not Chinese ships of war in ancient and medieval times engaged in the typically Graeco-Roman technique of ramming. A priori this would seem unlikely on account of the basic blunt-ended and flat-bottomed build where no keel invited elongation into a sharp under-water weapon of offence. Nevertheless the attachment of one or two such pointed protuberances to holes the enemy under the water-line was perfectly possible, and indeed there is a certain amount of evidence that these were in fact used. It does not appear, however, that this technique ever held the dominating position that it had in the ancient Mediterranean.

Among the ancient classes of warships there may have been one called 'Stomach-strikers' (Thu-wei). It appears for instance in a passage from the Yüeh Chieh Shu (Lost Records of the State of Yüeh) now preserved only in collections such as the Yuan Chien Lei Han encyclopedia.

As elsewhere it may well have done. "The ethnographic study of Noteboom (1) on the boph prows, "We are much indebted to Dr Lo Jung-Pang for discussing this with us in extenso by correspondence."

The passage is also quoted in PYYL, ch. 790, p. 106, ch. 809, pp. 74, 8a, quoting from Po Wu Chih and San Shen Chi (+348).

Although there is no ancient tradition that the fleets of Wu and Yüeh had engaged in ramming. From a book of which little is now left, Wan Chi Lan* (The Myriad Stratagems), written by Chiang Chi about +220, the following words have come down to us:

When Wu and Yüeh were fighting on the Five Lakes (mod. Thai-hu), they used ships with oars, which butted into each other as if with horns (hsiung chhua). Whether handled bravely or timidly all were overturned, whether blunt or sharp all capsized (and sank). Rams again, perhaps, yet the description does not quite suggest holing below the water-line. More reliably matter-of-fact is the description in the Hou Han Shu of the battles on the Yangzte River in +33 when Kungsun Shu was trying to set up an independent kingdom in Szechuan at the beginning of the Later Han period. He ordered his generals Jen Man, Thien J Chung and Chhêng Fan to lead twenty or thirty

With one of these types we are already familiar, the castled ships full of marines, hard though it is to say whether oars or sails were their principal means of propulsion. The two 'wing' classes must obviously be sailing-ships, and the 'bridge' ships may well have been small rowed boats pressed into service from normal use in pontoon bridges. As for the 'stomach-strikers' or 'colliding swoopers' it is difficult to interpret them as anything else than ships fitted with rams. But the date of the passage may not be quite what it seems. Another excerpt purporting to be from the same book occurs elsewhere in the Thai-Phing Yu Lan; it describes the 'Great wing' man-o'-war, following what may have been a lost book called "Wu Tzu-Hsii Shui Chan Fa" (Wu Tzu-Hsii's Manual of Naval Tactics). Each ship, 120 ft. long and 16 ft. in the beam, carried 26 marines and 50 rowers, with 3 sailors and helmsmen at both bow and stern, and an equipment of 4 long 'grappling-hooks' (chhang kou), 4 spears and 4 long-handled axes, under the command of four petty officers, together with five officers and master-archers, making in all a crew of 91. Similar details occur in a quotation from another lost book, Shui Chan Ping Fa Nei Ching (Esoteric Manual of Naval Tactics), due to Hung Mai, who towards the end of the +12th century remarked that after all the ships of Chou times must have been quite large. We may feel some hesitation in accepting such a conclusion for the -6th century, and prefer to regard these accounts as revealing the practice of the Han San Kuo or even Chin periods, but in any case the presence of rams on certain craft seems fairly sure. At least equally important to note here, however, is the mention of 'grappling-hooks', a subject shortly to lead us in unexpected directions.

No doubt there was an ancient tradition that the fleets of Wu and Yüeh had engaged in ramming. From a book of which little is now left, Wan Chi Lan (The Myriad Stratagems), written by Chiang Chi about +220, the following words have come down to us:

When Wu and Yüeh were fighting on the Five Lakes (mod. Thai-hu), they used ships with oars, which butted into each other as if with horns (hsiung chhua). Whether handled bravely or timidly all were overturned, whether blunt or sharp all capsized (and sank).
thousand troops down river on rafts to attack the Han army under the command of Tsenh Pheng. Having defeated three of his captains they took up position at a suitable spot where they constructed a floating bridge with fortified posts on it; this was protected by a boom which blocked the river and by forts on the surrounding slopes. When Tsenh Pheng came up he attacked several times but without avail, so he waited and equipped himself with castled ships (Lou chhuan 5), rowed assault boats (lu-jao 6) and ‘colliding swoopers’ (Mao-thu 7), a fleet of several thousand vessels, after which he successfully broke through and routed the Szechuanese. Li Hsien’s commentary of +676 explains that the advantage of the Mao-thu was that they could but (chu 8) in violent collision, i.e. that they could ram.

At this point we come to a curious gradual shift in technical terminology. It is clear that the earlier Mao-thu or Thu-wei ships were the predecessors of the attack ships later called Meng-chhung. 6 Already in +100 the Shih Ming says: 4 ‘(Vessels that are) long and narrow in appearance are called Meng-chhung; they dash (like battering-rams) against the ships of the enemy (i chhung thu ti chhuan ye kh 9 ).’ Towards the end of the +18th century Wang Nien-Sun, commenting at length on a list of ship names in the Kuang Ya of +230, remarked that ‘among ships there is the Meng-chhung just as among vehicles there is the battering-ram (chhing chhê 9 ), for meng 10 is the same thing as mao 10 and chhun 9 has the same sense as thu 11’. 5 But as we shall shortly see (p. 686) by +759 the term meng 10 in this combination has come to mean primarily ‘armoured’ protection for the crew (whether of wet leather, wooden planks or iron plates) and not an impetuous course leading to collision; we shall there translate the binome as ‘Covered swooper.’ The explanation is that the old word mao 10 had two quite distinct meanings, not only ‘rushing and colliding’ but also ‘hat or covering’. By +208, when Tung Hsi 12 acquired glory in naval fights between the Wu and Wei forces, Meng-chhung 6 ships had become common, 5 but it is permissible to think that while the emphasis changed in these centuries from the ram function to the armour build there was a continuity of nomenclature because shipwrights were under the impression that mao 10 had always been in the sense of ‘hat’ rather than the sense of ‘rush’. Presently we shall see how this would fit in with a general trend from close-quarters to projectile warfare discernible all through the history of Chinese sea tactics.

The question has been raised whether another argument for rams in early times may not some memory of ancient ramming tactics be the background of the argument? That the Chinese build of hull did not lend itself to the sticking on of ‘halberds’ or any other sharp-pointed part under the water-line is, as has been said, obvious, 6 but in this connection we may recall one most unusual type of boat still extant in modern China which possesses a bifid stem and stern. This is a sampan used near Hangchow, and its origin is quite unknown. 5 With its ram-like projection it resembles the boats of ancient Scandinavia and traditional Indonesia-Polynesia, the close connection of which was one of Hornell’s strangest discoveries. 4 Perhaps this sampan is a solitary relic of the Indonesian component in southern Chinese culture, but perhaps also it may be relevant to what evidence there is for the use of the ram in Chinese antiquity.

The passage which has generally been thought to give the clearest proof of rams in the Warring States period seems to us rather to prove something else, and to lead off in a different direction. It occurs in the Mo Tsu book, and tells how the famous engineer Kungshu Phan 8 came south about +445 and reorganised the navy of Chhu. 9

Formerly the people of Chhu and the people of Yüeh had a battle on the River. 4 The Chhu forces advanced with the current in their favour, but it was against them when they wanted to retreat. With success in sight they came on, but when defeat threatened them they found withdrawal quite difficult. Conversely the Yüeh forces had to advance upstream but could retreat downstream. In favourable conditions they could push slowly forwards but if the luck of battle turned they could get away quickly. With this advantage the Yüeh people greatly defeated those of Chhu.

Master Kungshu then came south from Lu to Chhu and began making naval warfare implements called ‘hook-fenders’ (kou chhing 9 ). 5 When an (enemy ship) was about to retreat, one used the hook (part); when an (enemy ship) came on, one used the fender (part). The length

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4. On this weapon see Sect. 306 below.
5. 龍行
6. 龍行
7. 無楸
8. 無楸
9. 汝楸
10. 龍行
11. 無楸
12. 龍行

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6. The discussion will be found in Chihien Han Shu, ch. 6, p. 198.
7. Nevertheless it is possible to find instances of ramming in Sung naval warfare. Indeed we have encountered them already. In Vol. 4, pt. 2, p. 430, we saw how in +1134 some of the big paddle-wheel warships used by the revolutionary forces of Yang Yio were equipped with rams (chhing huo 10) which sank many government vessels; see Sung Shih, ch. 365, p. 8a ff., esp. p. 109. So also on p. 422 we read of the shipwright Chhan Shih-Fu, who in +1205 built four-wheel warships with iron-armed rams and ‘spade-beak’ (hua kan 11) rams. His designs will be discussed more fully on p. 688 below. Since the speed of these ships was probably of the order of 4 knots, the impetus of their considerable weight would have made broadside-on impact rather effective. As late as the end of the +16th century, Wang Ho-Ming tells us, in his account of the Fu chhuan (Fukienese warships), that they could sink smaller enemy vessels with their ‘plough-share’ (lu), presumably some sharp offensive weapon fixed to the bows (Hiin Wen Hien Thun Kho, ch. 13, p. 397f. 3).
11. Ch. 40, p. 9a, b (pp. 301 ff.), tr. aunt, adj. Meit Yia-Pao (1), pp. 245 ff.
13. TPYL, ch. 33, p. 35, quoting these two sentences, has hou cha 14 instead of hou chhing, but the meaning is the same. We will see that we take the term as a binome, not two separate things, the hook and the ram, as do Meit Yia-Pao and others.
of this weapon was adopted as a standard for the ships, so that the vessels of Chhu were all standardised while those of Yiieh were not. With this advantage the Chhu people greatly defeated those of Yiieh.

Master Kungshu was proud of his ingenuity and asked Master Mo, saying: 'My warships have the “hook-fender” device (one part to pull and one part to push). Do you have anything like this in your (philosophy of) righteousness?' Master Mo replied: 'The “grappling-and-ramming” device in my (philosophy of) righteousness is much better than your war-boat gear...'

And Mo Tzu goes off into a sermon (excellent in its way) on ‘pulling with love and pushing with respect’, for which the whole story was no doubt a pretext. That of course does not mean that we should reject it as a valid account of something that happened in 4th-century naval warfare. But the “hook-fender” device was not exactly a ram; we believe it was a heavy T-shaped iron piece (like a dagger-axe in shape) fitted at the end of a long spar pivoted in derrick fashion at the base of the mast, and capable of being either dropped heavily on the retreating enemy’s deck to pin it at a desired distance, or lowered into position to fend off his closing ship at about the same distance away. In both situations the enemy was held at the best crossbow range. This leads directly to our next subject.

