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 Ch'in, Comptroller-General of Crops and Weather. Before his deification (so it was said) he was a rain-making magician and weather forecaster named Liu Chun, 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 p. 297). During his earthly pilgrimage his name was Huan Tzu-Yu 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, Lei Kung. Before he became deified he was Hain 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 Chun, 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-Yu bears witness that Naburianus and Hipparchus, al-Naqiṣḥ and Tycho, had worthy counterparts in China. The tools of Hain Hsing symbolise that great empirical tradition which informed the work of Chinese artisans and technicians all through the ages.
SCIENCE AND CIVILISATION IN CHINA

The Chymists are a strange Class of Mortals, impelled by an incomprehensible Impulse to take their Pleasure amid Smoke and Vapour, Flame and Flanne, Poisons and Poverty—yet among all these Evils, I seem to live so sweetly that may I die if I would change places with the Persian King!

Johann Beccher
Physica Subterranea, 1703

Quasi nimirum in Fatis esset, Sal hoc admirable non minus in philosophia quam bello streptius aderet, omniasque sonitus suo impler. (As if ordained by Fate, Nitre, that admirable salt, hath made as much noise in Philosophy as in War, all the world being filled with its thunder).
John Mayow
Tractus Quinque Medico-Physici, 1674

For it is now certainly known that the great Kings of the uttermost East, have had the use of the canon many hundreds of years since, and even since their first civilitie and greatnesse, which was long before Alexander’s time. But Alexander pierced not so far into the East.
Sir Walter Raleigh
History of the World, 1614

Dr John Bell of Antermony asked the Khang-Hsi Emperor’s Tartar General of Artillery: ‘How long the Chinese had known the use of gunpowder?’ He replied, above 2000 years, in fire-works, according to their records; but that it’s application to the purposes of war, was only a late introduction. As the veracity and candour of this gentleman were well known, there was no room to question the truth of what he advanced on the subject.
John Bell’s
1 Jan. 1721
Travels from St. Peters burg in Russia to Diverse Parts of Asia, 1703

And though it be very true that man is but the Minister of Nature, and can but duely apply Agents to Patients (the rest of the Work being done by the applied Bodies themselves), yet by his skill in making these Applications, he is able to perform such things as do not only give him a Power to master Creatures otherwise much stronger than himself; but may enable one man to do such wonders, as another man shall think he cannot sufficiently admire. As the poor Indians look upon the Spaniards as more than Men, because the Knowledge they had of the Properties of Nitre, Sulphur and Charcoal duely mix, enabled them to Thunder and Lighten so fatally, when they pleas’d.

Robert Boyle
Some Considerations touching the Usefulness of Experimental Philosophy, propos’d in a Familiar Discourse to a Friend, by way of Invitation to the Study of it, 1665
SCIENCE AND CIVILISATION IN CHINA

BY

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VOLUME 5

CHEMISTRY AND CHEMICAL TECHNOLOGY

Part 7: MILITARY TECHNOLOGY; THE GUNPOWDER EPIC

CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE
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To the memory of
FUSSU-NIEN
eminent scholar of history and philology,
then at Lichuang in Szechuan, and most friendly
welcomer to war-time China,
who led a discussion one evening while we were
there on the history of gunpowder in China;

and to
YÜ TA-WEI
physicist, then
Ping-kung-shu Shu-chang (Intendant-General of Arsenals)
1942-1946
whose 'field coffee' I used to drink with him in his
office, and with whom we had a happy reunion in 1984,

this volume is dedicated.
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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>BN</td>
<td>Bibliothèque Nationale, Paris.</td>
</tr>
<tr>
<td>CCL</td>
<td>Ch'i Chiang Lu (Biographies of [Chinese] Engineers, Architects, Technologists and Master-Craftsmen).</td>
</tr>
<tr>
<td>CCT</td>
<td>Chao Shih-Chên, Ch'ê Chhung T'ai (Illustrated Account of Muskets, Field Artillery and Mobile Shields, etc.), Ming, c. +1585.</td>
</tr>
<tr>
<td>CHHS</td>
<td>Chhi Chi-Kuang, Chi Hsiao Hsin Shu (New Treatise on Military and Naval Efficiency), Ming, +1560, pr. +1562, often repr.</td>
</tr>
<tr>
<td>CHS</td>
<td>Pan Ku, (and Pan Chao) Chhien Han Shu (History of the Former Han Dynasty), H/Han, c. +100.</td>
</tr>
<tr>
<td>CHSK</td>
<td>Ting Fu-Pao (ed.), Chhian Han San-Kuo Chin Nan-Pei-Chhao Shi (Complete Collection of Poetry from the Han, Three Kingdom, Chin and Northern and Southern Kingdoms), Peking, c. 1935. Index by Tshai Chin-Chung, Harvard-Yenching Institute, Paping, 1941 repr. Taipei, 1966.</td>
</tr>
<tr>
<td>CHTP</td>
<td>Chêng Jo-Tsêng, Chhau Hsiu Thu Pien (Illustrated Seaboard Strategy and Tactics), Ming, +1562, repr. +1572, +1594, +1624, etc.</td>
</tr>
<tr>
<td>CKKSL</td>
<td>Chung-Kuo Kho Chi Siih Liao (Materials on the History of Science and Technology in China), a journal.</td>
</tr>
<tr>
<td>CSHK</td>
<td>Yen Kho-Chhun (ed.), Chhian Shang-Ku San-Tai Chhinn Han San-Kuo Liu Chhao WIN (Complete Collection of prose literature (including fragments) from remote antiquity through the Chhin and Han Dynasties, the Three Kingdoms, and the Six Dynasties), 1836.</td>
</tr>
<tr>
<td>CLPT</td>
<td>Thang Shen-Wei (ed.), Chêng Lei Pên Jhahuo (Reorganised Pharmacopoeia), Sung, ed. of +1249.</td>
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</table>

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<table>
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>CTS</td>
<td>Liu Hsi, Ch'iu Thang Shu (Old History of the Than Dynasty), Wu Tai, +945.</td>
</tr>
<tr>
<td>CYMTYL</td>
<td>Attrib. Chêng Sau-Yuan, Chen Yuan Miao Tao Yao Lienh (Classified Essentials of the Mysterious Tao of the True Origin of Things), Ascr. Chin (+3rd) but probably mostly Thang (+8th and +9th).</td>
</tr>
<tr>
<td>HCC</td>
<td>Hsi Tung, Hu Chhien Ching (Tiger Seal Manual, a Military Encyclopedia), Sung, begun +962, finished +1004.</td>
</tr>
<tr>
<td>HHPT</td>
<td>Su Ching et al. (ed.), Hsin Hsiu Pên Tchhao (Newly Improved Pharmacopoeia), Thang, +659.</td>
</tr>
<tr>
<td>HHS</td>
<td>Fan Yeh &amp; Ssuma Piao, Hau Han Shu (History of the Later Han Dynasty), +450.</td>
</tr>
<tr>
<td>HKPY</td>
<td>Hwo Kung Pei Yao (Essential Knowledge for the Making of Gunpowder Weapons), alternative title of Pt. 1 of the Hwo Lung Ching, q.v.</td>
</tr>
<tr>
<td>HLC</td>
<td>Chiao Yu, Hwo Lung Ching (The Fire-Drake (Artillery) Manual), Ming, +1412, but probably continuing information dating from the previous half-century, perhaps back to +1300. In three parts. The first part of the back is fancifully attributed to Chhuo Wu-Hou (Chhuo Liang, +3d cent.) &amp; Liu Chi (+1411 to +1573). The latter appears as editor but was perhaps co-author. The second part of the book is attributed to Liu Chi, but Mao Hsi-Ping (+1632) was probably the writer. The third part is by Mao Yuan-I (fl. +1628) and has a preface by Chhuo Kuang-Lung dated +1644.</td>
</tr>
<tr>
<td>HSCH/TCTC</td>
<td>Liu Shih-Chi: Hsu Sung Chung-Hsing Pien Nien Tzu Chih Thang Chien (Continuation of the 'Mirror of History for Aid in Government' for the Sung dynasty from its Restoration Onwards), i.e. the Southern Sung from +1126. Sung, c. +1250.</td>
</tr>
<tr>
<td>HTCTC/CP</td>
<td>Li Tao Hsi Tzu Chih Thang Chien Chiang Phien (Continuation of the 'Comprehensive Mirror' of History for Aid in Government), dealing with events from +960 to +1126, i.e. the Northern Sung dynasty, Sung, +1189.</td>
</tr>
</tbody>
</table>
LIST OF ABBREVIATIONS

HTS  Ouyang Hsiu & Sung Chhi, Hsin Thang Shu (New History of the Thang Dynasty), Sung, +1061.

HWHTK  Wang Chhi (ed.) Hsiu Win Hisen Thang Khao (Continuation of the 'Comprehensive Study of (the History of) Civilisation'), Ming, +1586, pr. +1603.

LPSC  Chhi Chi-Kuang, Lien Ping Shih Chi Tsu Chi (Miscellaneous Records concerning Military Training and Equipment), an appendix to Lien Ping Shih Chi, Ming, +1568, pr. +1571.

MCPT  Shen Kua, Ming Chhi Pi Than (Dream Pool Essays), Sung, +1089.


PL  Ho Ju-Piu, Ping Lu (Records of Military Art). Ming, +1606, pr. +1628, later eds. +1630, +1632.

PPT/NP  Ko Hung, Pao Phu Tzu (Nei Phien), (Book of the Preservation-of-Solidarity Master, Inner Chapters), Chin, c. +320.

PTK  Li Shih-Chen. Pên Tshao Kang Mu (The Great Pharmacopoeia), Ming, +1569.

PTKMSI  Chao Hsüeh-Min, Pên Tshao Kang Mu Shih I (Supplementary Amplifications for the 'Great Pharmacopoeia' of Li Shih-Chen), Chhing, begun c. +1760, first prepared +1765, pro-legomena added +1780, last date in text 1803. First pr. 1871.

R  Read, Bernard E. et al., Indexes, translations and précis of certain chapters of the Pên Tshao 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 (5); if to a fish see Read (6); if to an insect see Read (7).

RARDE  Royal Armament Research and Development Establishment, Fort Halstead, Kent.

SCP  Chao Shih-Chen, Shen Chhi Phu (Treatise on Extraordinary (lit. Magical) Weapons, i.e. Muskets), Ming, +1598.

SF  Thao Tsung-I (ed.), Shao Fu (Florilegium of (Unofficial) Literature), Yuan, c. +1368.

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

SKCS/TMTY  Chi Yün (ed.), Ssu Khu Chhian Shu Tsung Mu Thi Yao (Analytical Catalogue of the Complete Library of the Four Categories), +1782; the great bibliography of the imperial MS collection ordered by the Chhien-Lung emperor of Chhing in +1772.

STTH  Wang Chhi, San Tshai Thu Hui (Universal Encyclopaedia), Ming, +1609.

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

TKK  Sung Ying-Hsing, Thien Kung Khai Wu (The Exploitation of the Works of Nature), Ming, +1637.

TPKC  Li Fang (ed.) Thai-Ping Kung Chi (Copious Records collected in the Thai-Ping reign-period), Sung, +978.

TPYC  Li Chhüan, That Pai Yin Ching (Manual of the White and Gloomy Planet (of War, Venus)), treatise on military and naval affairs, Thang, +759.

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

TSCC  Ohhen Meng-Lei et al. (ed.), Thu Shu Chi Chheng; the Imperial Encyclopaedia of +1726. Index by Giles, L. (2). References to 1834 ed. given by chapter (chhüan) and page. References to 1934 photolith reproduction given by tshè (vol.) and page.

TT  Wieger, L. (6), Taomine, vol. 1, Bibliographie Générale of the works continued in the Taoist-Patrolgy, Tao Tsang.

TTSLT  Thai Thu Shih Lu Thu (Veritable Records of the Grand Ancestor (Nurhachi, d. +1626, retrospectively emperor of the Chhing), with illustrations). Ming, +1635, revised in Chhing, +1781.


WCTYcc  Tseng Kung-Liang (ed.), Wu Ching Tsung Tao (Chhien Chi), military encyclopaedia, first section, Sung, +1044.

WHTK  Ma Tuan-Lin, Win Hien Thung Khao (Comprehensive Study of (the History of) Civilisation), Yuan, +1319.

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

WPHEL  Attrib. Chiao Yü, Wu Pei Hoo Lung Ching (The Fire-Drake Manual and Armament Technology), Ming, after +1628, but containing much material from earlier versions of the Hoo Lung Ching.

YCLH  Chang Ying (ed.), Yuan Chien Lei Han (encyclopedia), Chhing, +1710.
LIST OF ABBREVIATIONS

YH
Wang Ying-Lin, Yu Hai (Ocean of Jade, an encyclopaedia of quotations). Sung, +1267 but not pr. till Yuan, +1337/1340, or perhaps +1351.

YHSF
Ma Kuo-Han (ed.), Yu Han Shan Fang Chi 1 Shu (Jade-Box Mountain Studio Collection of [reconstituted and sometimes fragmentary] Lost Books), 1853.

AUTHOR'S NOTE

This volume has been forty-three years in the gestating. On 4th June 1943 Huang Hsing-Tsung6 and I landed at Lichuang6 in Szechuan after a rather adventurous journey down the Min-chiang and the Yangtse River from Wuthung-chhiao7,8. There, near the delightful little town, were the Chinese-German Thung-Chi9 University, and also the evacuated National Institutes of History and Sociology of Academia Sinica. These were then headed by two very famous scholars, Fu Ssu-Niena and Thao Meng-Hoa respectively, whom I was honoured to meet. Also in the neighbourhood were the evacuated National Archaeological Museum directed by Li Chi7, and the Institute for the History of Chinese Architecture under Liang Ssu-Chhiang8. One evening the talk turned to the history of gunpowder in China, and Fu Ssu-Nien himself copied out for us the earliest printed passages on its composition from the Wu Ching Tsung Yao of +1044, a book which we did not then possess. It was at Lichuang also that I first met Wang Ling (Wang Ching-Ning9), who was destined to be my initial collaborator in the writing of Science and Civilisation in China, from 1938 to 1957, in Cambridge. At that time, he was a young research worker in the History Institute of Academia Sinica, and made the history of gunpowder, in all its ramifications, a lifelong study. Later on, he pursued a distinguished career as research professor of the Institute of Advanced Studies at the Australian National University at Canberra.

Of the other two collaborators whose names are on the title-page of this volume, Ho Ping-Yü7, now Professor of Chinese at Hongkong University, has the great merit of having written the first draft of it. Having grown up in Singapore, he became an eminent historian of science, and later professor at Kuala Lumpur and Brisbane successively, since when he has produced many excellent books of his own. Finally, Lu Gwei Djen10 was one of the first who converted me to Chinese studies from 1937 onwards, at which time we planned the present series of volumes; and when, twenty years later, she returned from UNESCO in Paris to Cambridge, she succeeded Wang Ling as my chief collaborator. This she still is. For the present book we have together checked all the battle accounts and the entries in the military encyclopaedias.

With the production of this volume, it will be seen that all three of the fun-
damental inventions enumerated by Francis Bacon in +1620 have now been dealt with in detail. We quoted the *Novum Organum* fully in Vol. i, but the passage is well worth reproducing in shortened form here.b

Discoveries are to be seen nowhere more conspicuously than in those three which were unknown to the ancients, and of which the origin, though recent, is obscure and inglorious; namely printing, gunpowder, and the magnet. For these three have changed the whole face and state of things throughout the world, the first in literature, the second in warfare, the third in navigation; whence have followed innumerable changes; insomuch that no empire, no sect, no star, seems to have exerted greater power and influence in human affairs, than these three mechanical discoveries.

So, looking back, we dealt with the magnetic compass first, in Vol. 4, pt. 1, then with paper and printing, by the care of our valued collaborator, Professor Chhien Tshun-Hsün, in Vol. 5, pt. 1, and now finally with gunpowder in Vol. 5, pt. 7. Francis Bacon died without knowing that every one of the discoveries which he singled out had been Chinese. And although we have not been able to identify the personal name of any individual as the *fons et origo* of the three discoveries, no doubt whatever can remain about the people in the midst of whom they first came into being.

The present volume is the middle one of three on military technology. It is appearing ahead of the others simply because it is now ready. The first (Vol. 5, pt. 6), after an introduction, will deal with (b) Chinese literature on the art of war, (c) basic concepts of the classical Chinese theory of war, (d) distinctive features of Chinese military thought, (e) projectile weapons, the bow and cross-bow, (f) ballistic machinery—pre-gunpowder artillery, and (g) early poliorcetics—the siege and defence of cities. I owe a great deal of gratitude to my collaborators in these subjects, Wang Ching-Ning, Robin Yates, Krzysztof Gawlikowski and Edward McEwen.

The third part (Vol. 5, pt. 8) will deal with (i) close-combat weapons, (j) chariot warfare, (k) cavalry techniques, including the invention of the stirrup and its spread, (l) armour and caparison, (m) camps and formations, (n) signalling and other forms of communication; and the whole will end with some comparisons and conclusions. Here my principal collaborators have been Wang Ching-Ning, Robin Yates, the late Lo Jung-Pang and Albert Dien. Professor Robin Yates of Harvard is taking charge of the general editing of both these.

It is natural enough that the present volume should take its place among the military three because the finding of the gunpowder mixture in the middle of the +6th century was no doubt the greatest of all Chinese military inventions. The gunpowder rocket might indeed turn out, as we venture to say in this volume, to be the greatest single invention ever made by man, for if the sun cools or over-

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b P. 19.

a Menagù ed. (Latin), vol. 9, pp. 381-2; Ellis & Spedding ed. (English), p. 300. It is in bk. 1 of the original work, *Aphorism* 189.

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Heats, and we have to go somewhere else, the rocket will be our only means of doing so, since it is the sole vehicle known to man capable of navigating in outer space. Not of course the gunpowder rocket, as the Chinese military engineers knew it in the middle of the +12th century, but the rocket vehicles of today and tomorrow, powered by liquid fuels, or more probably by sub-atomic nuclear reactions.

In the same way, the story we tell here is far more exciting than it could have been if warlike applications alone had been in question. Quite apart from the application of explosions in mining, quarrying, and the building of human lines of communication—all civil engineering tasks—gunpowder, the first chemical explosive known to man, had a vital role in the development of all heat engines. Mechanical engineers were therefore also involved. Not everyone realises that before the steam-engine came into its heyday, Christian Huygens and Denis Papin in the late +17th century tried to make successful gunpowder-engines; and although they could never get them to work, it put them in mind of simple water and condensible steam. Hence Thomas Newcomen's success in +1712.