(6) **Armour-plating and ‘Grappling-irons’; Projectile Tactics**

**VERSUS CLOSE COMBAT**

If, as we believe, the application of thin sheets of metal to the under-water parts of hulls with a preservative purpose was at least as old in China as it was in the Mediterranean region, and if, as here (and in Sect. 30) we shall hope to show, the military and naval tactics most highly favoured by the Chinese in all periods tended to be those of projectile exchange and accurate fire rather than those of close hand-to-hand combat, it would be expected that a development of “armour-plating” above the water-line would occur among them at quite an early date, extending the concept of city-walls to the bulwarks of fighting-ships. And indeed this is just what we find. In these late medieval contexts, of course, ship-armour does not mean anything like what it came to see fully developed in the fleets of the great Korean admiral Yi Sunsin at the time of the Japanese expeditions of Hideyoshi to Korea (+ 1592 to + 1598). For Yi Sunsin then built a number of “Turtle ships” (“Kuei chhuan”), which proved very effective in the sea battles against the invaders off Chemulpo and in Fusan Sound. A whole flotilla of them is seen, together with other Korean war-junks, in a screen-painting of the +17th century.

It is rather difficult to get a clear idea of these Turtle ships, but though the sources are not very informative, Underwood gave much attention to them, assisted by Korean scholars such as Cheung Inpo. His conclusions were that a typical warship of this kind was about 110 ft. in length with a beam of 28 ft. and one main deck 7½ ft. above the ship’s bottom (Fig. 1505, pl.). The rowers’ positions were within the hull, on each side of a central line of cabins for stores and bunks, leaving the main deck free for the gunners and musketeers to maintain fire through 12 gunports and 22 loopholes. They in turn were protected by the sloping roof, the slot in which was probably closed by a sliding hatch before entering battle. The roof was certainly studded with spikes and knives, and though no contemporary text has been found which proves that it was always covered with metal plates, strong local traditions, dating back to the early

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*a* One may take a side-glance here at the practice of arming the water-gates of Chinese city-walls with plates of iron. In +1487 Chhieh Pu, the Korean traveller, saw eight or more of these at Ningpo and was much impressed by them (cf. Teakell tr., pp. 68, 69).

*b* pp. 407, 447, 631 etc. Another instance may be added here. At the Battle of Huang-chien-tang in +1130, some Falienese sailors advised the Chin Tatars to build protective bulwarks with cast-ports on their ships. Then at a time when the Sung warships were becalmed these galleys rowed towards them discharging incendiary arrows. The tactic was successful, but it pressed exactly what the Sung paddle-ships were afterwards to do even more successfully. See Sung Chih, ch. 364, pp. 79, 84, cf. WHTK, ch. 138 (p. 138); 3. Cf. Vol. 4, pt. 4, p. 416.

*c* Underwood (1), pp. 71 ff.; Hubert (1), vol. 1, pp. 349 ff., 372 ff., 399 ff.; vol. 2, pp. 15, 29 ff., 33 ff., 40 ff., 48 ff.; Osgood (1), pp. 198 ff. Yi was born in the same year as Drake, whom he might have met if Drake had visited Korea instead of the Philippines in +1579. And like Nelson, he died aboard his flagship in the last battle of a successful campaign.

*d* Strictly speaking, “Tortoise ships”.

*e* From the Prince Yi Household collection. Opp. preface in Underwood (1).

*f* From the Yi Chhengmu Kung Chhiu (Complete Writings of the Loyal and Martial Duke), i.e. Yi Sunsin, collected in 1795.

*g* See his figs. 46–49. The curious picture of von Pawlikowski-Cholowz (1), p. 32, is given, tantalisingly, with no references. Cf. Yi Unsang (1).
+17th century, affirm this. It would at any rate tally with the fact that none of these ships could be set on fire by the incendiary weapons of the Japanese, and that it was difficult, if not impossible, to pierce their walls with the projectiles of the time. On the other hand, it is certain that each Turtle ship carried an animal figure-head with a tube through which dense toxic smoke could be emitted, the result of the activities of chemical technicians hidden in the bows. Such compositions, popularly supposed to contain sulphur and saltpetre, had long been known in China (as in the Wu Ching Tsung Yao of +1044) and we shall examine them in a later place. Apparently there were 10 oars on each side, each worked by two men, but lug-sails were generally used as motive power, except when entering battle or making port.

Perhaps the most interesting feature of the whole episode is that Yi Sunsin was carrying to its ultimate conclusion the projectile tradition of Chinese sea warfare as opposed to shock tactics. The men of his Turtle ships were fully protected against arrows, musket-shots, and incendiary weapons, but also above all against the boarding-parties beloved of the Japanese. Keeping the beam fairly narrow, he built for speed so as to command the range, and adding smoke-screen equipment, he gained valuable superiority in surprise manouevre. Finally it seems that his armament outweighed the Japanese guns and hand-guns by a factor of forty to one. The tactics were therefore no longer to close and board, but to stand off and pound with projectiles. A line-ahead formation was used to deliver successive broadsides, and ramming might follow only if the enemy was disabled.

About the same time similar factors were leading in Europe to similar developments. According to Rudolfo (1) the Dutch, during the siege of Antwerp in +1585, gave partial protection with iron plates to a man-of-war, the 'Finis Bellis', but it was much less successful than the Turtle ships of Yi Sunsin, for it went aground at once and was captured by the Spaniards, who made no use of it. Rudolfo also reports a tradition that when Tunis was being besieged by Charles V in +1530 an attempt was made to protect a carrack, the 'Santa Anna', against incendiary weapons by attaching sheets of lead, but this seems inherently less likely. In spite of gunpowder, ship-armour was curiously slow in acquiring importance in Europe, and it would take us too far to follow here its use in the floating batteries of the +18th century until the famous duel of +1796 there was still at least one Korean Turtle ship, with two smoke-emitting heads, at the port of Yohsu in Cholla province. But it is possible to trace this type of vessel, and the tactics which it implies, much further back than Yi Sunsin's.

The conception was strikingly similar to the 'siphons' of Byzantine ships carrying Greek Fire. Another Byzantine analogy is near at hand, too, cf. p. 693.

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Covered Swoopers (Méng-chhung)\(^1\); these are ships which have their backs roofed over and (armoured with) a covering of rhinoceros hide\(^*\) (t^\(i\) h^\(a\) i k^\(a\) h^\(o\) m^\(g^\) h^\(w\) a^\(s\) c^\(h\) e^\(i\) p^\(c\) h^\(i\) ). Both sides of the ship have oar-ports; and also both fore and aft, as well as to port and starboard, there are openings for crossbows and holes for spears. Enemy parties cannot board (these ships) (t^\(i\) h^\(p^\(u\) t^\(e\) c^\(h\) a^\(c\) h^\(h\) a\), nor can arrows or stones injure them. This arrangement is not adopted for large vessels because higher speed and mobility are preferable, in order to be able to swoop suddenly on the unprepared enemy. Thus these (Covered swoopers) are not fighting-ships (in the ordinary sense).

Combat-Junks (Chan haisen)\(^2\); combat-junks have ramps and half-ramps\(^*\) above the side of the hull, with the oar-ports below. Five feet from the edge of the deck (to port and starboard) there is a deckhouse with ramparts, having ramparts above it as well. This doubles the space available for fighting. There is no cover or roof over the top (of the ship). Serrated pennants are flown from staffs fixed at many places on board, and there are gongs and drums; thus these (Combat-junks) are (real) fighting-ships (in the ordinary sense).

Flying Barques (T^\(s\) o^\(u\) s^\(o\) k^\(o\))\(^3\); another kind of fighting-ship. They have a double row of ramparts on the deck, and they carry more sailors (lit. rowers) and fewer soldiers, but the latter are selected from the best and bravest. These ships rush back and forth (over the waves) as if flying, and can attack the enemy unawares. They are most useful for emergencies and urgent duty.

Patrol Boats (Yu thing)\(^4\) are small vessels used for collecting intelligence. They have no ramparts above the hull, but to port and starboard there is one rook, row by four feet, varying in total number according to the size of the boat. Whether going forward, stopping, or returning, or making evolutions in formation, the speed (of these boats) is like flying. But they are for reconnaissance, they are not fighting-ships.

Sea-Hawks (or Sea-Greenbeaks) (Hai-hu)\(^5\); these ships have low bows and high sterns, the forward part (of the hull) being small and the after parts large, like the shape of the hu bird (when floating on the water).\(^6\) Below deck level, both to port and starboard, there are 'floating-boards' (\(f^o^u^p^a^n^\)) shaped like the wings of the hu bird. These help the (Sea-hawk) ships, so that even when wind and wave arise in fury, they are neither (driven) sideways, nor overturned.\(^7\) Covering over and protecting the upper parts on both sides of the ship are stretched raw ox-hides, as if on a city wall.\(^8\) There are serrated pennants, and gongs and drums, just as on the fighting-ships.

This text seems to show us that the general principle of projectile warfare at sea from 'armoured' ships which could approach their targets rapidly, deliver a broadside, and make away again, can be traced back to the +8th century at least. Although the Cover (or Covered swooper), and the Combat-junk, surely the lines of the turtle ships of Yi Sunsin, are said to be hardly fighting-ships in the strict sense, while the Combat-junks are specifically so termed, this may have been an explanation intended for military readers used to close combat on terra firma, and it would be wise to conclude that grappling and boarding had always been typical of Chinese naval practice in earlier times. Indeed the term Méng-chhung itself as a designation of naval vessels goes back at least to the +2 and century.\(^9\) Then the tendency to cover over the upper deck appears also in the sixth type, the Sea-hawks (Hai-hu), which from the description suggest some kind of converted cargo-boat like the Ma-yan-tzu or the river junks in Sung pictures.\(^10\) And the great majority of the crew and soldiers, except perhaps the artillerymen on the topmost deck, were clearly protected in the 'battleships' known as Lou chhuan.

So much for the general principle of ship-armour. But there is more than this, for we have several Chinese records of putting with iron considerably earlier than the time of Yi Sunsin. One scene was the confusion at the end of the Yuan period. In +1366 Ming Sheng\(^1\) had succeeded his father as ruler of an independent State of Shu (Szechuan) which was rising out of the ruins, but Chu Yuan-Chang mounted a Western Expedition against him which began to make its way up the Yangtze valley in +1370. The Ming Shih says:\(^11\)

Next year Liao Yung-Chung\(^2\) was deputy commander of the Western Expedition, and followed Thang Ho\(^3\) as admiral of the (river) fleet against Shu. Thang Ho had his headquarters at Ta-chhi-khou.\(^4\) (Liao) Yung-Chung set off in the vanguard, arrived at Old Khueifu\(^5\) and routed its defenders under the (Szechuanese) general Tsao Haing\(^6\) and others; then going on he reached the Chhi-thang\(^7\) Gorge. Here, where the cliffs are very precipitous and the water most dangerous, the Szechuanese had set up iron chains (\(t^i^h^e^k^i^h^a^i^k^h^a^\)) as booms, and bridges (\(c^h^a^h^i^k^i^o^a^\))\(^8\) to block the gorge horizontally so that no ships could get through. (Liao)

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\(^1\) Perhaps this word requires the reader's indulgence. It is necessary to translate the impression of rushing violent motion. The word 'destroyer' seems natural only because we are accustomed to it in a naval context, just as we are used to the idea that a submarine is not an apprentice sea-soldier.

\(^2\) A material of this kind was used in ancient Chinese armour, see Sect. 300 below.

\(^3\) Note that this word, so pronounced, had meanings such as a hen sitting on eggs, or soldiers in ambush.

\(^4\) WCTYC, ch. 11, p. 104 and TSCC, JUng ching chien, ch. 97, p. 8a, have Tou haio\(^*\) here.

\(^5\) It is to be presumed that some kind of crenellated bulwarks are meant.

\(^6\) Although nothing is said in either of these descriptions of mast and sails we are reluctant, in view of all else that is known of Chinese shipping, to assume that anything like galleys purely rowed was intended here.

\(^7\) For the birds in question see R258 and 314.

\(^8\) The text must be inverted here; we translate in corrected form.

\(^9\) The significance of this remark, in connection with what has already been said about hull shape of Chinese craft (p. 417 above), will not be missed.

\(^10\) This is a most important passage concerning leebords (see p. 618 above). Conflating TPYC with WCTYC and TSCC, it runs: 'the chi chihun nu feng chhao tsung ehr uo yu real chihing'.\(^10\) The existence of leebords in the +4th century gives China a long priority in their invention.
Yung-Chung therefore secretly sent several hundred men with supplies of food and water to make a portage with small boats, so that they appeared up river further than those defences. Now the mountains of Szechuan are so well wooded that he had ordered the soldiers to wear green garments and sleeveless raincoats (soi’1) made of leaves; and thus they descended through the forests and rocks. When agreed stations had been reached, the best troops were ordered to attack at Mo-yeh Ferry. At the fifth night watch the general assault began both by water and land. The bows of the naval ships were sheathed with iron (thieh kao chhuan shou4) and all kinds of firearms (tsau chhi2) were made ready upon them. Only as dawn was breaking was the army’s presence discovered by the Szechuanese, who threw in all their best troops for the defence, but unavailingly. When (Liao) Yung-Chung had captured six all of their positions, he assembled his commanders, including those who had led the boat-portage parties, and pushed on the fight, some attacking above (the defences) and some below, so that the Szechuanese were completely defeated, and Tsou Hsing lost his life. The three bridges were burnt, and the iron chains all cut.

And thus Liao Yung-Chung was able to enter Khuieich in triumph. This engagement was certainly a remarkable one, and much credit must go to the defeated Szechuanese for the ingenuity and engineering skill of their defences, chiefly organised, it would seem,4 by the Shu officials Mo Jen-Shou4 and Tai Shou.5 But the use of iron-ship-armour by Liao Yung-Chung is also of interest, since it occurred a couple of centuries before the sea-going Turtle ships of Yi Sunsin.

It was however far from new in +1170. For at the time of most rapid development of the Southern Sung navy, in +1203, a remarkable shipwright, Chhin Shih-Fu,6 built at the Chhihchow yards two prototype ‘Sea-hawk’ (Hai-hu) paddle-wheel warships the sides of which (and perhaps the flat roofs also) were armoured with iron plates. The decks were given complete protection by the overhead cover, and besides the usual arrangements for crossbows, archaballista, fire-lances, bomb-throwing trebuchets, etc., each ship was provided with a spade-shaped ram.7 The smaller vessel, of 100 tons burden and with two treadmill-operated paddle-wheels, needed a propulsion crew of 28 men; the larger, of some 250 tons though not very much greater in post of trebuchets (phao shih mu kan?) and also iron barrel guns (thieh chhung).8 At the ends of the bridges on the two banks were more trebuchets to resist our troops.9 Another example of the use of iron-chain booms had been recorded by Chiao Ju-Kus in the previous century (+1225). He described such a device in his chapter on Palembang, though it may perhaps have been used across the strait of Johore (Chu Pan Chih, ch. 1, p. 74); cf. Hirth & Rockhill (1), p. 62; Steiger et al. (1), pp. 112 ff. In Chinese design and practice suspension bridges and booms were closely related (cf. pp. 202 ff. in Sect. 28e above).

From a third account, the Phong Hia Lu8 (written by Huang Piao10 about +1544), p. 8a, it appears that these small-boat parties attacked the defences from the rear, using grenades and bombs (hao phao11) and fire-lances or hand-guns (hao chung12).b

This is confirmed in the same words by Huang Piao.

Hit by a rocket or incendiary arrow, according to Huang Piao.

According to the account in the Ming Shih Lu.

Cf. p. 300 above, and Underwood (1), pp. 86 ff. The essential words of description of the two cruisers are: Hsin yang thieh pi hua tsi phing mien Hai-hu chhuan chhuan.13 They come from the Sung Hui Yoo Koo, tuc 146 (Shih hao, ch. 300), pp. 348 ff., where very full specifications are given. See Lo Jung-Pang (2), p. 7, who discovered the passage.

Length, and apparently with four paddle-wheels, needed 42 men to work them and carried 188 marines.14 The paddle-wheels were protected by housing above the waterline.

To defend thus the mechanism of progression as well as the projectile-firing combat elements themselves was a very natural and logical step in the development of armour, but (failing the invention of the screw-propeller) paddle-wheels alone permitted it. It could not be done either for masts and sails or for projecting oars. There is thus more connection than might at first sight appear between the relatively early flourishing both of paddle-wheel propulsion and of ship-armour in Chinese culture. The history of the paddle-wheel boat we have already sketched in Sect. 27f above,15 and some of the texts there given show very clearly indeed how conveniently this motive device suited the tactics of rapid fire from a fast armoured ship. When paddle-wheel steam warships first approached the coasts of China in the early nineteenth century they brought nothing tactically novel, indeed they constituted the realisation of a dream which projectile-minded Chinese admirals had entertained for well over a millennium. Although the cruisers of Chhin Shih-Fu were said to be of ‘new design’, there is no special reason for regarding them as the first of all Chinese iron-armoured ships, and earlier examples may well come to light, though—at a guess—perhaps not before the beginning of the +12th century, when the foundation of the permanent navy occurred.16

We can follow out the contrast between projectile tactics and close-combat boarding-party tactics much further still in the context of ‘grappling-irons’. If we trace down the warship descriptions of the +8th-century Thai P’ien Yin Ching, in later compilations of naval knowledge, we find that the Wu Ching Tung Yao of +1104 inserted some very interesting material from a quite independent, and still older, source. Under its entry for the Patrol boats (Yu thing1) it included a description of the Wu-ya hien1 (Five-Ensign battleships) which should more properly have been put with the Lou chhuan1 (Castled battleships). After a slightly abridged version of the Thang text on the Patrol boats, the passage continues by quoting from the Sai Shu (History of the Sai Dynasty), the biographical parts of which were finished by +636. It tells the story of the building of fleets for the emperor Kao T’ai by a celebrated engineer Yang Su1 (of the naval battle in which they scaled the face of the Chien dynasty).17

It is perhaps worth remembering that Chhin Shih-Fu’s smaller cruiser was twice the size of one of Prince Henry’s caravels, and that his larger one was about the same size as Vasco da Gama’s flagship. Of course the Chinese paddle-wheel warships, so prominent in the Sung, worked primarily upon the lakes and rivers, where they were very effective. This means of propulsion was not suited to the sea until the days of iron hulls and steam engines.18

Vol. 4, pt. 2, p. 413.

Cf. Lo Jung-Pang (1), and p. 476 above.


In what follows we translate the parallel texts Wu Ching Tung Yao (Chien chih), ch. 11, p. 6a (Ming edition of +1510, ch. 11, p. 58); Sai Shu, ch. 48, pp. 28, 32; Yu Hao (apparently reproducing another version of Yang Su’s biography), ch. 147, pp. 118, 120. The Sai Shu text is much the fullest of these, but it does not contain all the statements which are relevant. For a full account of the battle, all three texts (and also other extant descriptions) would have to be conflated for translation, but we do not need to follow them. We follow mostly the Wu Ching Tung Yao version, additions from Sai Shu being added in square brackets. Tr. suct. Cf. WHTK, ch. 135 (p. 1380-3).

1 頜川
2 五牙舰
3 楼船
4 楼船

44
In the 4th year of the Khai-Huang reign-period (584), Sui Kao T'au commissioned Yang Su (as commander-in-chief) to destroy the Chhen. So coming down the gorges to Hainchow he built [at Yung-an] great war-junks (hsien) called Wu-ya hsien (Five-Ensign battleships). Above they had five decks, and their height was more than 100 ft. To left and right, and fore and aft, he set up six pho-kan (lit. striking- or patting-arms), each 50 ft. long. And of marines (each ship carried) 800 men, and many flags and banners flattered aloft.

...When the ship comes alongside an enemy ship, they let go the striking-arms (pho-kan) on top of her, and whether barque or barge she is all broken into fragments.

Then there were the Yellow Dragon (Huang lung) ships, each with 500 marines, while others embarked on smaller boats (cheh hsien) of many different kinds. (Yang) Su then led the fleet down through the gorges. When they got down to Ching-men the Chhen general ordered the Man (highlanders) of the Chhen fleet, breaking them to pieces, and so the river route was forced open.

What were these 'striking-arms'? It seems fairly clear that they were long heavy pointed spikes, probably iron-shod, and fixed at right angles at the end of elongated arms like guy-derrick jibs, then suddenly released from an approximately vertical position to crash down through the deck and hull-timbers of the enemy vessel. They were certainly not intended to 'grapple', i.e. to provide gang-planks for boarders, and the best name for them would be 'holing-irons'. We can actually see them, rather badly drawn as usual, in Fig. 1051, looking like thin hammers, and in the unarmed position.