We have also tried to tell the story of the internal-combustion engine, which followed upon his triumph, though long afterwards; and by 1890 Luigi de Cristoforis suggested fueling it with petrol. The oldest internal-combustion engine was of course the cannon, but from the engineering point of view its piston was not tethered, and the work it did was not useful work. With petrol and similar fuels the internal-combustion engine came into its own, permitting, among other things, the successful aviation of today. But petrol was nothing else than the old Greek Fire, first distilled from petroleum by Callimicus in +7th-century Byzantium. This was the greatest incendiary predecessor of gunpowder; and in fact the first use of the latter in warfare was as a slow-match in the ignition-chamber of a Chinese Greek-Fire projector. This event we date at +619. So the wheel had at last come full circle, and the only tragic aspect of the affair was the centuries of time it had taken for men to see the beneficial uses of a discovery, and the celerity with which its evil uses were found out and put into practice.

We end this volume with an excursion on the travel of the knowledge of gunpowder from east to west. Perhaps the most extraordinary fact is that all the stages, from the incendiary uses of the mixture right through to the metal-barrel hand-gun or bombard, with the projectile fully occluding the bore, were passed through in China, before Europeans knew of the mixture itself. Probably there were three comings. Roger Bacon by +1260 or so was able to study fire-crackers, doubtless brought west by some of his brother friars; and the Arabian military engineers in the Chinese service must have let Hasan al-Rammah know about bombs and rockets by +1280. Then, within the following twenty years, came the cannon, quite possibly directly overlaid through Russia.

The preparation of this volume has been accompanied by many changes in our group. First I must refer to the much-lamented death of Peter Burbidge in
May 1985. He had been not only Executive Vice-Chairman of the East Asian History of Science Trust, but also from 1984 onwards the presiding genius, and benign protector, of all our volumes, the publication of which he guided as Production Director of the Cambridge University Press. At our weekly meetings we have missed him tremendously. But we are fortunate that Colin Ronan, our collaborator in the Shorter Science and Civilisation in China series, has taken over as Project Co-ordinator.

Next, this volume has been passing through the press alongside the erection of a new and permanent building for the East Asian History of Science Library, on the basis of funds most generously subscribed both in Hongkong and Singapore. We owe particular gratitude to Dr Māo Wēn-Chí, Chairman of the East Asian History of Science Foundation Ltd. in Hongkong, with its members and benefactors; and to the outstandingly liberal beneficence of Tan Sī Tan Chīn Tuan of the Overseas Chinese Banking Corporation in Singapore.

Similarly, our East Asian history of Science Board, Inc. of New York, headed by Mr John Diebold, has concentrated rather on raising funds for the endowment and research necessitated by the Science and Civilisation in China project, and it is due to them that the National Science Foundation, the Luce Foundation, and the Mellon Foundation, have contributed generously to this end. And here Japan has also joined in, for the National Institute for Research Advancement (NIRA) of Tokyo has given a noble benefaction directed mainly for Vol. 7. Our deepest thanks are due to this organisation, directed by Dr Shimokobe Atsushi. One cannot be too grateful for such help in the payment of necessary emoluments and research expenses for our far-flung collaborators.

As usual, we would like also to thank those who have been of special help to us in the preparation of this volume. Thus we are glad to number among our friends Mr Howard Blackmore, formerly Deputy Keeper of the Armouries at H.M. Tower of London, who gave us valuable criticism throughout; Dr Nigel Davies, who arranged for experimental trials of gunpowders containing different nitrate percentages, at the Royal Armament Research and Development Establishment at Fort Halstead in Kent; and Dr Graham Hollister-Short, who greatly helped us in our work on the old gunpowder triers or testers, precursors of the gunpowder-engines, as also with the history of blasting in mines and quarries. Similarly, Dr Nakaoka Tetsuō gave us much help with the Japanese context of the Mōko Shūrai Ekotoba (p. 177), the only surviving picture of a 13th-century bursting bomb-shell. A special debt is owing to De Clayton Bredt of Brisbane, the discoverer of the 14th-century painting of a fire-lance, who read through the whole volume and offered numerous amendments.

Next we wish to record our indebtedness to all the staff of the East Asian History of Science Library. In particular we want to thank Mrs Liang Chung Lien-Chu who has attended to all the cross-references, as well as checking the proofs of Bibliographies A and B. When we have had occasion to seek linguistic help, we have turned, as before, to Prof. D.M. Dunlop for Arabic, the late Dr Charles Sheldon and Dr Ushiyama Teruyō for Japanese, and Prof. Shackleton Bailey for Sanskrit.

So now let us pull the lanyard and fire off this unpowder volume (to use an appropriate analogy) upon the Republic of Learning, not indeed with the intention of doing any damage, but rather hoping that it may help those still looking for enlightenment about the history of gunpowder-weapons and heat-engines. War may or may not have been a decisive factor in human evolution and social progress, but what cannot be denied is that the steam-engine and the internal-combustion engine have been this, and all were children of the cannon. And that in turn was one development of the fire-lance, while the other was the rocket, on which all space travel depends. Gunpowder-engines and the steam-engine no less than the rocket vehicle were thoughts springing from the European Scientific Revolution—but all the previous developments, through eight preceding centuries, had been Chinese.

1 毛文安 2 陳振濂 3 吳通海 4 中國哲學 5 梁錢雲祥
30 MILITARY TECHNOLOGY (cont.)

(f) PROJECTILE WEAPONS, III, THE GUNPOWDER EPIC

(1) INTRODUCTORY SURVEY

The development of gunpowder was certainly one of the greatest achievements of the medieval Chinese world. One finds the beginning of it towards the end of the Thang, in the 9th century, when the first reference to the mixing of saltpetre (i.e. potassium nitrate), sulphur, and carbonaceous material, is found. This occurs in a Taoist book which strongly recommends alchemists not to mix these substances, especially with the addition of arsenic, because some of those who have done so have had the mixture deflagrate, singe their beards, and burn down the building in which they were working.

The beginnings of the gunpowder story take us back to those ancient practices of religion, liturgy and public health which involved the 'smoking out' of undesirable things in general. The burning of incense was only part of a much wider complex in Chinese custom, purification as such (hū) that This procedure, carried on for hygienic and insecticidal reasons, was much older than the Han, appears to have emerged from a locus classicus in the Shih Ching (Book of Odes), where the annual purification of dwellings is referred to in an ancient song, datable to the -7th century or somewhat earlier. It is perhaps the oldest mention of the universal later custom of 'changing the fire' (kuan huo3, huan huo4), a 'new fire' ceremony annually carried out in every home. The medical fumigation (han5) of houses, after sealing all the apertures, with Catalpa wood (chhiu6), is referred to in the Kuan Tzu7 book not many centuries later, and the Chou Lii8, archaising in character even if a Former Han compilation, has several descriptions of officials superintending fumigation with the insecticidal principles of the plants Illicium.
and Chrysanthemum.\textsuperscript{4} From later literature we know that among Chinese scholars it was long the custom to fumigate their libraries to minimise the damage caused by bookworms, a great pest, especially in the centre and south.\textsuperscript{b}

As an extension of techniques like these, we find that the uses of scalding steam in medical sterilisation were appreciated as early as the +10th century. In his Ko Wu Ti Ka That\textsuperscript{1} (Simple Discourses on the Investigation of Things) about +980, Lu Tsan-Ning\textsuperscript{5} wrote:

When there is an epidemic of febrile disease, let the clothes of the sick persons be collected as soon as possible after the onset of the malady and thoroughly steamed; in this way the rest of the family will escape infection.

How general this practice was it would be hard to say, but it probably formed part of traditional hygienic usages from the Tang onwards.\textsuperscript{c}

Not only in peace, moreover, but also in war, the ancient Chinese were great smoke-producers. Toxic smokes and smoke-screens generated by pumps and furnaces for siege warfare occur in the military sections of the Mo Tzu\textsuperscript{1} book (c. 5th century BC), especially as part of the techniques of sapping and mining;\textsuperscript{4} for this purpose mustard and other dried vegetable material containing irritant volatile oils was used. There may not be sources much earlier than this, but there are certainly abundant sources later, for all through the centuries these strangely modern, if reprehensible, techniques were elaborated \textit{ad infinitum}. For example, another device of the same kind, the toxic smoke-bombs (\textit{huo chuhs} (h) of the +15th century, recall the numerous detailed formulae given in the Wu Ching Tsung Yao\textsuperscript{1} of +1044. The sea-battles of the +12th century between the Sung and the Chin Tartars, as well as the civil wars and rebellions of the Song, show many further examples of the use of toxic smokes containing lime and arsenic. Indeed, the earth-shaking invention of gunpowder itself, some time in the +19th century, was closely related to these, for it was at once seen to be connected with incendiary preparations, and its earliest formulae sometimes contained arsenic.

The whole story from beginning to end illustrates a cardinal feature of Chinese technology and science, the belief in action at a distance.\textsuperscript{d} In the history of naval warfare, for instance, one can show that the projectile dominance dominated over ramming or boarding, with its close-contact combat.\textsuperscript{5} Smokes, per-
Clearly this entire subject is concerned with power, a might and power placed in the hands of man as social evolution has gone on, power and might which form a couple of chapters only in the line of development which in the end has now given him mastery over the sub-atomic processes of suns, sources of inextinguishable energy, a mastery which has outstripped (it may be greatly feared) his ethical and moral maturity. Yet mastery over Nature remains the second grandest of ideals, as Robert Boyle wrote long ago, in 1664. He is well worth listening to.

And though it be very true [said he] that man is but the Minister of Nature, and can but duly apply Agents to Patients (the rest of the Work being done by the applied Bodies themselves) yet by his skill in making those Applications, he is able to perform such things as do not only give him a Power to Master Creatures otherwise much stronger than himself; but may enable one man to do such wonders, as another man shall think he cannot sufficiently admire. As the poor Indians look upon the Spaniards as more than Men, because the knowledge they had of the Properties of Nitre, Sulphur and Charcoal duly mixt, enabled them to Thunder and Lighten so fatally, when they pleas'd.

And this Empire of Man, as a Naturalist, over the Creatures, may perchance be, to a Philosophical Soul preserved by reason untainted with Vulgar Opinions, of a much more satisfactory kind of Power or Soveraigny than that for which ambitious Mortals are wont so bloodyly to contend. For oftentimes this Latter, being commonly but the Gift of Nature, or Present of Fortune, and but too often the Acquist of Crimes, does no more argue any true worth or noble superiority in the possessor of it, than it argues one Brasse Counter to be of a better Metal than its Fellows, in that it is chosen to stand in the Account for many Thousand Pounds more than any of them. Whereas the Dominion that Physiologie gives the Prosperous Studier of it (besides that it is wont to be innocent-ly acquired, by being the Effect of his knowledge), is a Power that becomes Man as Man. And to an ingenious spirit, the Wonders he performs bring perchance a higher satisfaction, as they are Proofs of his Knowledge, than as they are Productions of his Power, or even bring Accessions to his Store.

Here at the outset it would not be inappropriate to say something, for the benefit of those less familiar with the Chinese literary tradition than others, on what we might call the 'philological network'. Chinese historical writing cannot just be dismissed as unreliable, for no civilisation has had a greater historical tradition than China, and the accounts of what really happened in all the ages have been the work of thousands of meticulous and painstaking scholars. All that historians can do, they did, and archaeological finds have proved them right again and again, sometimes spectacularly. No other civilisation produced a

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* Everyone will remember the delicious and bitter satire of Jonathan Swift (2), in the 7th chapter of pt. 2 of his Gulliver's Travels (1726); where the voyager tells how he explained the nature and effects of gunpowder weapons to the King of Brobdingnag, and how utterly shocked and horrified this prince was when he heard about them. Gulliver affects to despise him for that—but Swift himself never knew that the explosive properties of gunpowder had already led a couple of dozen years earlier to the development of the steam-engine, which in its turn would generate the internal-combustion engine, with all the inestimable benefits which they have brought to mankind.

b (8), pt. 1, p. 20.
the discovery noted far one contemporary distinguished credit in antiquity. Though this was highly regarded, it was necessary to coin special adjectives, and to translate chia 1 as 'metallic juice' (not as potable gold), or mu yao 2 as 'lignic medicine'. Accordingly, encountering huo yao in nei tan texts of late date, it has to be translated as 'pyriyal salve', 3 i.e. the salivary Yang descending, in contrast with the 'aqueous salve', the seminal Yin, ascending: 4 essential components of the enychnoma to be formed at the centre of the body. But the lore of these two pro-enychnomas had an extremely limited readership, and we can be sure that very few Chinese scholars throughout history ever understood huo yao in any sense other than gunpowder.

Fig. 1 runs from left to right. Out of the remote depths of history come the incendiary substances, needing ignition, and burning, sometimes quite fiercely, in air. Attached to arrows (huo chien), they cross the stage and must have lasted down well into the Sung time or even later. One of these incendiaries was naphtha, derived from natural petroleum seepages; 5 but a great step forward was made in the 7th-century Byzantium, when Callinicus successfully distilled it to give low boiling-point fractions something like our petrol, which could be projected at the enemy by pumps which constituted flame-throwers. 6 We think we can identify naphtha under the name shih yu 7, and Greek Fire, as it was called, under that of ming huo yao 8. The 'siphon', or force-pump, was of particular importance because it was the site of the first use of gunpowder in war; this was the appearance of a slow-match impregnated with the material in the ignition chamber (huo lau) of the machine—and the date was 9319. That was a century which saw great commerce in these petrol fractions; they often came through from the Arab trade, but so much of the spirit was circulating among the rulers of the Five Dynasties period that the Chinese must surely have been distilling it themselves. 9

Without doubt it was in the previous century, around +850, that the early alchemical experiments on the constituents of gunpowder, with its self-contained oxygen, reached their climax in the appearance of the mixture itself. We need not harp upon the irony that the Thang alchemists were essentially looking for elixirs of life and material immortality. But it is only reasonable to recognise that once their laboratories had jars containing (among many other things) all the constituents (more or less purified) of the deagglutative and

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2. Of course where Shang or Zhou bronze vessels of artistic merit were concerned, the case is different. There was a great growth of antiquarianism from Sung times onwards (cf. Vol. 2, pp. 95 ff.), and forgeries certainly occurred.
3. This does not mean that every device described in late books such as the Wu Pi Chih (see p. 34 below) was necessarily used at the time; they are often liable to describe, with antiquarian zeal, inventions of the past, even when sometimes long disused. This has to be allowed for when reconstructing Chinese military engineering history.
4. One has to allow of course for legendary attributions to figures such as Yao, Shun, Huang Ti and even Gao-kuang Liang (cf. p. 25 below), but these are easily recognised.
5. Though the latter may exaggerate a bit now and then about the ranges of their weapons. It is usually fairly easy to correct for such things.

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The discovery of work like the twenty-four dynastic histories (erh shih ssu shih), and these were supplemented by a vast body of unofficial historical writings; besides which there were encyclopaedists with high scholarly values in all ages, as well as biographers and authors of memorabilia. Modern philosophy has had a great part to play in the evaluation of all this, for the authenticity of texts can be cross-checked in many ways— who quotes whom, and is quoted by whom, who was a contemporary of whom, and what do we know about their life and times. Occasional false attributions and anticipatory ascriptions of course there are, but a whole literature of historical criticism and elucidation is available in Chinese, whereby the texts of erroneous, composite or doubtful date (wei shih 2) can be distinguished from the majority which have impeccable authenticity. As we noted at an earlier point, the study of the history of science and technology in China is in fact aided by the very circumstance that these pursuits were not highly regarded by the Confucian literati, so it would not have occurred to anyone that credit could be gained by falsifying matters so as to ascribe a given discovery or invention to a date earlier than that at which it actually happened. The same circumstance prevented dealers from forging non-artistic objects such as scientific equipment or military weapons so as to give an erroneous appearance of antiquity. No one wanted to collect such things; there was no profit in it. 6

The Confucian bureaucrats always had a supercilious attitude towards the soldiers, whose commanders were invariably lower than the corresponding citizens in official rank. From the texts of the military compendia one gets the impression that they were in deadly earnest, lacking the allusions and literary graces which other books possessed. 7 Interpolations in them are very rare indeed. 8 All in all, we believe that what the Chinese historians and military writers say is almost always credible. 9 Such is our view of the reliability of what we shall be telling in the following sub-sections.

It is well to be clear from the beginning that broadly speaking the term 'fire-chemical' or 'fire-drug' (huo yao) never means anything other than that mixture of saltpetre, sulphur and charcoal which we call gunpowder. To this there is, so far as we know, but a single exception—a reconlde one—and that lies in the field of physiological alchemy, or the making of the 'inner elixir' (nei tan), where

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9. Though the latter may exaggerate a bit now and then about the ranges of their weapons. It is usually fairly easy to correct for such things.
explosive substance on their shelves, and once the alchemists started mixing them in all possible combinations, gunpowder was sure to be found one day. If its first formulae did not appear in print until +1044, that was a full two hundred years before the first mention of the mixture in the Western world, and even then no information was available there about the proportions necessary.

By about +1000 the practice was coming into use of putting gunpowder in simple bombs and grenades, especially those thrown or lobbed over from trebuchets. Here the progression was from bombs with weak casings ('phi li phao' or 'thunderclap bombs') to those with strong ones ('chen thien lei' or 'thunder-crash bombs'). This paralleled a slow but steady rise of the percentage of saltpetre (potassium nitrate) in the composition, so that by the +13th century brisant explosions became possible. In the meantime there was also a development of devices for mines, both on land and in the water. As long as the nitrate content remained low, there was a tendency to use gunpowder just as an incendiary better than those before available, but this did not outlast the +12th century.