Yu here doubtless implies ya chhi, 'dented' or 'indented' banners or standards, so called either because of the tooth or claw symbol at the top of the flagstaff, or because of their serrated edges. And indeed five can be seen at the bows in Fig. 1051. Whether this means from bottom to deck or from water-line to masthead we do not know.

The two editions of WCTY vary as to illustration. The Min edition of +1510, recently reproduced, and said to derive direct from the Sung edition of +1231, gives a picture of what is evidently a patrol-boat, with a crew of 14; but the SKCC edition, derived from a manuscript in the imperial Wte Yuan Kao library copied in +1278, illustrates the Five-Ensign battleship, as shown, though still entitled Yu thing (Patrol boat). This confusion was recognised by Audemard (2), who knew only the Chhing edition of WCTY, and never saw the Ming WCTY.

We have already met with the striking-arms under the name thieh chuang given above in the sub-section on navigation (p. 272).

Since, as we know from Vol. 4, pt. 2, p. 419, there were pho chhuan (ships with striking-arms) in a Liang fleet in +532, the device must go back to the earliest part of the 6th century.
If the shafts of the holing-irons were long enough, and if the enemy crews were not provided with gangways of the right length known beforehand, then even if they wanted to attack by boarding, they would be held, as it were, at arm's length, where the missiles of the battleship could play upon them and decimate them. Such 'grappling-irons for keeping people off', or what we may call 'fending-irons', are mentioned by Lu Yu in about +1190 in his *Luo Hsiu-Chen Pi Chi*, where he describes the campaigns which government forces had had to wage some sixty years earlier against an important equalitarian peasant revolt led by Chung Hsiang and Yang Yao. We have followed the fortunes of this before in connection with multiple paddle-wheel warships, which played so conspicuous a part in it; here we need only glance at another of their techniques.

Lu Yu says:

The rebels in the Ting-li region, such as Chung Hsiang and Yang Yao [the way they pronounce Hua] in those parts had fighting-ships (on the Tung-thing Lake), such as paddle-wheel ships (chhih chhuan), oared (yuhol?) vessels (chhian chhuan), and sailing junkt (lit. Sea-cells, Hai chhiu). Among their offensive weapons were the *na ta* commonly pronounced *na tzu* [the 'fish forks' (yi chha) and the mu luo ya. The *na ta* and the yi chha were on bamboo poles 20 to 30 ft. long like handles, and prevented (the government) marines with hand-weapons from boarding and attacking at close quarters. Chhing Chiang-yu's men, however, though from Tshaichow, were also skilled at the use of these, so they gained the day repeatedly. The *mu luo ya*, which was also called the 'no coreto logs' (pu chhieh mu), was a piece of wood strong and heavy just a little over 3 ft. long and sharpened at both ends; these were used by the war-ships (on both sides?) and proved very effective.

Lu Yu then goes on to talk about explosive bombs scattering lime, and other means of making poisonous smokes, but he has said enough to show that the *na tau*, 'kneaders' or 'pounders', were probably smaller versions of the holing-irons, and succeeded in keeping the enemy at an inconvenient distance. Another writer of the period tells us that the rebel ships mounted what might be called 'holing-derricks'. In his *Chi Yang Yao Pen Mo*, written about +1140, Li Kuei-Nien says:

The rebel ships had two or three decks, and some could carry more than 1,000 men. They were equipped with 'holing-derricks' (pho-ban), which were like great masts over a hundred feet high. Large rocks were hoisted up to the top of these by means of pulleys, and when a government warship attacked at this time see Sect. 308.

Here then, though the same technical term is used as for the holing-irons of the Sui, the projectile mentality had again overcome the conception of a shock weapon, and heavy weights were dropped from jib arms above in the attempt to hole and sink the opposing craft.

It is interesting that an exactly similar device is recorded as having been in common use at the same time, and perhaps somewhat earlier, in the Byzantine navy. It had Hellenic precedents, and Leonardo da Vinci was later to design one. But what a contrast all these Chinese 'grappling-irons' were with the celebrated *corvus* of the Romans, on which a notable monograph has been written by Wallinga. In the wars with the Carthaginians, e. - 260, the Roman tacticians decided to accept the necessity of head-on collisions, but to avoid the usual sequel in which the more agile ship would disengage and fatally ram the less agile. This they did by a device which would fix the ships together and at the same time give scope for their own superiority in hand-to-hand fighting by pouring their marines on to the Carthaginian decks. It consisted of a gangway in the bows, 36 ft. long and 4 ft. wide, armed underneath at its outboard end with a massive iron spike, and held in readiness by suspension over a pulley at the top of a 24-ft. post. When the plank had fastened itself to the enemy ship, the Roman legionaries could board it two abreast. The comparison of their short swords with the crossbows and catapults of the Chinese gives the measure between two utterly different conceptions of naval warfare.

A word may be added here about the mounting of trebuchet or mangonel artillery on Chinese warships. This is clearly attested for the +8th century in words which we read a few pages above (chih phao chhieh lei shih) in the *Thai Pai Yin Ching* (p. 685), and all the subsequent compendia confirm it. At that time, and also in the +11th century, when the *Wu Ching Tun Yang* was compiled, the trebuchets must have been of the classical manned type, but the only illustrations we have are later, and show the counterweighted type (Fig. 949). There can be no doubt that this was a constant practice through the ages.

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*Ah variant of the 'slitting-arm' technique was used at the Battle of Huang-chien-tang in +1190, when the Sung admiral Han Shih-Chung (cf. Vol. 4, p. 3, pt. 3, 418, 421, 439) equipped his warships with long 'plated iron cables' or chains with long links (shihk king) each with one or more hooks of iron on the end. As they passed the Chin ships, these were suddenly let go to smash her...

We have met with it already in Vol. 4, pt. 2, p. 435 and Fig. 634. The Chinese did not use the torsion catapults of Hellenistic antiquity, but a swage-like lever pulled down sharply at one end either by manned ropes or by a counterweight, and lobbing over the projectile in a sling from the other (see Sect. 307).

From the Ming (+1120) edition of *WCTY*. The Chhing palace edition deserves the trebuchet unjustly, looking like a flag on the end of a long staff caught in a crotch. The Lou chhuan in TSCC, Jung chchien tien, ch. 97, p. 58, has three counterweighted trebuchets on the upper deck, but the artist was half inclined to make them look like culverins.
spikes and bent or broke them. Then with the aid of quantities of hemp-seed oil poured on the water at several points, and ignited by torches more than 100 ft. long, the boats supporting the chain booms were set on fire, so that the chains themselves melted in the heat and no further obstacle remained to hold back the ships and the floating fortress. No doubt this huge craft might also be termed a floating battery, for trebuchet catapults were almost certainly mounted on it. It is a pity that no details were given of the joint hulls by which it was supported, but we may surmise some sixteen vessels each 150 ft. long. The idea could have arisen very naturally from the floating-bridge principle, which had been much used in Chinese antiquity. Although these facts have no bearing on the largest size ever reached by Chinese ships, as once was thought, they do supply yet another indication of the prevalent projectile-mindedness—if we have no strong-points or artillery-emplacements on the frontiers of the Wu territory, said the Chin strategists, we shall build a great one and float it right down into their midst.

Additional elements not essential to the design were:

(iii) The system of water-tight compartments, with its many advantages. These were almost surely in use by the +2nd century, but were not adopted in the West until the end of the +18th. Provenance was then recognised.  
(iv) The possibility of free-flooding compartments, found useful both on river rapids and at sea. This was not adopted to any extent in Europe. 
(v) The existence of a vertical member to which the axial rudder could be attached, in ’line closure’ rather than ’point closure’. See D (i).

29. NAUTICAL TECHNOLOGY

The most suitable ending for this Section on nautical technology will perhaps be a brief tabulation of the characteristics of Chinese craft, and the influence which they may have exerted upon Western practice through the centuries. Let us begin with the view, so highly probable, that the basic principle of Chinese ship construction was derived from the example of the bamboo stem with its septa, and indeed that in actual fact the earliest vessels of East Asia were rafts of bamboo. This led directly to (A) the rectangular horizontal plan. The following corollaries resulted:

(i) The absence of stem-post, stern-post, and keel, 
(ii) The presence of bulkheads, giving a hull very resistant to deformation, and leading naturally to 
(iii) The system of water-tight compartments, with its many advantages. These were almost surely in use by the +2nd century, but were not adopted in the West until the end of the +18th. Provenance was then recognised. 
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Additional elements not essential to the design were:

(i) Approximation to a flat bottom. This goes back many centuries in China, but was not adopted in Europe for ships of any size until the nineteenth century.
(vii) Approximation to a rectangular cross-section. This was also old in China, but again not adopted in Europe until the development of ships of iron and steel.

(viii) The placing of the largest master-couple well aft. This is still prevalent in traditional Chinese ships, and must be old, though how old has not yet been established; it was certainly current in the Thang (+8th century) and may well be earlier. Its interest for sailing vessels was not understood in the West until the end of the nineteenth century.

With regard to propulsion, Chinese seaman ship had the lead of Europe for more than a millennium. First, concerning the use of (B) oars and paddles, we note:

(i) The invention, not later than the +1st century, of the self-feathering 'propeller' or sculling-oar (the yuloh). Though universally used in China, this was never adopted in the West.

(ii) The invention of the treadmill-operated paddle-wheel boat in the +8th if not the +5th century, and its great development in the Sung (+12th century) for warships with multiple paddle-wheels and trebuchet artillery. Though proposed in +4th-century Byzantium, and discussed in Western Europe in the +14th and +15th centuries, no practical use of the principle was made there until the +16th century in Spain.

(iii) The complete absence of the multi-oared galley from Chinese civilisation, whether powered by slaves or free-men (apart from small patrol craft and the paddled dragon-boats used only for ritual races). This must partly be regarded as the result of a relatively advanced development of (C) sails and rig. Here several points are important.

(iv) Among miscellaneous ancillary techniques (E), the following are worthy of remark:

(i) The fundamental invention of the axial or median rudder. This device was fully developed in China by the end of the +2nd century (probably the +1st), and the attachment to the transom stern, if not already achieved, followed soon afterwards, certainly by the end of the +4th; but its first appearance in Europe did not occur until the end of the +12th century. Steering-oars and stern-sweeps, however, though thus relegated to a secondary position so early in Chinese nautical technology, were never completely abandoned, partly because of their value in negotiating river rapids, partly for manoeuvring when the ship was nearly stationary. Bow-sweeps lived on for the same reasons.

(ii) The invention of the balanced rudder, hydrodynamically more efficient than the unbalanced type. This was current in China at least as early as the +11th century, but was still regarded as a new and important device at the end of the +18th in Europe.

(iii) The further invention of the fenestrated rudder, also hydrodynamically advantageous. This was not adopted in Europe until the era of iron and steel ships.

Among miscellaneous ancillary techniques (E), the following are worthy of remark:

(i) Hull sheathing. Already in the +11th century the superimposition of layers of fresh strakes was usual in China; in Europe it became general in the +16th and later. Sheathing with copper plates was discussed, if not actually performed, in +4th-century China; lead had been used in Hellenistic Europe. The practical use of copper did not become general, both in East and West, until the +18th century.

(ii) Armour plating. The strong predilection of Chinese naval commanders throughout the ages for projecticle tactics as opposed to reliance on the close combat of boarding-parties led to the armouring of hulls and upper-works above the water-line with iron plates by the end of the +12th century, and this continued in later times with notable Korean contributions in the +16th. By that time similar developments were occurring, though rather half-heartedly, in Europe.
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(iii) The development of non-fouling ‘stockless’ anchors.
(iv) The invention of articulated or coupled trains of vesels, probably in the +16th century. This was not often employed in Europe for shipping, but greatly used in other fields of transportation.
(v) Ingenious dredging practices.
(vi) Advanced techniques of diving generated by the pearlimg industry.
(vii) Advanced techniques of bilge clearance by chain-pumps, admired by +16th-century Europeans.

So much for the genius of Chinese shipwrights and sailors. Of the most ancient influences acting upon their ship construction, we have been able to detect certain affinities with the naval architecture of ancient Egypt. These include (a) square-ended hulls, (b) bipod masts, (c) the anti-hogging truss in dragon-boats, (d) stern galleries, (e) some forward-curving sterns, and (f) the practice of facing rowing. If we knew more about the shipping of ancient Mesopotamia we might find that some of these radiated outward from there in both directions, yet on the whole the people of ancient Egypt seem to have been water-farers cleverer and more assiduous than any nations of the Fertile Crescent—save the Phoenicians, and they were much younger. Of Chinese connections with South-east Asian practices, the most important were (a) the interchanges in sails and rig, (b) the multi-paddled dragon-boats, and (c) the poling gangways, which may be connected closely with outriggers.

During the past two thousand years there seems to have been scarcely any century which did not witness the transmission of one or another element of nautical technology from Asia to Europe. It does no harm for us to realise this, children as we are of that accidental archipelago where maritime commerce arose and flourished so exceedingly, and whence the conquistadores set forth on their explorations of every strait and ocean. The succession may be sketched as follows:

+ 2nd century The sprit-sail (from India to the Roman Mediterranean).
+ 6th century The lateen sail (from the Arabic culture-area to Byzantium).
Late + 12th The mariner’s compass and the axial (stern-post) rudder (either by Arab–Crusader contact or overland through the West Liao State in Sinkiang).
+ 7th to + 15th Preconstructed rib frames as opposed to strake-morticed hulls with inserted frames, possibly derived from bulkhead construction.
+ 15th Multiple masts (from Chinese junks), the sprit-sail again (perhaps from Sinhalese craft), and the adoption of the lateen, first on all masts, then on the mizen with square-sails on the other masts.
+ 16th The protection of the hull by additional strake layers.
Late + 18th Leeboards.

* It will be seen that we do not feel able to accept the contention of Poujade (1), p. 296, that little or nothing was ever given to, or borrowed from, the Chinese culture-area in nautics. We are also very uneasy about his principle of conservatism (pp. 170, 175), namely that sailors never change the rig of their ships except under foreign domination, though hulls (p. 176) change more easily. The Chinese sails of the Maldives disprove this. Nor are we much attracted by the converse of this ‘law’ enunciated by Bowen (1), p. 82, (2), pp. 260, 287, who maintains that sails are very easily influenced by culture-contact while hulls are most resistant to change. The lorcha suffices as witness to the contrary. Such generalisations seem premature; we are still constrained to accumulate examples and suspend our judgment.

b Coracles would be a good example.
### BIBLIOGRAPHIES

**A Chinese and Japanese Books before +1800**

**B Chinese and Japanese Books and Journal Articles since +1800**

**C Books and Journal Articles in Western Languages**

In Bibliographies A and B there are two modifications of the Roman alphabetical sequence: transliterated Chh comes after all other entries under Ch-, and transliterated Hz comes after all other entries under H-. Thus Chikai comes after Chu and this system applies only to the first words of the titles. Moreover, where Chh- and Hz- occur in words used in Bibliography C, i.e. in a Western language context, the normal sequence of the Roman alphabet is observed.

When obsolete or unusual romanizations of Chinese words occur in entries in Bibliography C, they are followed, wherever possible, by the romanizations adopted as standard in the present work. If inserted in the title, these are enclosed in square brackets; if they follow it, in round brackets. When Chinese words or phrases occur romanized according to the Wade-Giles system or related systems, they are assimilated to the system here adopted without indication of any change. Additional notes come after all other entries under AND CHINESE BOOKS.

When in Bibliographies A and B, the abbreviation for a work or place name is followed by a note inserted in parentheses, these are enclosed in round brackets. When notes follow it, in round brackets. When Chinese words or phrases occur romanized according to the Wade-Giles system or related systems, they are assimilated to the system here adopted without indication of any change. Additional notes come after all other entries under AND CHINESE BOOKS.

### ABBREVIATIONS

See also p. xxxix

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Abbreviations for works in Western Languages are taken from those used in the AAS, ABBL, AHES, ASURG, AASUR, and other serials. Those which are not self-explanatory are defined elsewhere in this list. The two-letter abbreviations are used in the text, and the longer forms in the list. All abbreviations for works in Western Languages are referred to in the text in full form, with the initial capital letters and period, thus: AMNH. When abbreviations for works in Western Languages are cited in the text, they are followed by a note inserted in parentheses, these are enclosed in round brackets. When notes follow it, in round brackets. When Chinese words or phrases occur romanized according to the Wade-Giles system or related systems, they are assimilated to the system here adopted without indication of any change. Additional notes come after all other entries under AND CHINESE BOOKS.
<table>
<thead>
<tr>
<th>ABBREVIATIONS</th>
<th>NATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA</td>
<td>Memoirs American Anthropological Association</td>
</tr>
<tr>
<td>MAA</td>
<td>Memoirs American Anthropological Association</td>
</tr>
<tr>
<td>MAILTR</td>
<td>Memòires de l'Acad. des Ins. et Belles-Lettres (Paris)</td>
</tr>
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<td>MAPS</td>
<td>Memoirs of the American Philosophical Society</td>
</tr>
<tr>
<td>MASIB</td>
<td>Memoirs of the Asiatic Society of Belgium</td>
</tr>
<tr>
<td>MCTC</td>
<td>Techniques et Civilisations (formerly Mémoires et Civilisations)</td>
</tr>
<tr>
<td>MCW</td>
<td>Mongolian Chents and Beodchents</td>
</tr>
<tr>
<td>MCMG</td>
<td>Mathematics Magazine</td>
</tr>
<tr>
<td>MD</td>
<td>MD (Doctor of Medicine), cultural Journal for physicians (New York)</td>
</tr>
<tr>
<td>MDA/ATH</td>
<td>Mitteilungen der deutscher Archd. Instituts (Athénasie Abt.)</td>
</tr>
<tr>
<td>M3J</td>
<td>M3J (Middle East Journal)</td>
</tr>
<tr>
<td>MFSKUJE</td>
<td>Memoirs of the Faculty of Science, Karachi University, Ser. E (Biology)</td>
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<td>MGGMU</td>
<td>Mitteilungen d. geographische Gesellschaft München</td>
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<tr>
<td>MGGW</td>
<td>Mitteilungen d. geographische Gesellschaft Wien</td>
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<tr>
<td>MGS</td>
<td>Memoirs of the Chinese Geological Survey</td>
</tr>
<tr>
<td>MTE</td>
<td>Mémoires de l'Institut d'Egypte (Caire)</td>
</tr>
<tr>
<td>MIFAN</td>
<td>Mémoires de l'Institut Français d'Afrique Noire (Dakar)</td>
</tr>
<tr>
<td>MUT</td>
<td>Massachusetts Institute of Technology</td>
</tr>
<tr>
<td>MYBK</td>
<td>Münchener Jahrb. f. bildenden Kunst</td>
</tr>
<tr>
<td>MYLS</td>
<td>Madras Journ. of Lit. and Sci.</td>
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<tr>
<td>MYPGA</td>
<td>Mitteilungen aus Justus Perthes Geogr. Anstalt (Petersmann's)</td>
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<tr>
<td>MK</td>
<td>Marburger Zeitschrift (Berlin)</td>
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<tr>
<td>MMI</td>
<td>Mariner's Mirror</td>
</tr>
<tr>
<td>MQ</td>
<td>Modern Quarterly</td>
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<tr>
<td>MRDB</td>
<td>Memoirs of the Research Dep. of the Dyal Banho (Tokyo)</td>
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<td>MRMKV</td>
<td>Meddelingen van het Rijksmuseum voor Volkenkunde</td>
</tr>
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<td>MS</td>
<td>Monumenta Serica</td>
</tr>
<tr>
<td>MSIM</td>
<td>Monumenta Serica Monogr.</td>
</tr>
<tr>
<td>MSAA</td>
<td>Mem. Soc. American Archaeology (supplements to AMA)</td>
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<tr>
<td>MSAF</td>
<td>Mémoires de la Société (Nat.) des Antiquaires de France</td>
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<tr>
<td>MSB</td>
<td>Msoob Sovietarir</td>
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<td>MSOS</td>
<td>Mitteilungen d. Seminar f. orientali-phen Syrian (Berlin)</td>
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<td>MSRSI</td>
<td>Mem. Soc. Roy. Geog. d'Egypte</td>
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<td>MUJ</td>
<td>Museum Journal (Philadelphia)</td>
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<td>N</td>
<td>Nature</td>
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<td>NADA</td>
<td>Annual of the Native Affairs Department, Southern Rhodesia</td>
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<td>NAVC</td>
<td>Naval Chronicle</td>
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<tr>
<td>NAFSG</td>
<td>Nouvelles Annales des Voyages et des Sciences Geographiques</td>
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<td>NCR</td>
<td>Numismatic Chronicles (and Journ. Roy, Numismatic Soc.)</td>
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<td>NEPT</td>
<td>New China Review</td>
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<td>NGM</td>
<td>Neptune National Geographic Magazine</td>
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<tr>
<td>NMN</td>
<td>Nederlandse Indis Oud en Nieuw National Maritime Museum (Greenwich)</td>
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<td>NO</td>
<td>New Orient (France)</td>
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<td>NQJ</td>
<td>Notes and Queries on China and Japan</td>
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<td>NS</td>
<td>New Scientist</td>
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<td>NSQ</td>
<td>Nankai (University) Social and Economic Quarterly (Tientsin)</td>
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<td>NSN</td>
<td>New Statesman and Nation (London)</td>
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<td>NU</td>
<td>The Nucleus</td>
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<td>NVO</td>
<td>Nove Oriett (Prague)</td>
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<td>NZMW</td>
<td>Neue Zeitschrift f. Missionarissenschaft (Neuville Revue de Science Missionnaires)</td>
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<td>OAV</td>
<td>Orientalistisches Archiv (Leipzig)</td>
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<td>OAZ</td>
<td>Orientalistische Zeitschrift</td>
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<tr>
<td>OB</td>
<td>Orient Extremus (Kassel)</td>
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<tr>
<td>OLL</td>
<td>Orientischer Lloyd</td>
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<td>ORA</td>
<td>Oriental Art</td>
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<tr>
<td>ORE</td>
<td>Orient Extremus</td>
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<tr>
<td>OSIS</td>
<td>Oarit Oxford University Press</td>
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<tr>
<td>OUP</td>
<td>Pacific Affairs</td>
</tr>
<tr>
<td>PA</td>
<td>Proceedings of the American Antiqutian Society</td>
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<td>PAAGS</td>
<td>Palaeoan</td>
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### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>TASC</td>
<td>Transactions of the American Society of Civil Engineers</td>
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<tr>
<td>TCUT</td>
<td>Technology and Culture</td>
</tr>
<tr>
<td>TEAC</td>
<td>Transactions of the Engineering Association of Ceylon</td>
</tr>
<tr>
<td>TGK</td>
<td>Tōhoku Gakushi Kyōka (Kyoto Journal of Oriental Studies)</td>
</tr>
<tr>
<td>TGUS</td>
<td>Transactions of the Glasgow University Oriental Society</td>
</tr>
<tr>
<td>TH</td>
<td>T'oung Pao Monthly (Shanghai)</td>
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<tr>
<td>TIAU</td>
<td>Transactions of the International Astronomical Union</td>
</tr>
<tr>
<td>TIMEN</td>
<td>Transactions of the Institute of Marine Engineers</td>
</tr>
<tr>
<td>TINA</td>
<td>Transactions of the Institution of Naval Architects</td>
</tr>
<tr>
<td>TJSI</td>
<td>Transactions (and Proceedings) of the Japan Society of London</td>
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<tr>
<td>TMIE</td>
<td>Travaux et Mémoires de l'Inst. d'Ethnologie (Paris)</td>
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<td>TNR</td>
<td>Tanganyika Notes and Records</td>
</tr>
<tr>
<td>TNS</td>
<td>Transactions of the Nusonian Society</td>
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<tr>
<td>TNZI</td>
<td>Transact., New Zealand Inst.</td>
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<tr>
<td>TOCS</td>
<td>Transactions of the Oriental Ceramic Society</td>
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<tr>
<td>TP</td>
<td>Ts'oung Pao (Archives concernant l'Histoire, les Langues, la Géographie, l'Ethnographie et les Arts de l'Asie Orientale, Leiden)</td>
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<tr>
<td>TRIBA</td>
<td>Transactions, Royal Institute of British Architects</td>
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<td>TSE</td>
<td>Trans. Society of Engineers (London)</td>
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<tr>
<td>TNZAM</td>
<td>Trans. National Society of Naval Architects and Marine Engineers</td>
</tr>
<tr>
<td>TYG</td>
<td>Ts'oung Pao (Reports of the Oriental Society of Tokyo)</td>
</tr>
<tr>
<td>UAJ</td>
<td>Ursal-Altaiische Jahrbiicher</td>
</tr>
<tr>
<td>UC</td>
<td>Ulster Commentary (Govt. Information Service, Belfast)</td>
</tr>
<tr>
<td>UIB</td>
<td>University of Illinois Bulletin</td>
</tr>
</tbody>
</table>