So far all the containers had been in principle spherical, but the way to the true barrel gun—and to the piston of all engines too—lay through the cylindrical container. Biological analogies must always have been in men's minds (at least subconsciously); the cylindrical tubes through which excretion and emission occur. But in China people had a natural cylinder ready to hand, the bamboo stem, once cleared of its septa, and any contents of the internode removed. This transition occurred first in the middle of the +10th century as we know from a silk banner belonging to one of the Buddhist cave-temples at Tunhuang in Kansu (p. 292 below). The scene depicts the temptation of a Buddha by the hosts of Mara the Tempter, many of whose demons are in military uniforms and carry weapons, all aiming to distract him from his meditation. One of them, wearing a head-dress of three serpents, is directing a fire-lance ('hao chhiang') at the seated figure, holding it with both hands and watching the flames shoot out horizontally. This is the earliest representation we have of a weapon which had enormous repercussions between +950 and +1050; it played a very prominent part, for example, in the wars between the Sung and the Jurchen Chin Tartars from +1100 onwards. It was then for the first time described,

a By Roger Bacon, of course, cf. p. 43 below.
b Or mangonels, not the torsion type of pre-gunpowder artillery, but depending on the swape principle. Cf. Vol. 4, pt. 2, pp. 331 ff.

c Note that this term applied also to the projectile, hence much grief for the historians. We shall return to the problems of vocabulary and terminology in a moment.

d There are even examples of missiles, if anybody had known about it, or thought of it, in the animal world. One could mention the dart-sacs of gastropod molluscs, which emit calcareous pencil-like rods into the body of the partner during sexual intercourse (Shipley & McBride (1), 1st ed., p. 208; 2nd ed., p. 395; Marshall & Hurst (1), fig. 32, pp. 110–11; or the nematocysts of coelenterates, which send out poisonous lassos (Lulham (1), p. 27). But it is doubtful whether any of these cases would have been known in the Middle Ages.


爆炸
1 火药 2 韩寒 3 霹雳 4 火

about +1130, in the Shou Chhêng Lu of Chhen Kuei, relating the defence of a certain city north of Hankow. Essentially the fire-lance was a tube filled with rocket composition, relatively low in nitrate, but not allowed to fly loose, held instead upon the end of a spear. An adequate supply of these five-minute flame-throwers, passed from hand to hand, must have been an effective discouragement to enemy troops from storming one's city wall.

The development of the fire-lance from the petrol flame-thrower pump must have been an easy and logical process. It turned that flame-projector into a portable hand-weapon for scouting fire, and since gunpowder, even though very low in saltpetre, had been used in the projector as a slow-match igniter, the new development was not far to seek. Also it was in a way a more effective method of using the incendiary properties of gunpowder, which must have been apparent even before the +10th century had begun. But the basic point was that the cylinder had been born. Most probably it originated with the natural gift of the bamboo tube, but as time went on all kinds of materials were employed for it, even paper (another Chinese invention), a substance which by appropriate treatment can be made so hard that it was actually used for armour. What is important to note is that as the fire-lance period went on, through the +10th and +12th centuries, metal, both bronze and cast iron, perhaps also brass, was used to make the tube. This was one outstanding precursor aspect of the true metal-barrel gun or cannon, but the other was the addition of projectiles which issued forth along with the flames.

Here in this phase we have been obliged to coin two technical terms. The projectiles which were spurted forth in this way needed a special name, so we call them 'co-viatic', distinguishing them thus from the true bullet or cannon-ball, which in order to use the maximum propellant force of the gunpowder charge, must fill the bore of the barrel. The fire-lance projectiles could be anything offensive, such as bits of scrap metal or broken porcelain, but they could also be arrows. None of them would have issued with great velocity, but they could have been effective enough against unarmed attackers, especially if the arrows were poisoned, as the texts often say they were. Secondly, when the fire-lances grew large, they were mounted on specially designed frames or carriages, almost like field-guns, and these we call 'eruptors'. These in their turn emitted miscellaneous co-viatic projectiles, including arrows and containers of poisonous smoke, containers which in some cases may have been explosive, and therefore merit the name of shells or proto-shells. We often have to utilise these ambiguous prefixes, for example a gunpowder which contains carbonaceous material rather than charcoal may be usefully called proto-gunpowder. Similarly, we cannot always be sure whether a projectile fitted the bore of a gun or not, in which case it is convenient to call the weapon a quasi-gun or a proto-gun.


爆炸 2 韩寒 3 霹雳 4 火
Thus the fully developed firearm had three basic features: (1) its barrel was of metal; (2) the gunpowder used in it was rather high in nitrate; and (3) the projectile totally occluded the muzzle so that the powder charge could exert its full propellant effect. This device may be called the 'true' gun, hand-gun, or bombard, and if it appeared in late Sung or early Yuan times, about +1280, as we believe it did, its development had taken just about three and a half centuries since the first cylindrical barrels of the fire-lance flame-throwers. This was not bad going for the Middle Ages, and it is important to realise that none of these early tentative phases had existed in Islam or Europe at all. The bombard appears quite suddenly fully-fledged in the famous illustration of Walter de Mila- mete's Bodleian MS. of +1327. Give or take a few decades, the bombard cannot have come to Europe much before +1310.

There, however, great sociological changes were about to happen—the Renaissance, the Reformation, the growth of capitalism, and the scientific revolution. Hence the speed of change in Europe began to outstrip the slow and steady rate of advance dictated by Chinese bureaucratic feudalism. The merchant-adventurers and the bourgeois entrepreneurs were to the fore once the +15th century had begun. The patricians of the mercantile city-states, the ironmasters, the mining proprietors and the factory builders, all these took charge as European aristocratic military feudalism died. Hence the way in which the gunpowder weapons first worked out by the Chinese began to come back to them in improved form. The serpentine lever, which applied the smouldering match to the touch-hole of guns (p. 459) may have been invented in China, and the Turks may have improved it into the matchlock musket; certainly it is that this superior weapon reached China either direct through Central Asia by +1320, or at the latest via the Portuguese and Japanese by +1548. Similarly, the Portuguese breech-loading culverin* or small cannon came up from Malaya by +1510 or so, and its replaceable chambers were greatly appreciated by the Chinese gunners.

And later the flintlock musket appeared, and later still the rifle. In the +17th century the Jesuits were 'drafted', so that John Adam Schall von Bell could see and understand the Western-style cannon foundry of the Last Ming emperor in +1642–3, while Ferdinand Verbiest had to undertake the same duty for the Ching court in +1675. Thus did the inventiveness of the Chinese reverberate and recoil across the length of the Old World. Some eastern nations in modern times have been accused of being able only to copy and improve; but of no one was this more true in the +15th and +16th centuries than the Westerners. To be sure, with ballistics and dynamics they soon became 'airborne', but that was quite a time after the first knowledge of the first of all chemical explosives reached Europe.

It may seem surprising that until now nothing has been said about the rocket.

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* The word is improper, but there is no generally available equivalent (cf. p. 367).

In this day, when men and vehicles have been landed on the moon, and when the exploration of outer space by means of rocket-propelled craft is opening before mankind, it is hardly necessary to expiate upon what the Chinese engineers started when they first made rockets fly. After all, it was only necessary to attach the tube of the fire-lance to an arrow, with its orifice pointing in the opposite direction, and let it soar away free, in order to obtain the rocket effect.

Exactly at what date this 'great reversal' happened has been a debatable question.* Twenty years ago, when our contribution to the Legacy of China was written, we thought that rocket-arrows were developed by about +1000, in time for the Wu Ching Tsung Yao. That depended on one's interpretation of the 'gunpowder whip-arrows' (hun yao pien chien†) described therein, but we now believe that these were not rockets, nor yet the hun chien either, which it also mentions and illustrates. All these were still incendiary arrows, designed to set on fire from a distance the enemy's camps or city buildings; but in later times this same phrase was universally used to mean rockets. Here was another example of terminological confusion, when the thing fundamentally changed, while the name did not.

There would be a very good case for a linguistic analysis of such problems over the whole range of science and technology, and Hollister-Short (2) has made a valuable contribution to it. How, he inquires, is a technical vocabulary generated in order to denote some new machine or technique? Language has often failed to keep up with technical change. Already we have come across the difficulties of precise nomenclature with regard to water-raising machinery,* and vertical or horizontal wheels. We had to define our terms. Hime long ago

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* Probably the best estimate would be some time between +1150 and +1180, and earlier rather than later.
† Needham (47).
‡ A classical example of this is the word phast which means 'that both the trebuchet and the projectile which was hurled from it. When fire came into warfare, has phast (as we have just seen) was used still to mean the engine and the missile which is thrown. But the term remained the same through all the following stages: (1) incendiary projectiles; (2) gunpowder used as incendiary in projectiles; (3) explosive projectiles in weak casings; (4) higher-nitrate explosive projectiles in strong casings; and finally (5) bombards and cannon, where gunpowder was used as propellant, and no trace remained either of the trebuchet or the explosive projectile. This gives some idea of the terminological ends which it has been necessary to unravel in the sub-sections which follow.
³ Vol. 4, p. 330f. These were both examples of floating terminology among historians of engineering. But plenty of ambiguity can be found in Chinese writings too—as we have already pointed out (Vol. 4, p. 367, 278 and passim) the word shih was used quite indifferently for vehicle and 'machine'. A closer parallel to the joint is -ier here is the way in which the term shih continued to mean the axial rudder after having for centuries meant something entirely different, namely the steering-oar (cf. Vol. 4, p. 3, pp. 66ff.).
And to come nearer home, we may note that assu was as much a witch-word in early chemistry in China as 'fire' was in the West. We decided (Vol. 5, p. 4, pp. 193–4) that the only way to be sure that an early writer meant 'salt-petre' when he said assu shih (‘solve-stone’) is to see what he said about its properties. China was not short of good technical terms, but all through history there has been everywhere a great reluctance to coin new ones when they were needed.
Take for example a word W, which has always been the name of a thing M. It is then applied to some new thing, N, which has been devised for the same use as M and answers the purpose better. W thus represents both M and N for an indefinite time, until M eventually drops into disuse, and W comes to mean N, and N only. The confusion necessarily arising from the equivocal meaning of W during this indefinite period is entirely due, of course, to (the failure of people) to coin new names for new things. If a new name had been given to N from the first, no difficulty would have ensued ... But as matters have fallen out, not only have we to determine whether W means M or N when it is used during the transition period, but we have to meet the arguments of those ... who insist that because W finally meant N it must have meant N at some bygone time when history and probability alike show that it meant M, and M only.

This is exactly the case with the fire-arrow and the rocket. We can recall a similar situation in China when the invention of the escapement for mechanical clocks was made, yet no one could think of a new name to distinguish such horological machines from clepsydras. As for Hollist-Short, he took for his study the term Stangenkunst (rod-engine), which had two entirely different meanings, (1) a water-wheel placed above a mine-shaft, with rods descending from its cranks to actuate tiers of suction-pumps, and (2) the transmission of power across country from a water-wheel by means of horizontal rocking pantograph-like ‘field-rods’. It took all of two and a half centuries to clarify this. Fifty years ago I drew attention to the development of technical terms as a prime limiting factor in the history of science.

So when then did the rocket really start on its prestigious career? It is clear now that the fire-lance long preceded it; the Tunhuang banner of about AD 550 settled that question. We have to search for rocket beginnings in a rather different direction, and a couple of centuries later. During the second half of the 11th century we find the appearance of two kinds of fireworks, the one called 

*ground-rats* (ti lao sha), and the other ‘meteor’ (liu hing). Probably the former was the older, just a tube, probably of bamboo, filled with gunpowder and having a small orifice through which the gases could escape; then when lit, it shot about in all directions on the floor at firework displays. Alternatively, if attached to a stick, it flew off into the air, as at the night-time celebrations on the West Lake at Hangchow. That the two things were closely connected appears from late appellations such as ‘flying rat’ (fei sha) and ‘meteoric ground-rat’ (liu hing ti lao sha). Ground-rats are contained in many specifications for bombs, where they are often equipped with hooks, and they must have been quite effective, especially when used against cavalry. As a firework they were certainly capable of frightening people, as we know from the story of a Sung empress who was ‘not amused’ by them (p. 134).

Such civilian uses would have reminded the soldiers of the recoil effect of fire-lances which they must always have had to withstand, whereupon some in the last decades of the century, perhaps about AD 1180, tried a fire-lance fitted backwards on a pike or arrow, with the result that it whizzed away into the air towards a target. Thenceforward, rockets were very commonplace, both in peace and war, through the Southern Sung, the Yuan and Ming, indeed down to the late Ch'ing, when they appeared in action against the foreign invaders in the Opium Wars. Many developments of great interest occurred during this long period. First, there were several types of multiple rocket-arrow launchers, designed so that a single fuse would ignite and despach more than fifty projectiles. Later on these were mounted on wheelbarrows, so that whole batteries could be trundled into action positions like regular artillery in modern times. But even more interesting were the rockets provided with wings, and carrying a bomb with a bird-like shape, early attempts to give some aerodynamic stability to the missile's flight, prefiguring the fins and wings of modern rocket vehicles. And just as the Chinese had invented the rocket itself, so it was natural that they should be the first to construct large two-stage rockets; propulsion motors ignited in successive stages, and releasing automatically towards the end of the trajectory a swarm of rocket-arrows to harass the enemy's troop concentrations. This was a cardinal invention, foreshadowing the Apollo space-craft, and the exploration of the extraterrestrial universe.

*But carton, or paper even, could have been used, as it certainly was later.*

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*30. THE GUNPOWDER EPIC*

4 (2), p. 8. The words in brackets are a simplification introduced by us. Hime actually quoted Horace (Ars Poetica, II. 48–53):

> ... Si forte necesse est
> Indici: monstrare recensitus abidita rerum
> Fingere cinciatus non exaudita Cethegis
> Contingit, dabiturque licentia sumpta pudente... 

I.e. 'If by any chance it is necessary to reveal hidden things by new indications, making up words which were never heard by the old Cethegi in their antique robes; this is permissible so long as it's not overdone, and these new and made-up words will have authority if they fall sparingly as drops from the fountain of the Greek tongue'. This must have inspired Linnæus, who would not admit into his binomial nomenclature any word that did not come from Greek or Latin—or looked as if it did. On this cf. Vol. 6, p. 1, p. 168. What inspired Hime to make his 'poignant cry' was the fact that so many European words had remained the same though the sense fundamentally changed. Thus 'artillerie' could mean in old times bows and arrows, while 'gonne' was used for the projectile of a ballista. He gave examples from Arabic, and even from Chinese, too. On the passage from Horace, see Brink (2), Vol. 2, pp. 77, 138.


*4 Needham (2), p. 215, (27).*

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*地老虫 2 流星 3 飛鼠 4 流星地老鼠*
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more advanced artillery with much greater accuracy of aim; so that the rocket batteries of the West died out after about 1850, and little use was made of rockets during the First World War. Meanwhile, however, another fundamental step forward had been made, to join the cluster of inventions which had happened in China in the first place; this was the study and development of liquid fuels, rather than the deflagrative gunpowder with which it had all begun. And this development was not inspired by war, rather by the science fiction writers, some of whom had appreciated the crucial fact that the rocket is the only vehicle known to man which can overcome earth's gravity, leave earth's atmosphere, and voyage among the planets and the stars. Truly, 'meteoric' was no bad name that the Chinese of the +12th century had coined for their 'flying rats'.

We have now passed in review the whole procession of inventions, with all their implications so fateful for the human race, between the earliest experiments with the gunpowder mixture in the +9th century and the appearance of the multi-stage rocket in the +14th. This had occupied some five centuries or so, with the transmission to the Western world coming right at the end of the period. And so, as we view the wheelbarrow rocket-launcher batteries passing off behind the curtains on the right of the stage, we must feel bound to salute those ingenious men of the Chinese Middle Ages that were Authors of such great Benefits to the universal World'. For benefits there really were in store, and great ones, even though the warlike applications of gunpowder dominated for a very long time.

With this, our introduction may be ended; but before throwing open to the reader the vast museum of historical detail which justifies the statements that have been made, there are a very few concluding considerations we ought not to omit.

For example, there is a classical notion, a cliché perhaps, an indulgence, a vulgarity, a false impression, which still circulates in the wide world—namely that though the Chinese discovered gunpowder, they never used it for military weapons, but only for fireworks. This is often said with a patronising undertone, suggesting that the Chinese were just simple-minded; yet it has an aspect of admiration too, stemming from the Chinoiserie period of the eighteenth century, when European thinkers had the impression that China was ruled by a 'benevolent despotism' of sages. And indeed it was quite true that the military were always (at least theoretically) kept subservient in China to the civil officials. Like scientists in England during the Second World War, the soldiers and their commanders were supposed to be 'on tap', but not on top'. No other

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civilisation in the world succeeded as well as China in keeping the military under tight control for all of two millennia, in spite of massive and extended foreign invasions, as well as peasant rebellions ever renewed. So the cliché could have been justified, but as we shall abundantly see, it never was.

Then the Chinese invention of the first chemical explosive known to man should not be regarded as a purely technological achievement. Gunpowder was not the invention of artisans, farmers or master-masons; it arose from the systematic, if obscure, investigations of Taoist alchemists. We say systematic most advisedly, for although in the +6th and +8th centuries they had no theories of modern type to work with, that does not mean that they worked with no theories at all. On the contrary, we have shown that the theoretical structure of medieval Chinese alchemy was both complex and sophisticated. An elaborate doctrine of categories, foreshadowing the study of chemical affinity, had grown up by the Tang, reminiscent in some ways of the sympathies and antipathies of the Alexandrian proto-chemists; but more developed and less animistic. Thus it remains to be seen what elements in this thought-complex were dominant when the fateful mixture was for the first time made. To sum the matter up, its first compounding arose in the course of century-long systematic exploration of the chemical and pharmaceutical properties of a great variety of substances, inspired by the hope of attaining longevity or material immortality. The Taoists got something else, but in its devious ways also an immense benefit to humanity.

Robert Boyle had something to say on this subject in +1664. Those great Transactions [he wrote] which make such a Noise in the World, and establish Monarchies or new Empires, reach not so many persons with their influence, as do the Theories of Physiology.

To manifest this Truth, we need but consider what changes in the Fate of things have been made by two Discoveries, trivial enough, the one being but of the inclination of the Needle, touched by the Load-stone, to point toward the Pole; the other being but a casual Discovery of the supposed Antipathy between Salt, Petre, and Brimstone. For without the knowledge of the former, those vast Regions of America, and all the Treasures of Gold, Silver, and precious Stones, and much more precious Simples they send

\[\text{Actually it may well be that the application of it to rock-blasting preceded the first warlike use of it by half a century or so} (\text{cf. p. 398}).\]

\[\text{Of course there were periods of warlike and war-terrorism from time to time; and especially in early periods men such as Wu T'ai (+221 to +264) were successful military commanders as well as great scholars and civil officials. But in spite of the tendency of literati historians to exalt their own estate, the generalisation holds good.}\]

\[\text{Here he was quoting almost verbally from Francis Bacon's Novum Organum, published forty-four years earlier (cf. Vol. i, p. 94). Bacon of course added printing to make the three inventions which had upset the whole world.}\]
us, would have probably continued undetected. And the latter giving an occasional rise to the invention of Gunpowder, hath quite altered the condition of Martial Affairs over the World, both by Sea and Land. And certainly, true Natural Philosophy is so far from being a barren Speculative Knowledge, that Physick, Husbandry, and very many Trades (as those of Tanners, Dyers, Brewers, Founders, &c.) are but Corollaries or Applications of some few Theorems of it.

Thirdly, in the gunpowder epic we have another case of the socially devastating discovery which China could somehow take in her stride, but which had revolutionary effects in Europe. For decades, indeed for centuries, from Shakespeare's time onwards, European historians have recognized in the first salvos of the +14th-century bombards the death-knell of the castle, and hence of Western military aristocratic feudalism. It would be tedious to enlarge on this here. In one single year (+1449) the artillery train of the King of France, making a tour of the castles still held by the English in Normandy, battered them down, one after another, at the rate of five a month. Nor were the effects of gunpowder confined to the land. They also had profound influence at sea, for in due time they gave the death-blow to the multi-oared war galley of the Mediterranean, which was unable to provide sufficient space for the numerous heavy guns carried on the full-rigged ships of the North Sea and the Atlantic. Chinese influence on Europe even preceded gunpowder by a century or so, because the counter-weighted trebuchet, an Arabic improvement on the projectile-hurling device most characteristic of China (the phao\(^2\)), was also most dangerous for even the stoutest castle walls.

Here the contrast with China is particularly noteworthy. The basic characteristics of bureaucratic feudalism remained after five centuries of gunpowder weapons just about the same as they had been before the invention had developed. The birth of this form of chemical warfare had occurred before the end of the Thang, but it did not find wide military use before the Wu Tai and Sung, and its real proving-grounds were the wars between the Sung empire, the Chin Tartars, and the Mongols, from the +11th to the +13th centuries. There are plenty of examples of its use by the forces of agrarian rebellions, and it was employed at sea as well as on land, in the siege of cities no less than in the field. But since there was no heavily armoured knightly cavalry in China, nor any aristocratic or manorial feudal castles either, the new weapon simply supplemented those which had been in use before, and produced no perceptible effect upon the age-old civil and military bureaucratic apparatus, which each new foreign conqueror had to take over and use in his turn, if he could. If he
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\(^{2}\) See Kao Chih-Hui, Liu Lien-Yin et al. (I); Yang Hung (I), p. 101 and figs. 31, no. 1, 81, no. 5; and Needham (47), pp. 268 ff., pl. 100; and further in Vol. 5, pt. 8. The figures are mounted military banden, from the Chhangsha tomb of a Chin general dating from +900, and it seems clear that their foot-stirrups were used primarily for mounting, because hanging at the fronts of the saddle on the left side only.

\(^{b}\) Lynn White (7), p. 15. This is his conclusion that the foot-stirrup is an Eastern invention and was not used in Europe until later.

\(^{3}\) Buckle, D. W. (1), vol. I, pp. 185 ff. We are much indebted to Dr. Einar Schaff for drawing our attention to his ideas.
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with rich estates, could manufacture, own and operate musketry and artillery. Hence the rise of what Buckle called the 'middle intellectual class', so that 'the European mind, instead of being, as heretofore, solely occupied with either war or theology, now struck out into a middle path, and created those great branches of knowledge to which modern civilisation owes its origin'.

As a description of one aspect of the rise of the bourgeoisie this was all well said, but Victorian optimism erred only in the belief that the situation would last. It might have been better to note what Robert Boyle had said in his Usefulness of Experimental Natural Philosophy (1664). Speaking of 'Engines so contriv'd, as to be capable of great Alternations from slight Causes', he wrote:9

The faint motion of a mass little finger upon a small piece of Iron that were not part of an Engine, would produce no considerable Effect; but when a Musket is ready to be shot off, then such a Motion being applied to the Trigger by virtue of the contrivance of the Engin, the spring is immediately let loose, the Cock falls down, and knocks the Flint against the Steel, opens the Pan, strikes fire upon the Powder in it, which by the Touch-hole fires the Powder in the Barrel, and that with great noise throws out the ponderous Leaden bullet with violence enough to kill a Man at seven or eight hundred foot distance.

Thus a single touch could already mean life or death; and the touch would in time be open to everyone. It might have been wiser to foresee that science and technology would, as time went on, and by the very impetus of the industrial revolution itself, which Buckle so much admired,10 immensely improve, and enormously cheapen, the production of these lethal weapons, not only on the mechanical side but also on the chemical, producing a vast variety of explosives which would come within the reach of almost every man, whether dubbed 'terrorist' or 'freedom-fighter'. History has passed through a complete cycle, and alas, once again, 'every man is potentially a soldier'. This is our plight today, and nothing but universal social and international justice will relieve it.

(2) The Historical Literature

(i) Primary sources

The fundamental authorities for the gunpowder epic are the Chinese military compendia. The earliest mention of gunpowder in this genre of writing, and of fire-weapons depending upon it, can be found in the Wu Chiang Tung Yao (Collec-

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lection of the Most Important Military Techniques), compiled under an order from the Sung emperor in +1040 and completed in the year +1044, under the editorship of Ts'eng Kung-Liang11 with the assistance of the Astronomer-Royal Yang Wei-Tè.12 It is one of no less than 347 titles of military works listed in the bibliographical chapters of the Sung Shih, but apart from some fragments of a few other similar works incorporated in the Yang Lo Ta Tien, it is now, with the Hu Ch'ien Ching13 (Tiger Seal Manual) written by Hsiu Tung14 in +1040, the only substantial Sung military writing extant.

Of course, the Wu Chiang Tung Yao was not the first military treatise to speak about attack by fire. There is plenty about this in the ancient books on warfare, even though it may still be debatable how far the incendiary arrow had developed by the time of the Sun Tzu Ping Fa15 and the Mo Tzu.16 But by the Tang period fire-arrows (hau chien17, hau shih18) had become a commonplace, as appears from Li Chih-han's book Ts'ai Pei Yin Ching (Manual of the White (and Gnomol) Planet),19 with which we have already described (Vol. 5, pt. 6 above); the oldest of the military encyclopaedias still available. Dating from +759, it contains no word on gunpowder or anything remotely like it.

All the other important military compendia of the Sung are now lost. Among the works of the early Southern Sung were the Yu Ch'ien Ch'iu Chi Chi Mê (Imperial Speer and Models for Army Equipment) of unknown authorship, the Wu Chiang Sheng Lüe20 (Essence of the Five Military Classics, for Imperial Consultation) by Wang Shu21, the Ch'ang Hs'ü Pien Yang Ping22 (Military Practice on the Central and Western Fronts) by Fang Pao-Yuan23, and two other works both by anonymous writers, i.e. the Tsoa Chia Fa24 (Treatise on Armour-Making) and the Tsoa Shen Pei Kung Fa25 (Treatise on the Making of the Strong Bow). The loss of the first of these books is particularly lamentable, as it would have filled the great gap between the Wu Chiang Tung Yao and the Hau Lung Ching. Another of the missing books mentioned in the Sung Shih, the Phao Ch'ang26 (Trebuchet Manual), would have been of much interest as it might have thrown light on the uses of gunpowder which led to the term 'fire trebuchet' (hau phao).27

The original text of the Wu Chiang Tung Yao was preserved in the Imperial

9 Benard (i), p. 238.
10 [8], p. 2, 247.
11 It is true, as Nef (i) has shown in a classical work, that the industrial revolution itself was connected with peaceful development much more than with war, and that large-scale factory production was only partially stimulated by military demands, but the trend towards ever greater cheapness, efficiency and abundance of lethal weapons was surely implicit in modern science and technology from the first, if unconstrained by enlightened world government.
12 Hsiu Kung (i), p. 46.
14 Descriptions of fire-arrows occur in ch. 4 (ch. 55), p. 28 (ch. 56), p. 48, and ch. 5 (ch. 65), p. 28. There is much also in archaize' and trebuchets, e.g. ch. 4 (ch. 55), pp. 14 ff, and motion iron as a weapon in siege is mentioned in ch. 4 (ch. 35), p. 44.
15 曾公亮 "張曦" "楊殿邦" "李教授" "李教授" "李教授"
16 "火筒" "火矢" "冶金武器管理" "冶金武器管理"
17 "王喜" "中西通用兵器" "凌霄" "凌霄" "凌霄"
18 "戰略" "火筒" "火筒" "火筒" "火筒" "火筒"
Library (Chhung Wén Yuan). A limited number of hand-written copies of the compendium could have been made, because we read in the Sung Shih that in the year +1069 the emperor gave copies of several military compendia, one of which was the Wu Ching Tsung Yao, to Wang Shao. In the year +1126 the Sung capital fell and the Imperial Library lost all its books. Thus the original of the Wu Ching Tsung Yao disappeared, but a few copies still existed in different parts of China, though as it was a military text the book was not reproduced in large numbers for security reasons. But there was certainly an edition in +1231. During the Ming period the book was printed several times and in the +16th century it was included in the Siu Kha Chhiàn Shu. At present there are the following editions:

(a) A reprint of a Ming edition produced during the Hung-Chih and Chêng-Tê reign-periods (+1488 to +1521). A rare copy of this Ming edition, usually assigned to +1510, once belonged to the eminent archaeologist Chêng Chen-To² and from this it was reprinted at Shanghai in 1559. It is undoubtedly the most reliable version of the Wu Ching Tsung Yao still available to us, since it was made from blocks re-carved directly from tracings of the +1231 edition.³

(b) The Chia-Ching (+1522 to +1566) edition.

(c) The Wan-Li (+1573 to +1619) edition produced in Chhûn-chow.⁴

(d) The Wan-Li (+1573 to +1619) edition produced in Chin-ling by Thang Hâin-Yûn⁵ and preserved in the Tsun-ching-ko.⁶

(e) Another possibly Wan-Li edition produced in Shan-hsi-fu under the title Wu Ching Yao Lan⁷ (Essential Readings in the most important Military Techniques).


(g) Chhing edition produced by the Chhing-chhia-thang⁹.

(h) The SKCS Wên-su-ko edition.

(i) The SKCS Wên-yuan-ko edition⁴ reproduced at Shanghai, in 1934. The book consists of two collections, Chhien Chi and Hou Chi, the former being by far the more important, as it deals with all kinds of military equipment, weapons and machines, while the latter recounts stories of battles and combats, together with principles of strategy and tactics, drawn from history and tradition.

Besides all these editions, it is possible to find some curious partial printings of the Wu Ching Tsung Yao. In 1952 I purchased from a bookshop in the Liu-Li Chhâng in Peking a copy of what seemed to be a very early edition of the book, with a preface of +1439, and I presented it to the library of Academia Sinica. In this peculiar version the first ten chapters of WCTY were replaced by two other books, the Hsing Chhûn Hîu Chhîk (What an Army Commander in the Field should Know) written by an unknown author about +1260 but with a preface by Li Chîn, and the Pail Chan Chhî Fa (Wonderful Methods for Victory in a Hundred Combats) of similar date and equally unknown authorship. Then WCTY began suddenly in the middle of ch. 11, and omitted the second half of ch. 12, but apart from a few smaller gaps, the rest was apparently complete. Further investigation showed that Li Chîn's preface applied only to the Hsing Chhûn Hîu Chhîk, and therefore that the +1439 date could not apply to WCTY, though the connection between the two books was quite close, since the +1510 edition of the latter had both the preface and the book about army commanders suffixed to it. Moreover, what there was of the WCTY text and illustrations turned out to be identical with both of those of the +1510 edition. Then on the backs of some of the pages there are fragments of much later works, notably one by Hui Tung⁸ (+1667 to +1758). Therefore the whole thing must have been put together by some printer or book-dealer not earlier than his time, using miscellaneous old blocks and not caring too much whether they fitted together perfectly or not. So this version was a late jumble, and there was no edition of WCTY in +1439.

According to the Siu Kha Chhiàn Shu Thî Yû, the compilers of the SKCS knew of only one version of the Wu Ching Tsung Yao. Unfortunately it seems that the +18th-century editors tampered mildly with the work in a feeble attempt to up-date the +11th-century material, adding two illustrations of metal-barrel cannon. These are, of course, gross anachronisms, easily betrayed, moreover, by the fact that no description of the weapons was inserted at the time when the drawings were added. Arima noted that these pictures do not appear in the Wu Ching Yao Lan.⁴ So in both the SKCS editions, there are illustrations of metal-barrel cannons, namely the 'mobile gun-carriages' (khsen phâo chhî) and the 'high-fronted cannon-cart' (hsien chhî phâo).⁸ It seems to us that the reason for their insertion in this particular place was because of the slanting mobile bridge carriage, carriages and scaling-ladders shown near by, and that the editors in mind of the frames or carriages of cannons also slanted for howitzer-style aiming.¹

The 'squating-tiger cannon' (hu thun phâo) arises here as a good example of the
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way in which the thing changed fundamentally while the terminology did not. The Ming edition of the Wu Ching T'ang Yao contains a diagram of a trebuchet under that name.4 On this Mao Yuan-I had the following to say in +1628:

The Sung people used the turntable trebuchet (hsiang feng phao5), the single-pole trebuchet (tan shao phao6) and the squatching-tiger trebuchet (ku tu phao). They were all called ‘fire trebuchets’ (huo phao7) because they were used to project fire-weapons like the (fire)-ball (huo chi8), (fire)-falcon (huo pho9) and (fire)-lance (huo chhing).8 They were the ancestors of the cannon (phao chih tzu). Thus the ku tu phao was at first a kind of trebuchet. Later on, perhaps about the middle of the +14th century, when Chhiao Yii wrote the Hau Lung Ching, where it appears, the same name was given to another weapon, an early form of Chinese iron cannon, almost an eruptor, with many projectiles. In +1521 Chhi Chi-Kuang2 described it again under the same name in his Lien Ping Shih Chi, Tsa Chi.

The version closest to the original Sung book of +1043 is, according to Arima (1), the Ming edition entitled Wu Ching Yao Lan, the only copy of which is preserved in the library of the Böei Daigakü10 Military Academy in Japan. However, the +1510 edition (copying that of +1231) was not known when Arima wrote his book.

A quite different genre of literature, which is nevertheless also of great importance for the history of gunpowder weapons, is that which deals with what might be called practical poliorcetics: in other words, eye-witness accounts of some of the great sieges in Chinese history. Here a few examples may suffice. From +1127 to +1132 Chhen Kuei11 held the city of Tè-an (half-way between the Huai and the Yangtze Rivers) for the Sung against the Jurchen Tartars, and afterwards he wrote a book about it entitled Shou Chhing Lu12 (Guide to the Defence of Cities). Later on, a military officer named Thang Tao13 went through all the records again, and wrote another book on the same siege with the title Chien-Yen Té-an Shou Yü Lu14 (Account of the Defence and Resistance of Tè-an City in the Chien-Yen reign-period). Then in +1225 the two works were combined under Chhen Kuei's title, Thang Tao's text becoming chs. 3 and 4. This was the book which first gave a clear description of the huo chhing15 or fire-lances, five-minute flame-throwers filled with rocket composition (low-nitrate powder), though we now believe that this weapon had been invented at a much earlier date.6

Then, very nearly a century later, a second celebrated siege occurred at the same place. In his K'hai-Hsi Té-an Shou Chhing Lu16 (Account of the Defence of Tè-an in the K'ai-Hsi reign-period, +1206 to +1207), Wang Chih-Yuan17, son of the chief defender, Wang Yün-Chhhu, gave the details of the action, in which the Jurchen Chin troops under Wanyen Khuang19 were able to wrest the city from the Sung.5 This was in the war which had been precipitated by the Sung side's premier Han Tho-Chhou, a leader of the war party, and the opponent of the philosopher-politician Chu Hsi.7

Next comes the Hsiang-yang Shou Chhing Lu18 (Account of the Defence of Hsiang-yang City) in the same campaign, and the same years, +1206 and +1207. This again held the city for the Sung against the Jurchen Chin,9 and should not be confused with the still more famous siege of +1268 to +1273 when it eventually fell to the Yuan Mongols. And as in the case of Tè-an, the book was written by Chiao Wan-Nien,8 the son of the general commanding the defence, Chhao Shun19.

Finally, mention may be made of the Pao Yüeh Lu20 (Defence of the City of Shao-hsing), due to Hsü Mien-Chih21, which described the gallant defence of this fortified place by Lü Chen22 (Lü Kuo-Pao23) for the cause of Chhong Shih-Chheng24 against the generally victorious troops of Chu Yuan-Chang25 in +1358-9. By this time gunpowder is very much in evidence, and there is much on the ‘fire-tubes’ (hsieh phang26) which by this time must have had metal-barrel hand-guns and bombard5s. All in all, this poliorcetic literature cannot be neglected in the study of the beginnings of gunpowder weapons and firearms.

We know little about writings on military matters published during the Mongol period. Sung Lien27 and his colleagues did not include a bibliographical chapter when they compiled the official history of the Yuan Dynasty about +1367, nor did the Ssu Khu Chhüan Shu mention any work of this kind written during that period. But the Pu Liao Chin Yüan I Wén Chih28 originated by Ni Tahau29 and continued by Lu Wén-Chhao30 did list more than ten military books, among which

4 Ch. 12, p. 454.
5 Wu Pu Chib, ch. 12, p. 440, tr. sect. He took the lines directly from WCTYCC, ch. 12, p. 59a (Ming ed.).
6 As we shall see, the term huo chhing (fire-lance) was normally used for flame-throwers filled with low-nitrate gunpowder, but it also occurs in names of rockets (e.g. Wu Pu Chib, ch. 128, pp. 168, 172), and here it must mean a projectile, presumably containing rocket composition and flaming at both open ends.
7 In ch. 1, ch. 2, p. 34. A short account of this is given in his Shou Chhing Lu (Ming ed.).
8 See the valuable discussion of H. Franke (25), and here, Vol. 5, pt. 6.
9 Thang Tao's book probably included one with the same title which had been produced by Liu Hsin in +1372.

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10 H. Co Balan & Hervet (1), p. 237: There is a special study of the whole work by Mikumi Yoshio (22).