### A. CHINESE BOOKS BEFORE +1800

Each entry gives particulars in the following order:

- (a) title, alphabetically arranged, with characters;
- (b) English title, if any;
- (c) date as accurate as possible;
- (d) name of author or editor, with characters;
- (e) volume number, if any;
- (f) pagination, if any.

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<thead>
<tr>
<th>Title</th>
<th>Author/Editor</th>
<th>Date</th>
<th>Volume</th>
<th>Pages</th>
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<tr>
<td>Records of the Warring States</td>
<td>Clin</td>
<td>+1538</td>
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<tr>
<td>A New Treatise on Military and Naval Efficiency</td>
<td>Cin</td>
<td>+1538</td>
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<tr>
<td>Lives of the Judges</td>
<td>Ch'in</td>
<td>+1644</td>
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<tr>
<td>Biographies of the 108th Masters</td>
<td>Ch'in</td>
<td>+1644</td>
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<tr>
<td>The Story of (the Rebellion of) Yang Yao from Beginning to End</td>
<td>Ch'ang</td>
<td>+1644</td>
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<td>Complete Dictionary of the Sounds of Characters</td>
<td>Ch'eng</td>
<td>+1800</td>
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<tr>
<td>Complete Dictionary of the Sounds of Characters</td>
<td>Ch'eng</td>
<td>+1800</td>
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</table>
Yuan or Ming, +14th century.

Records of the Transportation Bureau of Fukien Province.

The General View of Water Control.

Records of the Country Search of Mount Hua [historical geography of Szechuan down to +1385].

Ching, +1684.

Chhing.

Shao Nan Ling Lieh Chih See Huan Nan Tzu.

The Book of the prince of Huai-Nan [compendium of natural philosophy].

C. Han, - +200.

Written by the group of scholars gathered by Liu An (prince of Huai-Nan) andペット.

Partial tras. Morgen (1); Erkes (1); Hughes (1); Chateley (1); Wigger (3).

Chung-Fs Index, no. 5. T'T7170.

Hua Chi Chuan [Wang Pi Shu] 湖南 (無) 本 專書.

[Prob. = Chen-Chung Hang-Pao Yuan-Pi Shu and variants].

The Ten Thousand Infalible Arts of (the Prince of Huai-Nan) [Taoist magical and technical recipes].

C. Han, - +200.

No longer a separate book but fragments contained in T'Yu, ch. 216 and elsewhere.

Reconstituted texts by Yeh T’eh-Hui in Kwan Chun Chhng Thang Shu, and Sun Fung-I in We Chhng Chhng Thang Shu. Attrib. Lien An-shan.

See Kallman (2), p. 12.

It is probable that the terms Chen-Chung 陳仲 often refer to a Confidential Pillow-Book; Hang-Pao 漢 中 Abstract Ten Thousand Infallible; and Yuan-Yu 英雲 Gardens of Secrets; were originally titles of parts of a Huai-Nan Wang Shu, which was the first to incorporate them in the work. A few chars. tr. Chavannes (6, 16); Pfizmaier (1045) pr. +1767.

Chen Huang 黄漢.

See Chih Lin Ching (2).

The 'Borrowed Jade Returned' Encyclopaedia.

Ho Sih Chi-Hsin 許氏 生訓.

Collected Materials on River Control Works.

Sun, +1218.

Chen Chung 鄭鴻.

Hon Shun 快 先.

The History of the Later Han Dynasty [+3 to -3]

L/Sun, +450.

Fan Yeh 伏德.

The mono-syllabic chapters by Shuian Ping

of Mount Huai.

Shao Nan Tzu book (q.v.) was the Nei Shu 内書.

Huang Ti Ni Chih, Ling Shu 黃帝內經 指 註.

The Yellow Emperor's Manual of Corporeal Medicine; The Spiritual Pivot (or Gate, or Driving-Shaft, or Motive Power) [medical physiology and anatomy].

Probably C. Han, - +1st century.

Writers unknown.

Edited, +764 by Wang Ping 王琳.
BIBLIOGRAPHY A

Kuang Chih 楚志
Extensive Records of Remarkable Things.
Chin, 4th century.
Kuo Fang-shih 爰昨
Brief Records. YHSF, ch. 74.
Kuang Ya 桑痕
Essays of the Erh Ya; Literary Exposition [dictionary].
San Kuo (Wei), + 230.
Kuang Ya Su Ching 蒯會精
Correct Text of the Enlargement of the Erh Ya, with Annotations and Amplifications.
Chin, +190.
Wang Nien-Sun 王年孫
Kuang Ya Thu 桑痕Thu
First printed, the word Kuang added, by Lu Hung-Hsien (譚洪先), Ming, c. +190.
Kuang Yun 桑雲
Enlargement of the Chihh Yen; Dictionary of the Sounds of Characters.
Sung, c. 1275.
Fan Chih-Ta 斐志大,
Kuei-Hsin Tzu 桑雲遵
Record of a Journey to the South.
Sung, +1260.
Li Ao 韜老
Lao Phai Lu 禮頽錄
Bibliography. The Rein script (narrative of his embassy to the Chin Tatars).
Sung, +1270.
Chou M 小周
See des Rotours (r), p. xxi; H. Franke (34).
Kuang Chih Tzu 桑志子
Miscellaneous Information from Kuai-Hsin Street (in Hangchow).
Sung, late 13th century, perhaps not finished before +1308.
Chou M 小周
See des Rotours (r), p. xxi; H. Franke (34).
Kuang Chih Tzu 桑志子
Miscellaneous Information from Kuai-Hsin Street (in Hangchow) (First Addendum).
Sung, c. +1298.
Chou M 小周
See des Rotours (r), p. xxi.
Kuei Thien Lu 趙庭樂
On Returning Home.
Sung, +1057.
Ouyang Hsieh 鄭經修
Kuang Hsin Tzu 桑志子
Blushfulness Overcome; Recollections of My Life and Times.
Sung, c. +1210.
Lou Yo 龙要
Kung Kuo K'o 办國志
Gradation of Merits and Faults.
Ascr. Thang, 6th century, in fact Ming, +1770.
Attrib. Lu Tung-Pin 蘭朋賢, actual writer Yuan Pao 完保.
Kung Shih K'o 玄史記
A Study of Halls and Buildings.
Chin, early +11th century.
Jen Chii-Yin 靳氏
Kung Shih Yao Cho Ching Shih Lu Pan Mu 玄史傳修事略 工師議政
The Timberwork Manual and Artisans’ Mirror of Lu Pan, Pension of all Carvers, Joiners and Wood-workers.
Date unknown, contents traditional and certainly partly medieval.
Repr. 1750 and many other dates.
Attrib. author Sscheung Wu-Jung 吳正夢, +1472.
Kuo Chao Wen Lei 繼朝文類
Classified Documents of the Present Dynasty (Yuan).
Yuan, c. +1350.
Su Thien-Chia 戴天潛.
Discourses on the ancient feudal States.
Late Chou, Chihh and Ch’in, containing early material from ancient written records.
Attrib. unknown.
Lai Nan Lu 麗南錄
Record of a Journey to the South.
Sung, +1280.
Li Ao 韜老
Lao Phai Lu 禮頽錄
Bibliography.
Notes from the Hall of Lessons (3d Age).
Sung, c. +1100.
Lu Ya 魯雅
Lieu Shu 聊書
A Classified Commonplace-Book (a great florilegium of excerpts from Sung and pre-Sung books, many of which are otherwise lost).
Sung, +1215.
Ed. T'ang T'ao 竭道.
Li Chi 立記
 [= Hsiao Tai Li Chi.]
Record of Rites [compiled by Tai the Younger].
Li Chi 立記
[= Hsiao Tai Li Chi.]
Record of Rites [compiled by Tai the Younger].