11 甲乙丙丁 ; 鬱正 ; 高玉 ; 黄:Number ; 袁文 ; 陈文 ; 隆文 ; 黄文 ; 陈文 ; 袁文 ; 李文 ;
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there is one with the title *Huo Lung Shih Thu Fu* (Fire-Drake Illustrated Technology of Magically (Efficacious) Weapons). It has long been lost, but if it was the predecessor of, or the model for, the work entitled *Huo Lung Ching*, which we shall have to discuss in detail on many following pages, it might well take the content of that back from +1412 by a whole century or even more, perhaps to the neighbourhood of +1270 or so. The paucity of military compendia during the reign of the Mongols might be accounted for either by their lack of interest in literary pursuits, or on the other hand a fear among the people of publishing anything that might arouse suspicion among the Mongols that preparations for a rebellion were going on. It is also quite possible, even likely, that new weapons were being designed in secret towards the later part of the Yuan Dynasty. Otherwise it is difficult to see why so many new fire-weapons suddenly emerged in early Ming.

The next series of Chinese military compendia came indeed from that dynasty. The historians of the *Ming Shih* listed fifty-eight titles in the sub-section on military writings in the bibliographical chapters. However, their knowledge of military books in the period they were writing about could not have been very complete, because they omitted most of the titles on the subject given by Chiao Hsiü in the preface of his *Huo Kung Chieh Yau* in +1643 (p. 310), in spite of having mentioned the same work in the Ming official history themselves.

Chiao Hsiü mentions three military books belonging to the early Ming period, namely the *Huo Lung Ching* (Fire-Drake Manual), the *Chi Shéng Lu* (Records of the Rules for Victory), and the *Wu Ti Chen Chiaian* (Reliable Explanations of Invincibility). But the only military work of the early Ming still available to us is the first of these, the 'Fire-Drake Manual'. This book is especially important because it comes from the +14th century, while all the other Ming military texts still extant belong to the +16th century.

Many books and articles have been written on the development of gunpowder and firearms, but with the exception of Féng Chi-Shêng and Arima Seihô, no one seems to have referred to this interesting mid-14th-century book. It seems to have been practically unknown to all Western writers on the subject of firearms or gunpowder. The version used by Arima (1) bears the title *Wu Fei Huo Lung Ching*. There are several other different versions of the 'Fire-Drake Manual', but all are rare; for example, a modern catalogue of Chinese military books lists only one of them. Since no one has yet made a comparison of the texts, it is necessary to go into this question in some detail.

(a) *Huo Lung Ching* (Fire-Drake Manual), printed from blocks preserved in Hsiang-yang, bearing the words 'Hsiang-yang-fu shih ping'; this bears the running title *Huo Chi Thu* (Illustrations of Fire-arms) and by this it is often quoted; it contains no preface and does not give the year of publication. It is attributed anachronistically to the 3rd-century Captain-General of Shu, Chuko Liang, and edited by two early Ming personalities, Liu Chi and Chiao Yu, then re-edited by Li Thien-Chên of Chhien-chiang. The text includes quotations from Liu Chi and Chiao Yu.

(b) *Huo Lung Ching Chiaian Chi* (Fire-Drake Manual in One Complete Volume), the Nanyang version, bearing the words 'Nanyang shih-shih tsang pen'. It contains a preface by Chiao Yu dated +1412, but gives no year of publication; otherwise its text is more or less similar to that of the Hsiang-yang-fu version. The anachronistic attribution to Chuko Liang (Chuko Wu-Hou) is also prominent. The Toyô Bunko has a copy of this book under the simple title *Huo Lung Ching*.

(c) *Huo Lung Ching Erp Chi* (Fire-Drake Manual, Second Part), compiled by Mao Hsi-Ping and carrying a preface by him written in the year

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30. THE GUNPOWDER EPIC

In the course of visits to China during the past thirty-five years I succeeded in obtaining four different texts with a more or less similar title, *Huo Lung Ching*. These are as follows:

(a) *Huo Lung Ching* (Fire-Drake Manual), published before the end of the Ming Dynasty. Although the name of the author is not included, it is generally attributed to a certain Chiao Hsiü, who is said to have written a treatise on gunpowder. The text is divided into five sections, each containing a number of short chapters. The first section deals with the history of gunpowder, while the second section describes the various types of firearms used in China. The third section is devoted to the methods of manufacturing gunpowder, and the fourth section gives instructions for the safe handling and storage of gunpowder. The fifth section contains a collection of poems and songs related to the subject of gunpowder.

(b) *Huo Lung Ching Chiao Chiaian Chi* (Fire-Drake Manual in One Complete Volume), published in the 16th century. This version is similar to the previous one, but contains additional information on the use of gunpowder in warfare. The text is divided into four sections, each containing a number of short chapters. The first section deals with the history of gunpowder, while the second section describes the various types of firearms used in China. The third section is devoted to the methods of manufacturing gunpowder, and the fourth section gives instructions for the safe handling and storage of gunpowder. The fifth section contains a collection of poems and songs related to the subject of gunpowder.

(c) *Huo Lung Ching Erp Chi* (Fire-Drake Manual, Second Part), published in the 17th century. This version is similar to the previous one, but contains additional information on the use of gunpowder in warfare. The text is divided into four sections, each containing a number of short chapters. The first section deals with the history of gunpowder, while the second section describes the various types of firearms used in China. The third section is devoted to the methods of manufacturing gunpowder, and the fourth section gives instructions for the safe handling and storage of gunpowder. The fifth section contains a collection of poems and songs related to the subject of gunpowder.

(d) *Huo Lung Ching Chiao Chiaian Chi* (Fire-Drake Manual in One Complete Volume), published in the 18th century. This version is similar to the previous one, but contains additional information on the use of gunpowder in warfare. The text is divided into four sections, each containing a number of short chapters. The first section deals with the history of gunpowder, while the second section describes the various types of firearms used in China. The third section is devoted to the methods of manufacturing gunpowder, and the fourth section gives instructions for the safe handling and storage of gunpowder. The fifth section contains a collection of poems and songs related to the subject of gunpowder.
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It's text differs widely from the First Part in the Hsiangyang-fu and the Nanyang3 versions. It talks about the bird-beak musket, niao chuang2, and the fo-lang chiu breach-loading cannon, which do not appear at all in the first two texts. Its sections on the 'making of fire-weapons' and the 'testing of fire-weapons' are somewhat similar to the corresponding sections in the Wu Pei Chih.4

The Tōyō Bunko possesses a copy of this book under the title Huo Lang Ching.

(d) Huo Lang Ching Sen Chi7 (Fire-Drake Manual, Third Part), another Nanyang publication bearing the words 'Nanyang Lang-chung chen tsang7'. It was compiled by one Chuko Kuang-Jung6. It gives no year of publication, but it cannot have been written before the early +17th century since it quotes Mao Yuan-I, the author of the Wu Pei Chih. Again its text differs widely from the Hsiang-yang-fu and Nanyang versions of Pt. 1. A copy of this book also is in the Tōyō Bunko.

(e) Huo Kang Pei Yao9 (Essential Knowledge for the Making of Gunpowder Weapons), reprinted in the year 1884 and bearing the words 'Tua Huo Shu Wu Chhiung chen'11 showing that it derived from earlier blocks. It carries the preface by Chhiao Yü, and its text is similar to those in the Hsiang-yang-fu and the Nanyang versions of Pt. 1. 

(f) Lastly comes the version of the 'Fire-Drake Manual' used by Arima (t) and entitled Wu Pei Huo Lang Ching12. It was produced in 1637 from an earlier first impression, bearing the words 'Pao Pei Shen Pung Kien hsin13' and it carries the preface by Chhiao Yü. It appears that this book is available only in Japan, in the Bōei Daigakko14 Military Academy.

Hence there are at least three different portions of Chhiao Yü's 'Fire-Drake Manual'. The work should indeed be considered a main nucleus with two supplements, summarising the development of successive gunpowder weapons after +1280. Chhiao Yü had been, as we shall see, a leading artillery officer in the army of Chu Yuan-Chang which finally conquered China for the Ming in +1643. Arima noticed that the Wu Pei Huo Lang Ching contains later additions, 

4 Mao Hsi Peng is quoted in the Wu Pei Chih, ch. 117, p. 114.6
6 But there is a mention of nio chuang, i.e. bird-beak fire-lostines, in Pt. 1, ch. 1, p. 130, in connection with poisonous smoke attacks (see Wu Pei Chih). Either this was a later interpolation, or the 'bird-beak' epithet applied to a fire-lostine before it was applied to a true gun.
7 Ch. 1, p. 34; A, p. 204; and p. 276 resemble Wu Pei Chih, ch. 119, p. 30 to p. 64.
8 One of us (H. P. Y.) obtained a photocopy of this text through the courtesy of this institution. For a preliminary report see Ho Peng Yu & Wang Ling (1). All the others are in the Easian Asia History of Science Library at Cambridge, and the University Library has a copy of (t). They have been indispensable sources for the account which here follows.
9 Private correspondence with Dr. Feng. See also pp. 349ff. below.
10 In the biographical section on meritorious officials in the Mung Shih, there is a man named Chhiao Cha7. He is the only person to be found bearing the title Tung-Ning Pei (Comes of Tung-ning), an appellation which Chhiao Yü also bore, so it must have been the same family, and perhaps Chhiao Cha was the general's father or grandfather. On Chhiao Yü's life and writings there is an interesting study by Chhafeng Tung (1).
11 Rh. 1637.
12 Chhiao Yü is mentioned in Chhiao Shih-Chen's Shen Chih Ch'ü (1658) and Chhiao Hsü's Tse Ko Lu (otherwise known as Huo Kang Chhiung Tao) of the year +1643. His name is also referred to by Ho Ju-Fin in the P'ing Lu in +1606. Arima (t) believes that much of the text of the 'Fire-Drake Manual' must have been written by Chhiao Yü in the middle of the +14th century. This is of great importance when one remembers the key date of +1327 for the first picture of a bombard in Europe.

In the Preface Chhiao Yü says that there were no firearms during Han times, but Chuko Liang (in the +3rd century) met an extraordinary person who revealed to him the secrets of attacking with fire. Chhiao himself met an adept named Chhiao-Chih Tao-Jen15, who told him to support Chu Yuan-Chang16 and gave him a book on fire-weapons and their uses. Chhiao Yü presented to Chu Yuan-Chang several fire-weapons which he had cast according to his teacher's instructions. Chu ordered Hsü Ta17 to prove them, and himself watched the tests, which pleased him much. After the conquest of the Mongols standard gunpowder factories were established in the capital, and arsenals were made to keep the 'magical weapons'. Thus gunpowder weapons were an important factor in the rise to imperial power of Chu Yuan-Chang.
30. MILITARY TECHNOLOGY

We translate the Preface in full as follows:* 

In the days of old when the Yellow Emperor fought the battle at Chou-lu, he had Feng Hou as his teacher; when Yu the Great waged war on the San Miao (tribes) he had Po I as his teacher; at the battle of Ming-thiao Chcheng Thang had a teacher in Yin, and during his invasion of Mu-yeh (King) Wu Wang had a teacher in Lu Wang. Such was the beginning of military tactics. When both sides have equal strength one can win if it has superior virtue: in the case of equal virtue the righteous (i.e. side will win. The ancient victors) resonated with the mandate of Heaven above, and abided by the will of the people below. Then when it came to the Spring-and-Autumn period there were struggles among the Five Hegemons, and during the time of the Warring States the Seven Powers waged war among themselves, endangering the lives of the people—there was hardly a single day of peace. Yet we learn no details concerning the deployment of fire in battle. Then, with Chang Liang as his teacher, the (Han emperor) Kao Tsu fought at the battle of Ssu-shang, brought about the downfall of Hiang (Yu) and found ed the empire (of Han). (The emperor) Kuang Wu (-Ti) began his campaign at Khun-yang with Teng Yü as his teacher, and suppressed (Wang) Mang to restore the dynasty of Han. But again, nothing concerning fire-weapons (in those days) has been heard of.

When it came to the time of the Three Kingdoms we saw the rise of many tactician-advisers and great soldiers. Tshao Tshao with villainous might controlled the central part of the empire, while Sun Chhuan, inheriting his father and elder brother, firmly occupied the eastern part of the empire around the Yangtze River. No one else could match their power. At that time, when the Crouching Dragon (i.e. Chuko Liang) was farming in Nanyang, without any desire to seek fame, he met an extraordinary man who secretly taught him the use of fire in warfare and the tactics of battle formations. Then, touched by the sincerity of the First Ruler (of the Shu Han) Chhi-ian, who thrice visited him, he exerted every ounce of his strength to serve him. He set the military farms ablaze in Po-wang, when he deployed his troops at Chihh-pi; and he burnt the soldiers of Meng Hua by setting fire to the ratten armour (worn by them). He attacked Shang-fang and led an expedition beyond the Chi-shan mountains. All this resulted in a partition of the Empire into three Kingdoms.

(Chuko Liang) won every battle that he fought. His tactics baffled his enemies more and more, frightening Tshao Tshao out of his wits, and Sun Chhuan too. Incendiary techniques in warfare reached perfection in the hands of Khung-Ming (Chuko Liang). As for his mine-setting in (the Battle of) Hu-lu-ku valley, both Ssuma (I) and Ssuma *

* This is a reference to the unacceptable tradition that Chuko Liang knew of gunpowder in the 4th century, and used it to make land-mines.

* From the Hau Kung Pii Kao version of the 'Fire-Drake Manual' in the text.

* The word 'virtue' here can also be interpreted as 'element', in which case the Law of Mutual Conquest comes into play. See Vol. 2, p. 236.

30. THE GUNPOWDER EPIC

Chao (father and son), would have been burnt to ashes if it had not been for an (unexpected) sudden downpour of heavy rain. (It was mainly due to his efforts that) people were prevented from forgetting the Han Dynasty completely. If it had not been for the will of Heaven that the empire be divided into three (kingdoms), he could easily have marched his army right through, and brought about a re-unification of the Empire. At that time, if it had not been for the fire-weapons of Chung-Ming, even though the Shu Kingdom had the famous Five Tiger Generals, the Wu and Wei Kingdoms, each with their own strengths, might not necessarily have feared the Shu Kingdom as a veritable tiger. Hence to be invincible nothing excels the expertise of using fire-weapons.

As for fire-weapons, there are those used only for combat, those that are set buried in the ground, those used only for attack, those used for defence, those used only on land, those used on water, and finally those used on city-walls. For charging and annihilating the enemy the fire must be intense and the weapons far-reaching. For sniping at enemy camps and producing chaos among the enemy, the fire must be far-reaching and the weapons sharp. For guarding a city-wall and holding a fort, the fire must be strong and the weapons heavy. Those that fly overhead are called 'heavenly thunder' (then le') (i.e. projectiles from bombards, or grenades and bombs hurled by trebuchets); those that are buried in the ground are called 'earthly thunder' (li le') (i.e. mines); those that are set off in water are called "water thunder" (shui le'); and finally those carried as weapons by the soldiers themselves are called 'human thunder' (ren le') (i.e. hand-guns and arquebuses). How fierce these weapons are depends on the nature of the fire, while the intensity and direction of the fire depend on the wind. When used openly they should be set off just at the right moment, and when they are used secretly they should be set to explode at a precisely predetermined time. The very existence or destruction of the Empire, and the lives of the whole armed forces depend on the exact timing of these weapons. This is what the army is all about.

From my early days onwards I read the Confucian classics, and studied books on military affairs. I roamed about the whole country, hoping to meet someone who had acquired the Tao. One day, when I was travelling in the Thien-thi mountains, I came across a Taoist wearing a yellow cap and black robe, with blue-green eyes and a grey beard, humming and dancing under a pine-tree. I approached and bowed to him. With his gown fluttering in the wind, he gave me the impression of being truly one of the holy immortals. Clearing a space on a great rock, I sat together with him, and tried to find out what he knew. (I discovered that) in the arts (he took) Confucius and Mencius as his teachers, but in military affairs (he had) inherited the (skill of) Sun Wu; above, he had exhausted the knowledge of the stars and astereisms, below, he could distinguish between all the different mountains and streams. I paid homage and knelted to him asking him to be my teacher. Later, we travelled the four quarters together, for three years. He styled himself Chih-Chih Tao-Jen, who was actually the 'Knowing-when-to-stop Taoist' and never spoke about his personal name or surname. One day we visited the Sheng Chen Yuan Hua Tung Tien's cave in the Wu-i mountains, and he looked at me, saying: 'When I

* The 'Five Tiger Generals of the Shu Kingdom' were Kuan Yu, Chang Fei, Chao Yun, Ma Chhao and Huang Chung.

b Cf. Vol. 2, p. 236. We assume that Chih-Chih was intended.

Rising to the truths of universal change.
of armour. The emperor Thai Tsu was delighted at the result, and said, 'With these types of fire-weapons I shall be able to conquer the whole empire as easily as turning the palms of one's hands upside down. When we confront them, I shall bestow upon you high honour as a Founding Officer of the Empire.'

From then on in one expedition we captured Ching-chou and Hsiang-chou, and in another we took (the administrative provinces of) Chiang and Chê, while in a third Han captured all its surrounding waters surrendered. 4 In a fourth campaign we stormed the whole of Chih (i.e. Shantung). 5 We also annihilated (Chihen) Yu-Liang and took the whole region of Chihin, Chin, Yen and Chao. 6 The Mongolian barbarians fled to the north and our capital was established at Ching-lung (Nanking). (Thus Thai Tsu) re-unified the whole empire, and began reigning over a new dynasty that will last for thousands of years. In the capital he set up a Gunpowder Department (hsao yao chê) for the manufacture of the explosive, and an Armoury (hsu kâi) for storing the magically effective weapons (chê chih). 7 Such was the attention our first sage-emperor paid to military matters.

The types of fire-weapons (made for the emperor), however, did not fully represent all the secrets passed on to me by the holy immortal. The sacred accomplishments and military exploits (of our first emperor) should ensure peace in the Empire for ten thousand generations. Yet in order to safeguard it one must not forget in time of peace about protection against dangers. Let these fire-weapon techniques might be lost during a long period of (peace), I have endeavoured to illustrate in diagrams, and describe them accordingly in writing, for the benefit of soldiers and tacticians who will serve our country as loyal subjects ready to die for its cause. They will be able to appreciate the immeasurable (applications) of the secrets handed down by the holy immortal (and the rare opportunity that I, their predecessor, enjoyed). It is not easy to meet an emperor and to become Master of his Ordinance. I fervently hope that none will be like Chao Khus, who only read his father's writings (but failed badly when he tried to put them into practice). 8 (May the reader) bear this in mind.

Preface (written during the) 10th year of the Yung-lo reign-period (+1412 by the Count of Tung-ning 9, Chiao Yü 10).

One or two interesting problems arise out of the versions of the 'Fire-Drake Manual' that Arima (1) did not see. In the preface of the Wu Pei Hua Lung Ching it is stated that Chiao Yü himself made for the first Ming emperor a hsuo lung

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1 Chiang-chou and Hsiang-chou referred to the territory formerly occupied by the state of Chihin in the Spring-and-Autumn Period, including the modern provinces of Hopei and Hankow and portions of Honan, Anhwei and other provinces. The occupation of these regions by the Ming army occurred in the years +1364 and +1365 under the able commanding generals, Hua Ta and Chiang Yu-Chihon. See Ming shih, ch. 1, p. 110; p. 123. Fukien surrendered to the forces of Chua Yu-Chang in +1365. See Ming shih, ch. 1, p. 72. Fukien surrendered to the forces of Chua Yu-Chang in +1365. See Ming shih, ch. 1, p. 72.

2 The Mogol shih, ch. 2, p. 13, says: 'On a far-a-day in the second month of the first year of the Hong-Wo reign-period (20 February +1368), Chihin Yu-Chihon captured Tung-chihing and thus conquered Shantung.'

3 i.e. roughly the whole of Shensi, Shanxi, Honan, and Hopei provinces. Chihin Yu-Liang was killed by a stray arrow on 1 October +1363 during a battle against the Ming forces. See Ming shih, ch. 123, p. 48. Dreyer (1), p. 525.

4 Chao Khus was a militarycommander of the State of Chao in the 3rd century. In his youth he talked so much about military matters that he wore his father Chao Shih's breastplate, and which he had previously adorned with Chao Shih's decorations. When this was under attack from the Chihin army, which was then also advancing on Chao Shih's turne to face the Chihin invaders, he was slain and his whole army annihilated by Pai Chih. See Shih chu, ch. 81, p. 68; Ke-Kien (1), p. 31.

5 6 7 8 9 10
chhiang (fire-drake spear or lance), which Arima believed was the earliest form of the musket or arquebus. But this weapon is not mentioned anywhere in the text of the Wu Pei Huo Lung Ching. Arima thought that it had been purposely left out because of the highly secret nature of the weapon, one which writers of later military compendia like the Shen Chhi Chu and Tse Kho Lu of course knew well. But the term huo lung chhiang does not appear in the preface in any of the other versions. The preface in the Nanyang edition and that in the Huo Kung Pei Yao both use the term huo chhi (fire-weapons). So this evidence by itself will not establish the existence of the arquebus or musket in +1355, even though it may perhaps have been known to Chiao Yu.

There is room for some speculation about the oldest version of the Hua Lung Ching. A few pages earlier we mentioned the Hua Lung Shen Chhi Thu Fa (Fire-Drake Illustrated Technology of Magically (Efficacious) Weapons) which Lu Wén-Chao listed in his completion of the Yuan bibliography, and if this went back to the beginning of the dynasty it could mean about +1280. Another work, the Hua Lung Wu Shen Shen Yao Thu Fa (Illustrated Fire-Drake Technology for a Myriad Victories using the Magically (Efficacious) Gunpowder) is known only by title from Chhien Tseng's Tu Shu Min Chhiu Chi catalogue of Sung and Yuan editions finished in +1684, but it must have belonged to the same family of texts. Most interesting is the Hua Lung Shen Chhi Yao Fa Pien (Fire-Drake Book of Magically (Efficacious) Weapons, with the Method of Making Gunpowder), which exists as an anonymous MS. in the library of the History of Science Institute of Academia Sinica at Peking. This has illustrations similar to those in the printed Hau Lung Ching editions, but more delicate and precise. Its relationship to these has not yet been elucidated, but perhaps further study will establish it as a Yuan work or an early copy of one.

Under the Chhing, the Hua Lung Ching, like the Wu Pei Chhih, was of course for centuries a prohibited book. It is full of expressions such as 'northern barbarians' (pei 1 i lo3), which would have made it impossible to reprint under the Manchu rule. Only when the Ming period had receded so far into the past that it had no contemporary relevance at all was it possible to give the book historical study and bring out new editions of it.

But perhaps the most interesting feature about it was that it was distinctly earlier than any component of the Bütchenschiffers' literature of Europe. From the Master-gunners of the West hardly anything has come down to us before +1400, though it is reasonable to place Chiao Yu's composition between +1360 and +1375, even though it was not first printed till +1412. The nearest approach to this is an untitled manuscript of about +1355. Then comes the well-known Bellifortis of Konrad Kyeser, dating from +1405. After that the European artillers wrote and limned copiously; the book of the Anonymous Hussite engineer and that of Giovanni da Fontana both came about +1430. Many interesting works, still in manuscript, followed—a Strebzuebel in +1435, a Feuerwerkbuch in +1437, the Kunst aus Büchsen in +1471, and a similar treatise in +1496. Meanwhile there was the Mittelalterliche Hausbuch, often previously referred to, in +1490. We need not pursue this literature further here, but the fact is that those who towards the end of the +14th century in Europe began to write down what they knew about bombardies, hand-guns, ribaudequins and gunpowder, had all been preceded by Chu Yuan-Chang's Master of Ordnance from +1355 onwards.

After the Hua Lung Ching there came about a dozen books on military affairs which touch on firearms to a varying extent, from the first half of the +16th to the first half of the +17th century. One of the earliest among them is the Wu Pien (Military Compendium) by Thang Shun-Chih (+1507 to +1560). It was included in the Suu Khau Chhihuan Shu collection, but the author is criticised by his bibliographers as being too bookish, for he met with disastrous results when he led an army against the Japanese wo-ko'at pirates who raided the Chinese coast during his time. He had to be rescued by Hu Tsang-Hsien in +1559. We do not know the exact date of the Wu Pien, though we can infer that it must be some time between +1548 and +1558, since Thang Shun-Chih mentions the 'bird-beaked gun' which was first introduced to China from Japan in the former year.

About +1561 Chên Jo-Tsêng wrote the Chhau Hai Thu Pien (Illustrated Seaborad Strategy and Tactics). There are five different editions of this book, one of which was published by the grandsons of Hu Tsang-Hsien, who dropped Chêng's name. Then came the Chiang-nan Ching Liù (Military Strategies in Chiang-nan), again written by Chêng Jo-Tsêng in +1566. The next writer of
important was the famous Ming general Chi Chi-Kuang (1429-1507), who wrote the Lien Pin Shih Chih (Treatise on Military Training) in 1517, and on the Chih Ho Hsia Shu (New Treatise on Military and Naval Efficiency) in 1575. These two are valuable books for the study of Chinese firearms, but they have received less attention than the Wu Pei Chih (Treatise on Armament Technology), though they preceded the latter by half a century. Another book of Chi-Chi-Kuang's was the Wu Pei Hsin Shu (New Book on Armament Technology). All these three military works of Chi were included in the Siau Ku Chihuan Shu collection. Similarly incorporated was the Chen Chih (Records of Battle Arrays), written in 1591 by Ho Liang-Chh'en; it gives a long list of firearms.

Before the end of the century came two further military works, namely the Shen Chi Pha (Treatise on Magically (Efficacious) Weapons), i.e., firearms, written by Chao Shih-Chhen in 1598, and the Teng Ting Pi Chhui (Knowledge Necessary for Army Commanders), written by Wang Ming-Hao in 1599. Wang was also the editor of another military book, the Ping Fa Pei Chhun Ching (Manual of Military Strategy for a Hundred Battles). A multitude of firearms and weapons, too, are illustrated and described in the Ping Lu (Records of Military Art) that Ho Ju-Pin wrote in 1600. This book describes the theory of the gunpowder formula in great detail, treating it like a medical prescription, regarding saltpetre and sulphur as the 'sovereign' (chih) components, carbon as 'minister' (shih) and other substances added to the mixture as the 'adjuvants' (ts'ieh). In 1607 came the Chu Chih Ming Shu (Book on Saving the Situation) written by Liu Khun.

Probably the most significant Chinese military compendium ever written was the Wu Pei Chih (Treatise on Armament Technology) in 240 chapters, completed by Mao Yuan-Fen in 1628. He also wrote an interesting Hsiao Yu Pha.

Of course, many monographs on guns and cannon were produced during this century. Hu Tsung-Hsien, the commander-in-chief in the Southeast from 1556 to 1560, himself wrote two, the Wu Li Shek Shen Chi Hua Yoo (Rhapsodical Ode on Gunpowder) about the same time; almost simultaneously, another military encyclopedia with a rather unusual title, the Phing Pai Chi Faung (The Wasmuthian's Precious Salve; Appropriate Techniques of Successful Warfare), edited by Hui Lu, also appeared. It reproduces many illustrations from the older books, adding also new ones, on the trebuchet principle and on the telescope, but it is not particularly good on firearms. Yet another late Ming military book was the Chin Thang Chih Chh Shih-Eh Chhoo (Twelve Suggestions for Impregnable Defence), by Li Phan.

Towards the end of the Ming Dynasty Chiao Hsiü, with the help of the Jesuit Adam Schall von Bell, wrote the Hsiao Kung Chhia Chhoo (Essentials of Gunnery) in the year 1645. From the 1634 reprint onwards, this work has also borne another name, the Tsü Kho Lu (Book of Instantaneous Victory). Chiao Hsiü mentions the 'Fire-Drake Manual', and his name leads one to speculate on a possible relationship between him and Chiao Yü; he could have been a descendant working in the Imperial Arsenal, but there is, as yet, no positive evidence for this. Jesuit intermediation was not the only channel which brought the knowledge of Western firearms to China. Contact with the Portuguese led to at least one book, the Hsi-Tung Hsiao Chih Tu Shoo (cf. p. 393 below); and there were also the Vietnamese, the Japanese and the Turks, as will appear in due course (pp. 310, 420, 440).

We have only mentioned those military compendia of the Ming which describe firearms and are still available to us. There were other military writings now lost or extremely rare, as for example, the Hsi Chih Thu (Illustrated Account of Gunpowder Weapons and Firearms) written by Ku Pin. The Wu Pei Chih and some of the others mentioned were naturally prohibited books in the Chhing period. In general military works were regarded as 'classified' items during the early part of that time, a fact which explains the difficulty of gaining access to them now.
and the Wu Lüeh Huo Chhi Thu Shuo⁴, both on muskets and gunpowder compositions and their use in various tactical situations. These were embodied in a very rare collection edited by Phan Khang⁵ and entitled Wu Pei Chhian Shu⁶, which contains a number of other interesting books as well. Another book with a closely similar title but of rather earlier date, the Wu Lüeh Shen Chih⁷ by Hu Hsienc Chung⁸ also dealt with the tactical employment of musketeers. Then there was Huang Ying-Chia's⁹ Huo Chhi Thu Shuo⁹, closely similar to the later forms of the 'Fire-Drake Manual'; and two works the names of the authors of which have not come down to us, a Huo Kung Chen Pa³ on the tactical use of guns and artillery, and a Huo Yao Miao Phih⁵ on gunpowder compositions and what they were good for. Thus all in all the late Ming was a very prolific period for works on gunshot weaponry.⁴ They help to explain the high figures for military writings of all kinds during this dynasty which we noted at an earlier stage.⁵

Firearms are also described in some general technological writings, and other encyclopaedic works. For example, the San Tshai Thu Hui⁶, written by Wang Chhi¹⁰ in +1609, illustrates the 'bird-beaked' gun' matchlock musket. A small section on firearms is contained in Sung Ying-Hsing's¹¹ Thien Kung Khai Wu¹² (The Exploitation of the Works of Nature) of +1637.¹³ Fang I-Chih's¹⁴ Wu Li Hsiao Shih¹⁵ (Small Encyclopaedia of the Principles of Things), finished by +1643, also has something to say about fire-weapons. However, none of these gives as much information on firearms as is found in the specialist military treatises.

During and after the Ming dynasty, Chinese military compendia seem to have made their appearances mainly during times of particular need or emergency. Early in the Ming the Huo Lung Ching described some of the weapons used to overthrow the Mongols. During the mid 16th century a host of military works appeared soon after the introduction of the Portuguese breech-loading cannon (fo-lang chi¹⁶), and the arquebus, the so-called 'bird-gun' or 'bird-beaked gun'. Such were the Wu Pien, the Chhau Hau Thu Pien, the Chhia-Nan Chih Lüeh, the Lien Ping Chhi Chih and the Chi Hsiao Hsin Shu. That was also the time when the Chinese coasts were plagued by the Japanese wo-kho¹⁷ pirates, often led by Chinese renegades. In the 1590s the Chinese were engaged in Korea against Japanese invasions led by Toyotomi Hideyoshi (+1536 to +1598). That was the time when Ho Liang-Chhen wrote the Chen Chi, and when Chiao Shih-Chen submitted blueprints for the making of more powerful muskets in his Shen Chih Piu. That was also the time when the Teng Than Pi Chhau made its appearance.

By the beginning of the +17th century the Ming military power had waned and it never recovered. Some scholars, seeing the urgency of rearmament and the need for acquiring military knowledge, hoped to restore the dynasty by compiling military works. We have a new crop of publications in late Ming including the Ping Lu, the Chhi Ming Shu, the Phing Rai Chhi Fang, the Chih Tsang Chhi Chhieh-Erh Chhau, the Wu Pei Chhi, and the Hoo Kung Chhih Tao. The first six included accounts of Western firearms which became known through Japanese contacts, while the last incorporated knowledge of Western guns and cannon introduced directly to China by the Jesuits. Our list is of course incomplete. We know of other military books now quite lost, for example the Hsi-Fang Huo Kung Thu Shuo¹⁸ (Illustrated Treatise on European Gunning) written by Chhang Tiao¹⁹ and Sun Huieh-Shih²⁰ before the year +1625.²¹

But by and large the Chhing period was one of peace, so that military compendia were produced less frequently, ²² but before the echoes of the Manchu conquest had completely died away Lü Phan²³ and Lu Chhing En²⁴ produced in +1675 their Ping Chhien²⁵ (Key to Martial Art).²⁶ This time artillery had entered the modern world (cf. Figs. 145 and 147 below). These authors gave a good deal of attention to naval affairs, incorporating in their book several important rutters, and registers of compass-bearings.²⁷ Moreover, the Man-Chhau Shih Lu²⁸ (Veritable Records of the Manchu Dynasty) contains a number of valuable illustrations showing the use and disposition of artillery pieces in the field, some of which we reproduce below (Figs. 152, 155). From the study of Chhien Wên-Shih (²⁹) we know that all the technical handicrafts and industries were poorly developed among the Manchus before the time of Nurhachi, but Chinese and Korean craftsmen were attracted to give their aid, and the first Manchu cannon was cast in +1631. Thereafter military needs long dominated. To trace the development of military writing in Japan would take us too far from our present theme, but this may perhaps be the place to mention the Honchô Gunnikô (Investigation of the Military Weapons and Machines of the Present Dynasty), a famous work by Araki Hukaseki²⁹ begun about +1705 and printed in +1737. It is

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²¹ See Bernard-Maire (7), p. 446, and Pelletot (53), p. 192. This work had no connection with the Jesuits, and probably emanated from friends of the Portuguese gunners who were sent up from Macao to help the Ming.

²² Some of which the audience would be lost for, examples the Hoo Chih Liueh Shau (Clasified Explanations of Firearms) by Wang Ta-Chhíhuan; and the Hoo Chih Chen Chih Chih Chhieh (Analytical Explanations of Firearms and Instructions for Using Them) by Shen Hsiu-Ching. We do not know their exact dates.

²³ Preface of +1696.

²⁴ Two of these have been reprinted and edited by Hsiang Ta (5). Cf. Vol. 4, pt. 3, pp. 581 f.

²⁵ Cf. Vol. 5, pt. 6 above.

²⁶ This we shall have occasion to discuss later, on pp. 187, 437 below.

²⁷ On this subject see the book so known in Wao-Wai (1).
very detailed on suit-armour and close-combat weapons, but it has almost nothing at all on gunpowder and firearms.\(^6\)

The publication of military compendia during the Ching dynasty was also correlated with national emergencies. For example, the Hai Kuo Thu Chih\(^7\) (Illustrated Record of the Maritime Nations), written by Wei Yuan\(^8\) and incorporating articles on Western firearms and gunboats, appeared in 1841, immediately after China’s defeat in the Opium War. Lin Tsê-Hsu\(^9\) lent a hand to get it published, and indirectly contributed much to it.\(^6\) This was the time of Li Shan-Lan’s tractate Hua Ohi Chen Chiu\(^10\) (Instructions on Artillery); he was an outstanding mathematician and technologist, later one of the group at Anking, predecessor of the Kiangnan Arsenal.\(^11\) It is not generally known that in the Chiang-nan Chih T'ao Chi Chi\(^12\) (Records of the Kiangnan Arsenal) of 1905 Wei Yün-Kung gave brief histories of gunpowder weapons in China, including some which the Arsenal may never have had occasion to make, such as the fire-lance and the war-rocket.

But the Ko Cha Ching Yuan\(^13\) (Mirror of Scientific and Technological Origins), written by Chhen Yuan-Lung\(^14\) in 1735, had already had much to say on weapons.\(^6\) It quotes from books like the Wu Yuan, the Pai Phien, the Shih Wu Chi Yuan and the Chiu Chiang Shu on the phao trebuchets, mentioning battles where mines were used, incendiary arrows, rocks, early Chinese bombs, guns, cannons, breech-loaders, the ‘bird-beaked’ musket and multiple-barrel guns. Of course, books such as this are only late secondary sources.