BIBLIOGRAPHY A

Li Chi (cont.)
[cf. Ts Tai Li Chi.]
Ascr. Tsan, c. +70 to +50, but really HsiaHan, between +80 and +105, though the earliest pieces included may date from the time of the Analects (cf. +450 to +450).
Attrib. Ed. Tai Sheng 湲師.
Actual ed. T’ao Pao 端平.
Tr. Legge (7); Courvire (3); R. Wilhelm (6).
Yin-T’ie Index, no. 37.
Li-Chiang Fu Chih Lieh 立 Fraserflbers 鏡
Classified History and Topography of Li-chiang (Yunnan).
Chin, +1750.
Li Sao 郎遜
Elegy on Encountering Sorrow [ode].
Chou (Chihh), c. +290.
Chihh Yuan 魯原.
Tr. Hawkes (1).
Li Tai Ming Chen Tso Tou I 歷代名臣尺稿
Memorials to the Throne by Eminent Ministers in all Ages.
Ming, +1415, for the Palace Libraries only, printed for general circulation in +1505.
(Orig. eds.) Huang Hwei 梁辉 & Yang Ssu-Shing 鄭生 (later ed.) Chiang Phu 鐘福.
Li Tai Chiang Chi Lien 歷代邊疆親職
Essentials of the Comprehensive Mirror of History.
Chin, +1572.
Li-Hsia Liang Chi Man Chih 論古今知名士
Comprehensive History and Geography of the Sea-Walls of the Two Chekiangs [two parts of Chekiang province].
Chin, +1750.
Fang Kuan-Chiang 方覇章.
Liang Chi Chih Chiu 立強之書
Bridge Pool Essays.
Sung, +1170.
Fan Chih-Ta 斐志大.
Chihh or at least +8th century.
Chang Phu 藤浦.
Li-Shan Chih Chi Man Chih 序古知名壹
Only one chapter now extant.
Li Kang Ting Chien Chi 賤廣賢記
Published.
Liang Shu 立書
History of the Liang Dynasty [+502 to +506].
Chin, +506.
Yao Chia 稽家
and his son Yao Ssu-Lien 稽家廉
For translations of passages see the index of Frankel (1).

Liang Shu Kung Chi 立書同臣
Tales of the Four Lords of Liang. Thang, c. +650.
Chin, +650.
Liao Shih 厉史
History of the Liao (Chhi-tan) Dynasty. +1106 to +1125.
Yuan, c. +1350.
Tho-Sho (Tokoço) 藤原 & Ouyang Ssu-Min 趙受敏
Partial tr. W. Pingfogel, Feng Chia-Sisend et al.
Yin-T’ie Index, no. 35.
Liu Hsien Chao 立現超
Lives of Famous Hsien (cf. Shen Hsien Chiao).
Chin, +53rd or +49th century, though certain parts date from about +35 and shortly after +107.
Attrib. Liu Hsiang 劉易.
Tr. Kalesmark (3).
Liu Hsian 立見
[= Ching Hsia Ch’ing Ching.]
The Book of Master Lieh.
Chou and Ch’in, 4th to 15th centuries.
Attrib. Lieh Yu-Yiou 理有秋 (cf. H. Franke (14)); R. Wilhelm (7); Graham (6).
TT (4).
Liu I (Kui) 立伊 (顧) 慧
Records of Liu I (State) and Province.
Chin or at least pre-Sui.
Attrib. unknown.
Ling Pao Lao 立bao 梧
Southern Ways of Men and Things [the special characteristics and natural history of Kuangtung].
Thang, c. +935.
Liu Hsin 立信.
Ling Shu Ching 立書經
Sung.
Ling Wei Tai 故外台
Information on What is Beyond the Passes (lit. a book in lieu of individual replies to questions from friends).
Sung, +1178.
Chou Chihh-Tui 齊志.
Li-Chiu Kuo Chih Liang 立朝匡時梁
Alternate title of Tung Kuan Chi Shih, q.v.
Account of the Liu-Chiu Islands.
Chin, +1572.
Chou Hsiao 齊小.
Liu Pin-Kho Wu Chi 立隄宇文章
Literary Collections of the Imperial Tutor Liu.
Thang, after +802.
Liu Yu-Hsi 立宇義.
Lo Chiang Lu 立讓居
Record of the Naked Creatures (i.e. the Barbarian Peoples).
BIBLIOGRAPHY A


Nyu-Min Ki 入明記
(alternatively Nyu-Ts’u Ki 入唐記).

Diet of Travels in the Ming Empire. Wang Chhi 威章三世通志.

Pai Pei 桃妃.

Leaves of Grass [encyclopaedia]. Miing, +1522.

Ed. Thang Shun-Chih 趙運之.

Pei Chou 魏周.


Pei Shih 費史.

A few chs. tr. Pfizmaier (I).

Ts’ao Chi 粵治
Chhen Fu (Taoist) 聲符 (道者).

Thong, Ed. Kuang Chhao-Khuei 夏朝獻-秦的小國志;

A few chs. tr. Pfizmaier (I).

Pei Shih 費史.

Chihung, +1711.

Pei Shih 費史.

History of the Northern Dynasties [Nan-kiou 國史].

Tr. War (3). Partial tr. Feiffer (1, 2); Wu & Davis (3, 4).

Ko Hung 王宏.

The Great Pharmacopoeia. Ming, +1596.

Li-Shih-Chen 李時珍. 

Paraphrased and abridged tr. Read & collaborators (1 & 7) and Read & Pak (1) with index.

Phin Thao Piao Lin Ching Yang (in Pao-chihien)

Systematice Compendium of Materia Medica

Imperially Commissioned.

Ming, +1593; Ed. Lo wen-Thai 閩文泰, Wang Phan 王磐, & Kuo Ching-Ho 軍甲和.

Phei Wino Yau Fu 偏文詠副

Encyclopedia of Phrases and Allusions arranged according to Rhyme.

Chihung, +1711.

Ed. Chang Yu-Shu 張玉書 et al.

Pei Yu 魏俠.

The Book of the Expeditionary (i.e. Additions to the

Literary Expositor).

Sung, +1196.

Lu Tien 魏騰.

Phin-Chou Kuo Ben (cross to be read)

Phin Swong Table-Talk.

Sung, +1199 (referring to +1086 onwards).

Chu Yu 季書.

Phin Hia Lin (in Pao-chihien)

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The 29 'Chin Wen' chapters mainly Chou
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Ching Imperial MS. Collection.
A var MS. collection commissioned by
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years some 350 scholars, headed by Chi
Yun, were employed in collating the
texts of the +671 books regarded as the
most noteworthy and valuable. 6,793 books
of lesser interest were described in the
analytical Catalogue but not embodied in
the collection. Each of the finished sets
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Li Hsin-Chang (7) 李欣章

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GENERAL INDEX

by Muriel Moyle

Notes

(1) Articles (such as 'the', 'of', etc.) occurring at the beginning of an entry, and prefixes (such as 'de', 'van', etc.) are ignored in the alphabetical sequence. Stains appear among all letters of the alphabet according to their proper names. Styles such as Mr, Dr, if occurring in book titles or phrases, are ignored; if with proper names, printed following them.

(a) The various parts of hyphenated words are treated as separate words in the alphabetical sequence. It should be remembered that, in accordance with the conventions adopted, some Chinese proper names are written as separate syllables while others are written as one word.

(b) In the arrangement of Chinese words, Chh- and Hs- follow normal alphabetical sequence. It should be remembered that, in accordance with the conventions adopted, some Chinese proper names are written as separate syllables while others are written as one word.

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# CHINESE ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABA</td>
<td>Agric. History Research Annual (Vienna)</td>
</tr>
<tr>
<td>AHRA</td>
<td>Agric. History Research Annual (Tokyo)</td>
</tr>
<tr>
<td>APS</td>
<td>Acta Paedologica Sinica</td>
</tr>
<tr>
<td>AS:BJHP</td>
<td>Bulletin of the Institute of History and Philology (Academia Sinica)</td>
</tr>
<tr>
<td>AS:CJA</td>
<td>Chinese Journal of Archaeology (Academia Sinica)</td>
</tr>
<tr>
<td>BCGS</td>
<td>Bull. Chinese Geological Soc. (Chihli)</td>
</tr>
<tr>
<td>BCS</td>
<td>Bulletin of Chinese Studies (Chihli)</td>
</tr>
<tr>
<td>BK</td>
<td>Bunka (Culture), (Sendai)</td>
</tr>
<tr>
<td>BSRCA</td>
<td>Bulletin of the Society for Research in the History of Chinese Architecture</td>
</tr>
<tr>
<td>CHYT</td>
<td>Ch'ing-Hua (Ch'ing-Hu) Journal of Chinese Studies (New Series, publ. Taibei)</td>
</tr>
<tr>
<td>CIB</td>
<td>China Institute Bulletin (New York)</td>
</tr>
<tr>
<td>CLET</td>
<td>Chen Li Tsa Chih (Truth Miscellany)</td>
</tr>
<tr>
<td>CJC</td>
<td>Chigaku Zasshi (Journ. Tokyo Geogr. Soc.)</td>
</tr>
<tr>
<td>CFT</td>
<td>Far Eastern Trade (London)</td>
</tr>
<tr>
<td>HCH</td>
<td>Hein Chao-Hsin (New Korea)</td>
</tr>
<tr>
<td>HHJP</td>
<td>Hein Hua T'ieh Pao (Peking)</td>
</tr>
<tr>
<td>HHYK</td>
<td>Hein Hua Yieh Khan (New China Magazine)</td>
</tr>
<tr>
<td>JGSC</td>
<td>Jihmin Kenkkyu (Ochhe)</td>
</tr>
<tr>
<td>JY</td>
<td>Jen Min T'ieh Pao (People's Daily)</td>
</tr>
<tr>
<td>KDK</td>
<td>Kodaigaku (Palaeological), (Osaka)</td>
</tr>
<tr>
<td>KHS</td>
<td>Kho Hieh (Science)</td>
</tr>
<tr>
<td>KTH</td>
<td>Kho-Ka Thong Hiein (Archaeological Correspondent), (cont. as Kho Ka)</td>
</tr>
<tr>
<td>LSYC</td>
<td>Li Shih Yen Chia (Journal of Historical Research, (Peking))</td>
</tr>
<tr>
<td>MOULA</td>
<td>Memoirs of the Osaka University of Liberal Arts and Education</td>
</tr>
</tbody>
</table>