In looking back over the whole of this literature, several interesting thoughts present themselves. It is quite remarkable that after the first appearance of gunpowder in war it took about a century and a half before anything concerning it was put down on paper; the literate scholars so long failed to take notice of what the technicians were doing. Gunpowder appears first as a low-nitrate composition used in slow-match ignition in puffed naphtha flame-throwers (p. 81 below). This is datable to +919.\(^5\) Similarly, an account of a siege in +904 tells of ‘flying fire launched from machines’ (fa ch'i fei huo), i.e. low-nitrate gunpowder used in the form of incendiary projectiles or ‘bombs’ hurled from trebuchets (p. 85 below). Yet nothing much got into print about these things until the Wu Ching T'iao Yoo of +1044. And then what a long gap was until the writing of the Hua Lung Ching three centuries later! Today we can only fill it by the judicious use of the narratives of the historians, both official and unofficial, as indeed the rest of this Section will show.\(^a\)\(^b\)\(^c\)

(ii) Arabic and Western Sources

One of the earliest European texts mentioning gunpowder is the famous Liber Ignium ad Comburentos Hostes (Book of Fires for the Burning of Enemies) attributed to Marcus Graecus (Mark the Greek, or Byzantine),\(^d\) We have come across it before\(^6\) in connection with a recipe for the distillation of strong alcohol, which occurs as one of the latest of its components, belonging to c. +1280. The gunpowder formula also belong to this last stratum, perhaps as late as +1300, in contrast to the earliest entries which may well go back to the +8th century. Several Latin versions of the manuscript, only about six pages long, exist,\(^6\) but none of them bears a Greek title, and there is no evidence that the author or compiler of the work was a Byzantine. Marcus Graecus was certainly not, as some have supposed, the Marcus mentioned by Galen (d. +201), nor the Graecus referred to by Mesue (d. +1015),\(^e\) nor yet the +12th-century Mark of Toledo, who translated the Holy Koran into Latin, nor yet again the King Mark of England mentioned in late Arabic alchemical texts.\(^f\) Perhaps he was not a real person at all—nomen et praeterea nihil, just a name for a collection. The Liber Ignium is more probably of Arabic origin, perhaps translated and put together gradually by Jewish scholars in Spain, for it mentions certain climatological conditions not found in Europe, and leaves a number of Arabic and Spanish words untranslated. Moreover it contains\(^g\) several specifically Arabic +12th-century recipes for ‘automatic fire’\(^h\) and ‘oil of bricks’.

The Liber Ignium certainly belongs to the group of collections of ‘secrets’, lacking all classification or order. Of its 35 recipes, 14 are concerned with war, 11 for

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\(^*\) Judicious we say, because the pitfalls are inconceivable, largely owing to the continuing lack of precise technical terminology. Cf. p. 29 above.

\(^6\) All the modern work on it has been summarised and cited by Partington (15), pp. 42 f.; this largely superseded previous accounts. But Sutton (11), vol. 2, p. 1937 and Thornhill (19), vol. 2, pp. 352, 378, 385 ff. are still worth consulting.

\(^7\) Vol. 3, pt. 4, p. 133.

\(^8\) There is a printed version of the text by de la Forte du Theli (1804), and others by Bertelot (19), pp. 89 ff. and Hoefert (11), vol. 2, pp. 376 ff., and cf., p. 377, ff. with translations. But none are wholly satisfactory, and there is no modern critical edition.

\(^9\) Probably Malawiyah al-Mansur of Baghdad.

\(^10\) Bertelot (19); Bertelot & Hoefert (11), pp. 13, 15, 124. But this personage was associated with sal ammoniac, another of the new things that came to the Arabs (like sulphate) from China; cf. Vol. 5, pt. 4, p. 437.

\(^11\) Partington (15), pp. 42, 50, 55, 196, 198.

\(^12\) This was brought about by mixtures of quicklime with combustibles such as petroleum, sulphur and other things, which took fire when set in motion in any way. Cf. p. 67 below, and Partington (15), pp. 53 f., Caben (11), p. 147.

\(^13\) This was half-recognised hydrochloric acid, going far back into the Middle Ages; see Vol. 5, pt. 5, pp. 257 f., pt. 4, p. 128. It got the name of those balsamis and Roger Bacon spoke of it as ‘Bester’ oil (De Elementis Medicinali, §18, Welburn (19), p. 53) or ‘unreasonably in view of its use in pharmacy; cf. Caben (11), p. 148.
lamps and lights, 6 for preventing or curing burns, and 4 for preparing chemicals, especially saltpetre. Of the 14 military entries, 10 are for various incendiary mixtures, 3 of them containing quicklime; these recipes belong mainly to the early and middle strata, and it is directed that some of the mixtures should be shot off, after ignition, with javelins or arrows. The remaining 4 recipes all contain saltpetre.

It is noted in the 

Liber Ignium (§14) that

saltpetre is a mineral of the earth, and is found as an efflorescence on stones. This earth is dissolved in boiling water, then purified and passed through a filter. It is boiled for a day and a night and solidified, so that transparent plates of the salt are found at the bottom of the vessel.

The book contains two compositions of 'fire flying in the air' (ignis solatilis), which Berthelot (10, 14) interpreted as rockets. The first (§12) gives one part of colophonium resin, one of native sulphur, and 6 (?) parts of saltpetre. The second (§13) gives 1 lb of native sulphur, 2 lbs of linden or willow charcoal, and 6 lbs of saltpetre. There are also two compositions for ignis solatilis in aere (§§32 and 33), one having equal parts of saltpetre, sulphur and linseed oil; the other 9 parts of saltpetre to one of sulphur and three of charcoal. If we take the carbonaceous materials as equal to charcoal, this means, when tabulated:

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The text of the first of these being of doubtful interpretation, we clearly have to do with low-nitrate gunpowders which would deflagrate and not explode, or if so but weakly. The descriptions certainly sound like primitive rockets, though these seem to have been primarily incendiary or intended to terrify, since there is no mention of a propelled arrow or its warhead; but as Hime and Partington pointed out, the composition may well have been used in fire-lances such as were known to the Arabs, having appeared three centuries earlier still in China. The trouble with the expression 'flying fire', or 'fire flying in the air', here, is exactly the same as that met with in Chinese historical writings (cf. p. 22), where fei huo

ch'iang might be either 'flying fire-spears' or (as is much more probable) 'flying-fire spears'. The historians cannot be blamed if, as is possible, they had never seen rockets, and knew only fire-lances. Lastly there is the thunder mentioned in the Liber Ignium, but that need not imply detonation, since deflagration in a confined space could produce a similar effect. Thus, to sum up, we have in this important, though unsystematic work, clear evidence of saltpetre and low-nitrate gunpowder, no more, and certainly no use of gunpowder as propellant in a gun. Prior to its probable date, +1280, only one other European reference to gunpowder is known, and presently (p. 47) we shall take a look at it.

From the Arab world the literary monument most corresponding to the Liber Ignium is the Kitāb al-Farfūsya wa'l-Manāṣib al-Harbīya (Treatise on Horsemanship and Stratagems of War), written also about +1280 by Hasan al-Rammāh (the lancer) Najm al-Dīn al-Abdāb (the hunchback), probably a Syrian. Giving many formulae for gunpowder, it resembles Graecus in concentrating on incendiary compositions and deflagrating powders suitable for fire-lances and rockets, but it differs from him (or them) in giving many more overt signs of Chinese ancestry. Although al-Rammāh does not call saltpetre thi'li al-Sin (Chinese snow), only bārūd, he draws a great deal from Chinese practice, partly for recreational pyrotechny, and he has a variety of Chinese habits such as incorporating arsenic sulphide, lacquer and camphor in his compositions, or using expendable birds to carry incendiaries.

If we examine some of the gunpowder formulae in the book of al-Rammāh, we find a tendency to have the saltpetre content rather higher than anything certain in Marcus Graecus. One could apply some kind of correction for this, which would make the percentage of saltpetre appear higher, but the mixtures would still deflagrate, not explode.

The two known MSS, both in Paris, have been studied by Quatremère (2), Hime (1) and others, but the most judicious assessment of that by Partington (5), pp. 200 ff. See also Sarton (1), vol. 2, p. 139.

As Partington (3), p. 202 well noted. This was recognised even by Mercier (1), p. 117.

Besides 10 parts of 'Chinese iron'. If this was powdered cast iron, or iron filings, it was to give a white flame (cf. Audot (1); Brock (1), p. 93; Davis (17), p. 97). But it could have been what the Arabic alchemists called 'Chinese iron', i.e. hadd al-hanfī or kādab (cf. Vol. 3, pt. 4, p. 450), in which case it would have been copper-nickel. And copper gives a blue or purple flame (Davis (17), p. 65, 67).


Thus, although not so high as the theoretical value of 75%, these powders were distinctly more lively than the slower blasting or rocket levels of 60 to 68%.

1 This was one of the many farāiusya treaties on military arts, the bibliography of which has been studied by Rieu (4).

2 The two known MSS, both in Paris, have been studied by Quatremère (2), Hime (1) and others, but the most judicious assessment of that by Partington (5), pp. 200 ff. See also Sarton (1), vol. 2, p. 139.

3 As Partington (3), p. 202 well noted. This was recognised even by Mercier (1), p. 117.


5 Among the fireworks there are 'wheels of China', 'Rows of China', white and green lotuses, coloured snakes (as in WPC, ch. 160, pp. 34 ff), etc.

6 There are 11 parts of 'Chinese iron'. If this was powdered cast iron, or iron filings, it was to give a white flame (cf. Audot (1); Brock (1), p. 93; Davis (17), p. 97). But it could have been what the Arabic alchemists called 'Chinese iron', i.e. hadd al-hanfī or kādab (cf. Vol. 3, pt. 4, p. 450), in which case it would have been copper-nickel. And copper gives a blue or purple flame (Davis (17), p. 65, 67).

al-Rammâh never talks about bombs or detonations, accidental explosions were certainly to be feared in the Arabic arsenals of the time, since the exact proportions of saltpetre would necessarily be inadvertently exceeded. Again, gunpowder was an incendiary used on arrows or thrown in pots from trebuchets, and as flame-throwers filled into fire-lances; it was propellant only for rockets (much more certain than in Marcus Graecus), and not behind projectiles in guns or cannon of any kind. But it is very significant that the characteristically Chinese co-axiative projectiles appear, thrown out from fire-lances as balls, 'chickpeas', of burning material. In the book of al-Rammâh many important descriptions of things are given too, such as fuses (ikrî:ki) and incendiary 'bombs' or naphtha pots (qâdr). By itself alone the Kitâb al-Farâisiya ... would serve as striking evidence for the westward passage of gunpowder and all military pyrotechnics from the Chinese culture-area.

Finally, al-Rammâh it was who gave the first description of the purification of saltpetre (bûnâd) by a Muslim writer. The solution of the mixture containing potassium nitrate was treated with wood ashes to precipitate the deliquescent calcium and magnesium salts, then decanted or filtered and allowed to crystallise. So this knowledge was shared with the author of the Liber Ignis.

Hasan al-Rammâh's book was not of course the earliest Arabic treatise on military incendiaries (nafūj). A work by Murad ibn 'Ali ibn Murad al-Tarsusi was composed for the famous commander Saladin (Salâh al-Dîn) about +1185. It had a memorable title: Tahsirat arba'b al-ilbî:îs fi Kâhayyat al-Najîsh fi'l-Harîm wa-nahsh al-lâm al-lîm fi'l-'udud wa-li 'âlî al-mu'înâ 'âlî liqîq al-adâ'. (Information for the Intelligent on how to Escape Injury in Combat; and the Unfurling of the Banners of Instruction on Equipment and Engines which assist in Encounters with Enemies.) Here the important point is that neither saltpetre nor mixtures containing it are mentioned—which is not surprising since the first mention of potassium nitrate among the Arabs comes with Ibn al-Bayrâm about +1240.

The book therefore parallels the Thai Pai Yin Ching 1, and the fact that that was written four centuries earlier simply points up the dialogue between China and Western Asia or Europe. There is naturally much about nafîj (naphtha), though it is not called Greek Fire, and 'automatic fire' is prominent too. 2 Other Arabic

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1 This was also the opinion of Bonaparte & Favâ (1), vol. 3, p. 33.
2 This was later widely adopted in Western pyrochemistry; cf. Broek (1), pp. 191 f. Babington in +1696 spoke of 'truncaux of fire which shall cast forth divers fire balls', and this, it has been thought, is one of the earliest references to Roman candles. Cf. Bar (1), writing in the previous year.
3 It is generally said that the expression itself, 'Roman candle', first appears in Maryton's Peter Simple (1552), but this cannot be right because it was prominent as a display in +1769 (Broek (1), p. 192). The name originated, according to him, as a reference to a traditional pre-Lent carnival at Rome, where each merrymaker sought to extinguish the castle of his neighbour while keeping his own alight. But there is no certainty of sense, and one wonders whether, if the usage could be traced further back, the adjective 'Roman' would not be found to mean East Roman, i.e. Byzantine—like Greek Fire itself. Were fire-lances not known to the Byzantines since between +1250 and +1450?
6 Cf. Wiedemann (9), p. 26; repr. in (14), vol. 1, p. 220. The expressions hâl-al-arâf (the mouth of the projector-pipe) and hâl al-mi'âd (the mouth of the Chinese fuse-pipe) occur in the Mabsûl al-Shir (Ref. of the Sciences) written by Abu 'Abdallah al-Khwârizmi al-Kârib in +976. These occur, it is said, in naphtha-thowers and ejectors (al-nâbîshâ al-wâr jardâli).
7 Arrows are mentioned among these (cf. p. 274 below).
hand-gun. If the date is right, there is not much point in denying to the Arabs the knowledge of true guns and bombardats at this time. Even if Quatremère (2) was correct in saying that midafa' did not mean a cannon until +1383, it remains that the technique of early artillery was spreading in the Middle East and the Maghrib in the +14th century just as it was in Europe, having started in China in the +13th, as we shall see (p. 294). Of course the older methods still continued, for the Rzevuski MS speaks of incendiary ‘bombs’ thrown from trebuchets or arcuballistae, and also ‘Chinese arrows’, i.e. rockets.

The Mamlük dynasty, centered on Cairo, lasted from +1250 to +1517, and the process of chemicalisation of warfare during its sway has been studied in an interesting book by Ayallon (1). The earliest mentions of midafa’ that he could find dated from +1342 and +1352, but he could not prove that they were true hand-guns or bombardats. However, the decisive eye-witness description by the encyclopaedist Shihāb al-Dīn Abū al‘Abbās al-Qalqashandī of a metal-barrel cannon shooting an iron ball at Alexandria must lie between +1365 and +1376. By

the end of the century the use of true artillery was becoming widespread just as in Europe. One of the historian’s troubles in this era is that as incendiary substances changed to deflagrating low-nitrate gunpowder, and as that in turn evolved into explosive and propellant high-nitrate gunpowder, the name did not change. So naft came to mean gunpowder, and they spoke of midafa’-naft. Even when they gave that up, they transferred the term barīd from saltpetre to gunpowder itself, which made matters no better. True, the fact that in the beginning gunpowder was itself used as an incendiary substance renders the continuation natural enough, but can hardly condone it. Although the same unfortunate failure to develop new technical terms for new things also bedevils the situation in China (cf. p. 11 above), this particular trouble does not arise there, and huo yao (the fire chemical) invariably indicates the existence of the gunpowder mixture.

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1. After all, Lavin (1) shows that cannon (meeno) were used by the Moors besieged in Algiers in +1343.
2. Many of these pottery containers, notably from the siege of Fustat in +1168, are illustrated in the plates of Mercier (1), whose book was vitiated however by a dating of Marcus Graecus a couple of centuries too early, and a belief that saltpetre was known and used in the West several centuries before it actually was. Cf. Figs. 3 and 4. On the naphtha ‘bombs’ see also Lenz (1) and Gohlke (3).
would consort well enough with what Hasan al-Rammāh tells us (p. 41 above), as also with the passage of such gunpowder techniques from China previously. But gunpowder has no name of its own; saltpetre and naphtha both do duty for it.

Very different in material content, if not in phrasing, is the passage in al-Qalqashandi’s geography and description of Egypt and its government written a decade or so before his death in +1418. He says:*

And (one kind of) these (siege instruments) is makhālī al-bārīd, and these are al-maddīfī from which one shoots by means of nafī. In part they shoot big arrows, which almost pierce a stone, ⁶ and in part they shoot balls of iron weighing from 10 to over 100 Egyptian nafīs. And (another kind of) these (instruments) is qawārīr al-nafī, and these are qudūr and the like (pots), into which the nafī is put, and these are (lit and) thrown at fortresses with the purpose of burning with fire.

Here there were clearly true bombardes as well as incendiary projectiles of ‘petrol’, but nothing could better show the confusion of the Arabic terminology, in which neither saltpetre nor naphtha was distinguished from gunpowder.

Indeed, current standard Arabic still to this day speaks of gunpowder as bārīd, and saltpetre is now called mīlī al-bārīd (the gunpowder salt). Occasionally, however, there was used another term, dawāt, the ‘drug’, ⁷ normally applied to any prescription or therapeutic preparation, or even to wines, but here it may have some historical significance since it evokes so closely the Chinese term huo yao, ‘fire-drug’ or ‘fire-chemical’.

We must now return to +13th-century Europe and take up the celebrated references to gunpowder in Roger Bacon and Albertus Magnus. One may recall that the Franciscan ‘doctor mirabilis’ was born probably in +1210 ⁸ and died about +1298. ⁹ Among his earlier works was that commentary on the translation of Pseudo-Aristotle, Secretum Secretorum, which we came across in the context of elixir chemistry; ¹⁰ this belongs to the time between +1243 and +1257, at which

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* Ayaloni (1), pp. 212-2 (3). We could not find the passage in the translation of Wustefeld (1), so perhaps it only occurs in certain MSS.

² Note the similarity with Walter de Milamete’s bombards (pp. 287, Fig. 82).

³ For this information we are indebted to Prof. Douglas Dunlop. The transition from al-naft to bārīd for what was essentially a new thing, different from either, was already pointed out by Caenini (2) in 1770, vol. 2.

⁴ Cf. Partington (5), pp. 204-5, 313, following Reinaud & Favé (2), p. 310, from the Rzevuski Ms. (c. +1350), cf. p. 45 above.

⁵ Frankel (1), p. 163.

⁶ Cf. the case of ‘kraut’, p. 168.

⁷ Some say +1214, and there is evidence for both dates.

⁸ On Roger Bacon’s life see DBB, vol. 1, pp. 537 ff.; Sarton (1), vol. 2, pp. 592 ff.; and Thorndike (1), vol. 9, pp. 616 ff. On his alchemical interests see Mulhauff (1), p. 185; Welhoren (1). Partington (5), pp. 64 ff. gives an elaborate discussion of Bacon and Albertus from the point of view of the history of explosives, but we cannot follow him in every respect. We recall, however, a fascinating discussion with him on the subject in JRA 1959.