### CHINESE ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSC</td>
<td>Wen Shih Chia (Literature, History and Philosophy), (Shantung University)</td>
</tr>
<tr>
<td>WUQISS</td>
<td>Wuhan University Quart. Journ., Social Science and Philosophy</td>
</tr>
<tr>
<td>WWTK</td>
<td>Wen Wu T'ahem Kao Tan Liao (Reference Materials for History and Archaeology), (cont. as Wen Wu)</td>
</tr>
</tbody>
</table>

### CHINESE ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>YAHSS</td>
<td>Yenching Shih Hsueh Nien Pao (Yenching University Annual of Historical Studies)</td>
</tr>
<tr>
<td>YCHP</td>
<td>Yenching Hsueh Pao (Yenching University Journal of Chinese Studies)</td>
</tr>
<tr>
<td>YK</td>
<td>Yu Kang (Chinese Journal of Historical Geography)</td>
</tr>
</tbody>
</table>
INTERIM LIST OF EDITIONS OF CHINESE TEXTS USED

By Léonie Callaghan et al.
INTERIM LIST OF EDITIONS OF
CHINESE TEXTS USED

At the outset of the present work it was envisaged that many readers of these Volumes who understand Chinese would naturally wish to refer to the original sources. Especially where translations of passages have been given would they be likely to want to find the originals conveniently, and since editions of Chinese books are often multifarious, it would be desirable to know the edition used. The fulfilment of this promise (cf. Vol. 1, p. 20 on Bibliography A, entries (m) and (n); Vol. 4, Part 1, p. xxviii; and Vol. 4, Part 2, p. xlvi) could hardly be postponed until the end of Volume 7, so we present here an interim list, prepared with the assistance of Miss Léonie Callaghan. The following points of explanation are needed.

1. The book-titles in the main part of the list (A) are placed in alphabetical order just as they occurred in the bibliographies of the several Volumes, but conflated. The rules of Bibliography A continue to apply, such as all Chh- after Ch-, and all Hs- after H-.

2. The list continues (B) with the tshung-shu collections, each being given a standard abbreviation in roman letters, used in list (A) to indicate in which one a particular text is to be found. This list includes not only tshung-shu in the strict sense, but also a number of collections of separate books, even when these are the work of the same author.

3. Not all the books listed in the bibliographies of the several Volumes will be found here, for some could only be quoted by title and author, as their texts have never been available to us. The reader is reminded that books not now extant in any form do not appear in the bibliographies at all and references to them can be sought only through the general indexes.

4. Works in Chinese script published in Japan, Korea, Vietnam, etc., are placed here according to the Chinese pronunciation of the characters of the title and not, as in the previous Volumes themselves, according to the Japanese, Korean or Vietnamese pronunciations.

5. Sometimes more than one edition is given if these were all consulted by us.

6. Some texts have been seen only in microfilm form; when this is so the fact is noted.

7. Some editions at our disposal are almost impossible to identify, owing to loss of title-page or last page by rebinding or otherwise, but it is hoped that the information given will generally be sufficient.

8. The present list includes no entry in Bibliography B. There is of course a certain overlap between Bibliographies A and B, for the date of 1800 is an artificial one adopted for convenience, and some collections such as HCCC straddled it; however, in general the information in Bibliography B has always been more precise.
A BOOK TITLES

In alphabetical order according to the romanisations (not in stroke order); including books in Japanese, Korean, etc. Abbreviations in capitals refer to the list of shuho -collections used (List B).

LIST OF EDITIONS USED

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LIST OF EDITIONS USED

922

923

In the text, the following abbreviations are used:

- BH: B. H. Drower
- HWTS: H. W. Tucker
- SF: S. F. Baird
- TLS: T. L. Smith
- CPTS: C. P. T. Smith
- SCSS: S. C. S. Smith
- KCS: K. C. Smith
- YHSF: Y. H. Smith
- TRC: T. R. C.
- TSCH: T. S. C. H.
- HSL: H. S. L.
- TSCC: T. S. C. C.
- TSHCC: T. S. H. C. C.

The text also includes references to various libraries and archives:

- Cambridge University Library
- British Library
- Library of Congress
- Harvard University Library
- National Library of China

The document contains a list of editions used in the research, including titles and publication dates.
In alphabetical order according to the romanisations (not in stroke order).

B. TSHUNG-SHU COLLECTIONS

In alphabetical order according to the romanisations (not in stroke order).

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In alphabetical order according to the romanisations (not in stroke order).

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<table>
<thead>
<tr>
<th>Period</th>
<th>Dynasty</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>221 to 265</td>
<td>Chinese dynasty</td>
<td>-221</td>
<td>-265</td>
</tr>
<tr>
<td>265 to 220</td>
<td>Han dynasty</td>
<td>-265</td>
<td>-220</td>
</tr>
<tr>
<td>220 to 207</td>
<td>First Unification</td>
<td>-220</td>
<td>-207</td>
</tr>
<tr>
<td>207 to 202</td>
<td>Chihen Han (Earlier or Western)</td>
<td>-207</td>
<td>-202</td>
</tr>
<tr>
<td>202 to 9</td>
<td>Han interregnum</td>
<td>-202</td>
<td>-9</td>
</tr>
<tr>
<td>9 to 23</td>
<td>Hou Han (Later or Eastern)</td>
<td>-9</td>
<td>-23</td>
</tr>
<tr>
<td>207 to 265</td>
<td>Three Kingdoms period</td>
<td>-207</td>
<td>-265</td>
</tr>
<tr>
<td>265 to 220</td>
<td>First Unification</td>
<td>-265</td>
<td>-220</td>
</tr>
<tr>
<td>220 to 796</td>
<td>Wei dynasty</td>
<td>-220</td>
<td>-796</td>
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<tr>
<td>796 to 280</td>
<td>Wu dynasty</td>
<td>-796</td>
<td>-280</td>
</tr>
<tr>
<td>280 to 265</td>
<td>Second Unification</td>
<td>-280</td>
<td>-265</td>
</tr>
<tr>
<td>265 to 1279</td>
<td>Northern and Southern dynasties (Nan Pei chhao)</td>
<td>-265</td>
<td>-1279</td>
</tr>
<tr>
<td>1279 to 1280</td>
<td>Northern and Southern dynasties (Nan Pei chhao)</td>
<td>-1279</td>
<td>-1280</td>
</tr>
<tr>
<td>1280 to 1368</td>
<td>Yuan dynasty</td>
<td>-1280</td>
<td>-1368</td>
</tr>
<tr>
<td>1368 to 1644</td>
<td>Ming dynasty</td>
<td>-1368</td>
<td>-1644</td>
</tr>
<tr>
<td>1644 to 1912</td>
<td>Republic</td>
<td>-1644</td>
<td>-1912</td>
</tr>
</tbody>
</table>

Summary of the Contents of Volume 4

**PHYSICS AND PHYSICAL TECHNOLOGY**

Part I, Physics

With the collaboration of Wang Ling and the special co-operation of Kenneth Robinson

26 Physics

- Introduction
- Waves and particles
- Mass, measurement, statics and hydrostatics
- The Mohists and metrology
- The study of motion (Dynamics)
- Surface phenomena
- Heat and combustion
- Dispersion on luminescence
- Light (Optics)
- Mohist optics
- Mirrors and burning-mirrors
- Mirrors of unequal curvature
- Cameras obscuras
- Lenses and burning-lenses
- Rock-crystal and glass
- Chinese glass technology
- Burning-glasses and the optical properties of lenses
- Eye-glasses and spectacles
- Shadow-play and stereopt

Sound (Acoustics) [with Kenneth Robinson]

- Introduction
- Correlation of sound with flavour and colour
- The concept of sound in relation to acoustics
- Conducts for sound, the military diviner and his humming tubes
- The evolution of equal temperament
- The recognition of sound as vibration
- The detection of vibrations
- The free sound
- The search for accuracy in tuning
- Resonance phenomena and the use of measured strings
- The manufacture and tuning of bells
- Pith-pipes, siller-grades and metrology
- Western music and Chinese mathematics
- The special co-operation of Chiu Ta-yi

Magnetism and Electricity

- Introduction
- Magnetic attraction
- Electromagnetic phenomena
- Magnetic directivity and polarity
- Appearance of the magnetic compass in Europe and Islam
- Development of the magnetic compass in China
- Sudden compasses, wet and dry
- Reference of the Thang and earlier
- The Han diviners and the lodestone poem
- Literature on the diviner's board
- References to the 'south-pointing' compass
- The 'saddle of majesty'
- From the spoon to the needle
- The use of the compass in navigation
- The mariner's compass and the compass-card
- The direction-finder on the imperial lake
- The evolution of the compass
- Early observations of declination
- Magnetic variation and inclination
- The meridian, declination, and obliquity
- Magnetic variation and inclination
- Comparisons of instruments
- Comparative physiology of games
- General summary

N.B. When no modifying term in brackets is given, the dynasty was purely Chinese. Where the overlapping of dynasties and independent states becomes particularly confused, the tables of Wiegand (1) will be found useful. For such periods, especially the Second and Third Partitions, the best guide is Eberhard (9). During the Early Chin period there were no less than thirteen independent states (Hsienpi, Hsienpi, Turkic, etc.) in the north.
27 Mechanical Engineering

28 Civil Engineering

29 Nautical Technology