⁹ Vol. 5, pt. 4, pp. 444. This work, the title of which could be expanded as ‘The Secret of All Secrets, which Aristotle expounded to Alexander the Great’, seems to have been of Arabic origin, about +900. This Kitāb Ser al-Dawr was translated into Latin by Philip of Tripoli (or, of Salerno) about +1200. It exists in a host of manuscripts, in several languages besides Latin, and discusses personal conduct, royal policy, medicine, astrology, and all kinds of real or supposed strange natural phenomena. See Thorndike (1), vol. 2, pp. 267 ff., 310, 653.
later date Roger became a Friar Minor. Then came the papal mandate of +1266, as the result of which he submitted to Clement IV his three greatest works, the Opus Maius in +1267 and the Opus Minus and Opus Tertium in the following year—but by that November the Pope had died, and answer came there none, nor thanks, nor any financial support either. By +1278 Bacon's enthusiasm for experimental science, chemical medicine, natural wonders and empirical technology, perhaps his criticisms of theologians and canon lawyers, led to some kind of imprisonment, and the last years of his life are obscure. The Epistola de Secretis Operibus Artis et Naturre, et de Nullitate Magiae (Letter on the Secret Workings of Art and Nature, and on the Vanity of Magic), sometimes alternatively entitled De Mirabilis Puteator Artis et Naturre (On the Wonderful Powers of Art and Nature), has often been dated before the three Opus books, but it is more likely to be later, belonging rather to the seventies, and may even be a popularising condensation of those writings done by another hand.8

Taking first Bacon's assuredly authentic words, we find in the Opus Maius and the Opus Tertium9 two passages which are so alike that it is permissible to conflate them into one. But before giving that, we must reproduce what he says in the earlier work about incendiaries and Greek Fire:4

Certain of these works by contact only, and so destroy life. Malta (naphtha), which is a kind of bitumen plentiful in the world, when projected upon a man in armour, burns him up. . . . Similarly, yellow petroleum, i.e., oil produced from the rocks, when properly prepared (distilled) burns every thing it meets by a consuming fire not extinguishable by water, and only with great difficulty by other things. Certain inventions disturb the hearing to such a degree that if they are set off suddenly at night with sufficient skill neither cities nor armies can endure them. No thunderclap can compare with such terrifying noises; nor lightning playing among the clouds with such frightening flashes . . . It would certainly seem that Bacon had witnessed an explosion.

What this could have been appears from passages in both the books, here made into one:6

We have an example of these things (that act on the senses) in [the sound and fire of] that children's toy which is made in many [diverse] parts of the world; i.e. a device no bigger than one's thumb. From the violence of that salt called saltpetre, [together with sulphur and willow charcoal, combined into a powder]9 so horrible a sound is made by the bursting of a thing so small, no more than a bit of parchment [containing it], that we find [the ear assaulted by a noise] exceeding the roar of strong thunder, and a flash brighter than the most brilliant lightning. [Especially if one is taken unawares this terri-

\footnote{Let alone any sign of interest in Roger Bacon's devotion to natural philosophy, with all its inklings of modern science, still 300 years or so in the future.} 
\footnote{ Cf. Thormike (1), vol. 2, p. 689.} 
\footnote{ 31.} 
\footnote{ All the references are given in Partington (5), pp. 76 ff., with Latin texts.} 
\footnote{ Square brackets indicate words only in the Opus Tertium.} 
\footnote{ This knowledge of the composition of the mixture was signalled by Sarton (1), vol. 2, p. 957.} 

\footnote{This was exactly what had happened in China a century or more earlier, with the development of the first actual tarre 24, or cast-iron bombs filled with high-nitrate gunpowder (cf. pp. 170 below).} 
\footnote{ This conclusion has also been reached by Foley & Perry (1), p. 207. And Winter (5), p. 9, agrees that fire crackers were what he had in hand.} 
\footnote{ The traditional composition is N. S. C. 66:6; 16:6:15:8 (Davis (17), p. 112), like blasting powder.} 
\footnote{ Cf. Sinor (3, 7, 9).} 
\footnote{ Sinor (8).} 
\footnote{ Pellole (10), pp. 2; Sinor (7).} 
\footnote{ Cf. Vol. 1, pp. 189, 224; Hudson (1), pp. 134 ff. It may be of significance that Roger and William were personally acquainted. The reference in Opus Maius is vol. 1, p. 354. At Rockhill (5), pp. 331 ff., pp. 7; Twaas fortunate for Friar William that he met, probably during his short stay in France, that brilliant and appreciative writer Roger Bacon, for he alone saved him and the results of his arduous journey from utter oblivion for three centuries and a half: There is nothing about gunpowder or crackers in his text as we have it today, but that does not signify much. Cf. Sarton (1), vol. 2, pp. 99 ff., 1053.} 
\footnote{ Sinor (9).} 
\footnote{ Not forgetting a nose on the mixture of the nature.} 
\footnote{ (1), (1), pp. 102 ff.} 
\footnote{ The extensive literature on this may be followed in Partington (5), pp. 189 ff.} 

\footnote{ 鉴 等 子}
lacks all manuscript authority, and appears only in the earliest printing (+1342), where it may be a corruption of some Greek quotation. It does not even belong to one of the probably authentic chapters. Still, in ch. 6 we find an approximate repetition of the passages about the gunpowder crackers just given, and prophecy of 'greater horrors' to come.

As for the involvement of the great Dominican, Albertus Magnus, a scholar who had the honour of being beatified both by the Church and by science, it turns out to be, like the Baconian cryptogram, a non-starter. Albert of Bollstadt was born in +1193 and died in +1280, but the De Mirabilibus Mundi (On the Wonders of the World) is of highly doubtful authenticity, and may not be +13th century at all. Perhaps it was written by Arnold of Liège about +1300, possibly by Albert of Saxony as late as +1350. In any case, what it says about gunpowder and 'flying fire' is verbally identical with §15 of Marcus Graecus, so it adds nothing to our picture of the earliest European knowledge of the explosive mixture.

There are two outstanding parallels between Roger Bacon's knowledge of gunpowder and what happened in other fields. First, mechanical clocks. We know that almost the first reference to a time-keeper of this kind comes from Dante in +1310, but also that Western men were heard at work about +1271 trying to arrest the motion of a wheel so as to make it keep time with the apparent diurnal motion of the heavens. So also the first bombard got into an illumination in +1327, while Bacon knew approximately the gunpowder formula in +1268. Secondly, just as he was the first person in the West to acquire this knowledge and to write about it, so he was also the first Westerner to talk like a Taoist, saying that if only we knew more about chemistry human life could be immeasurably prolonged. Chinese influences in all these parallels are unmistakable. And the paradox was only repeating itself 120° of longitude West, that those who sought elixirs of longevity and immortality should find an explosive mixture as well—all knowledge and all skill inevitably fraught with danger if mankind should not be conscious of the ethics of the employment of such mastery.

Gunpowder formulae are of course given in all those early European treatises of military technology at which we have already had a look (p. 40). The oldest

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3. The Gunpowder Epic

Illustrated MS, which may be dated about +1305, contains a recipe for gunpowder, a method for the making, purifying and testing of saltpetre, together with crude coloured illustrations of guns. Konrad Kyser's Bellifortis, written between +1400 and +1405, mentions rockets, guns and a number of peculiar formulae for gunpowder. München Codex 197 is a composite work, the notebook of a military engineer writing in German, the Anonymous Hussite, and that of an Italian, probably Marianus Jacobus Taccola, writing in Latin; it contains dates such as +1427, +1438 and +1441. It gives gunpowder formulae and describes guns with accompanying illustrations. A curious feature, very Chinese (cf. pp. 114, 361), is the addition of arsenic sulphides to the powder; this dates from fire-escape days but probably had the effect of making it more brisant, hence it could have been useful in bombs and grenades. + The +15th-century Paris MS, supposedly before +1453, De Re Militari, perhaps by Paolo Santini, shows a gun on a carriage with a shield at the front, mortars shooting incendiary 'bombs' almost vertically to nearby targets, a bombard with a tail (cerbotane or tiller), and a mounted man holding a small gun with a burning match. But we need not pursue the European literature further here.

(iii) Speculations and research contributions

Roger Bacon and his friends could have had only the faintest idea about the location of those 'diverse parts of the world' which had produced the crackers, and where the invention of gunpowder had been made, though the travelling friars of the +13th century had been well aware of the existence of Cathay. But by the +15th century an abundant use of firearms during the preceding century, Europeans were less occultically minded, and it seemed inconceivable to them that the invention could have occurred in any other continent—hence the legend of Berthold Schwartz, variously believed to have been an alchemical monk or friar, usually thought German, but in the earliest sources (perhaps significantly) a Byzantine Greek.

Probably the earliest appearance of this personage is found in a MS of about +1410, described by Köhler, where he is a 'Meister von Kriechenland', Niger Berchudsallus. A more circumstantial relation was apparently given by Felix Hemmerlin, writing about +1450, in his De Nobilitate et Rusticate Diologus; but
the details need not detain us. After this, the story was repeated by innumerable writers, including Polydore Vergil from +1500 onwards, and Guido Panciroli from +1600. Panciroli was puzzled, like many others, by the long time which the invention had taken, if the story of its much earlier appearance in the East was true, to find dissemination among the European peoples.

Some Writers of the Indian History tell us [he said], that Guns as well as Printing were found out by the Chinese many Ages ago. They say also that they were in Use among the Moors long before they were known in Germany: But how is it possible or credible, that an Instrument so necessary for the besieged to repel the Attacks of their Enemies, should lie dormant so long? Whereas, as soon as ever the Use of Guns was known to the Venetians, and Printing to the Romans, it was presently communicated to other People, so that now nothing is more common throughout the World.

Already in +1572 Sebastian Munster had posthumously popularised the account of Schwartz, having obtained it, so he said, from his friend Achilles Gasser.

For nearly five centuries the Berthold Schwartz story battled with the growing conviction that gunpowder, unknown to the ancients, had originated in the East. The only surprising thing is that it lasted as long, a tribute to the Europocentrism of Westerners. William Camden the antiquary, writing in +1605, was sceptical about the Eastern origin.

If ever the witte of man [he said] went beyond belief itselfe it was in the invention of artillerie or Engines of warre...

Some have said a long course as farre as Chiza, the farthest part of the world, to fetch the invention of guns from thence, but we know the Spanish proverbs 'long waies, long lies'. One writeth, I know not upon whose credit, that Roger Bacon, commonly called Friar Bacon, knew how to make an engine which with Saltpeter and Brimstone, should prove notable for Batterie, but he, tendering the safety of mankind, would not discover it. The best approved authors agree that guns were invented in Germanie, by Berthold Swarte, a Monke skilful in Gebers Cookery or Alcumy, who tempered Brimstone and Saltpeter in a mortar, perceived the force by casting up the stone which covered it, when a sparke fell upon it...
To make the monk thus a mere transmitter was exactly what some of the scholars of China and Japan themselves propounded after they had come to hear of him, as we shall shortly see.  

Besides, the idea was not a new one. It had already been suggested, as far back as +1585, by Juan de Mendoza, in his famous Historia de la Casa mas Notables, Ritos y Costumbres del gran Reyno de la China. One section of this was entitled: 'How that with them they have had the use of Artillery long before us in these parts of Europe'. In Robert Parke's translation.

Amongst many things worthy to be considered, which have been and shall be declared in this historie, and amongst many other which of purpose I omit, because I would not be tedious with the reader, no one thing did cause so much admiration unto the Portugals, when they did first trade in Canton, neither unto our Spaniards, who long time after went unto the Philippines, as to find in this kingdom artillery. And wee finde by good account taken out of their histories, that they had the use thereof long time before us in Europe.

It is said that the first beginning was in the yeare 1330, by the industry of an Almaine, yet bowe he was called there is no historie that dooth make mention, but the Chinos saie, and it is evidently seene, that this Almaine dooth not deserve the name of the first inventor, but of the discoverer,  for that they were the first inventors, and from them hath the use thereof been transported unto other kingdoms, where it is now used...

Meanwhile Isaac Vossius, who did so much in the seventeenth century to give credit where credit was due, included in his Variarum Observationum Liber of +1685 two pieces about gunpowder in relation to China. The first was part of his De Artibus et Scientiis Sinarum, and the second followed immediately upon it—De Origine et Progressu Pulserii Belloci apud Europaeos.

Vossius began by saying that 'the powder of nitre, with cannon great and small', usually considered an invention of Christians, had in fact been very well known to the Chinese sixteen centuries before his time; while guns of exquisite workmanship dated there at least eight centuries back. The first of these statements was a wild exaggeration, the second rather a good guess. The Siamese, as Tabernarius had rightly affirmed, got their gunpowder originally from China, and better made too, than that of Christendom. The Europeans, though in most matters of military art long superior to the Chinese, must yield in part to them where the warlike uses of gunpowder were concerned. As for recreational fire-works using the same powder, in these the Chinese truly excelled, what with flames of all colours, forms and figures of any kind they pleased, nay, whole pictures picked out with light in the empty air: 'The Europeans in all their wars have not lavished more gunpowder than the Chinese have in these joyful spectacles.' And then he goes on about the Great Wall, and how the dregs of society were sent to guard it, the Chinese being greatly given to peaceful literary pursuits; until during the past forty years the wars caused by the invading Manchu Tartars had led to great misery. In any case, he concluded, 'everything we have in the arts and sciences we owe either to the Greeks or to the Chinese'.

In the second of his essays Isaac Vossius was really rather sagacious. He was sure that gunpowder had not been known in the West above four hundred years past (which would make it +1285), and he did not believe that either Roger Bacon or any other nameable person had been responsible for it. Fire itself, of course, had been used in war much earlier, which was easy to show from the 'automatic fire' of Julius Africanus, the naphtha of the Persian and Gothic wars, and the Greek Fire invented by Callinicus about +685 or a little before. It was still incendiaries that frightened the host of St Louis in the Crusades, as told by Joinville. Of flame and thunder there is often mention, but of stone or metal bullets, or explosions, all is silence. So who among the Christians had first begun to use gunpowder bombardards with projectiles of iron, lead or stone, we really did not know. The description of one of these guns of 20 in. calibre in Froissart remained among the earliest references. The danger of bursting such pieces had led to the ribaudequins or multiple-barrel cannon, where the charges could be less. Who had first introduced corned powder Vossius also did not know, but Tabernarius (Tavernier) had, he said, described the gunpowder compressed into little rods characteristic of Tonking and Siam, which was very good. On account of their love of peaceful humanism, the Chinese had neglected to adopt such improvements, and so when they were necessitated to oppose the Manchu Tartars, they prevailed upon Christian Masters to cast cannon for them.
ness, without any application of fire. I shall but just mention a fatal event which lately happened in Germany, from an experiment made with balsam of sulphur terebenthinated, and confined in a close chemical vessel, and thus exploded by fire: God grant that mortal men may not be so ingenious at their own cost, as to pervert a profitable science any longer to such horrible uses. For this reason I forbear to mention several other matters far more horrible and destructive, than any of those above rehearsed.

Whatever would Boerhaave have said, one wonders, about nuclear weapons? He was a high-minded and far-seeing chemist, but the part about Schwartz, which mainly interests us here, received a debunking footnote from Boerhaave's translator, Peter Shaw, in 1753, a footnote which we cannot omit, since it shows how careful history as well as sympathetic ethnology was proving the Schwartz story legendary. He simply said:

What evidently shows the ordinary account of its invention false is, that Schwartz is held to have first taught it to the Venetians in the year 1580; and that they first used it in the war against the Genoese, in a place antiently called Fossa Caedean, now Chiggiola. For we find mention of fire arms much earlier: Peter Messorius in his variae lectiones, relates that Alphonsus XI, king of Castile, used mortars against the Moors, in a siege of 1498; and Dom Pedro, bishop of Leon, in his chronicle, mentions the same to have been used above four hundred years ago by the people of Tunis, in a sea-fight against the Moors of Sestil. Du Cange adds that there is mention made of this powder in the registers of the chambers of accounts in France, as early as the year 1398.

Thus no one could fix his exact date, or find evidence of his existence.

To sum it all up, Partington concluded that 'Black Berthold is a legendary figure like Robin Hood (or perhaps better, Friar Tuck); he was invented solely for the purpose of providing a German origin for gunpowder and cannon.' If we widened this to European in general we would not go far wrong.

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1. This and the ensuing examples were taken from a variety of oxidation of organic substances by concentrated nitric acid; cf. Mellor (1), p. 312. What Boerhaave 'forbears to mention' is not altogether obvious, for mercuric fulminate was not found and studied till the early years of the following century. Cf. Partington (10), p. 590.
3. Actually, the bombards were used by the Moors against the Spanish in the siege of Algiers, and the date was 1543; cf. Lavin (1).
4. This would make it about 1550.
5. Perhaps he got some of this from Gram (1), who made the point earlier in Denmark.
6. This was also the conclusion of Godolfino (1) in 1911. A vivid picture of these perplexities occurs (as Mr Michael Moriarty has reminded us) in Laurence Sterne's Tristram Shandy, bk. 6, p. 317 (+1756) where Uncle Toby is discussing the origins of gunpowder with Corporal Trim. He knows that Bacon long preceded the supposed date of Schwartz, and also gives several examples of the use of gunpowder weapons in war during that time, adding: 'And the Chinese embarrass us, and all accounts of it, still more, by boasting of the invention some hundreds of years even before him.' 'They are a pack of liars, I believe,' cries Trim. And Uncle Toby goes on to say that he thinks they must somehow be deceived, because of the backward state of fortifications among them. This of course took no account of the role of distinctly modern science and technology in such designs in the Western world alone.
8. He lives on to this day, moreover, in the works of such writers as Laffin (1), p. 15; or is dismissed along with all the Chinese evidence in a common uncritical condemnation, as in Lindsay (1), p. 4.
30. MILITARY TECHNOLOGY

One of the ironies of the situation was that Schwartz got transmigrated into East Asian literature to mystify the scholars of that part of the world. In 1832 J. N. Calten, a Dutch gunnery officer, wrote a book entitled *Leidraad bij het Onderwijs in de Zee-artillerie* ... in which he said that gunpowder had been discovered accidentally in an alchemical laboratory by Schwartz in +1320, who later invented cannon to make use of it. This book was translated into Japanese by the chemist Udagawa Yōan,4 and his colleagues, who incorporated it into the *Kaijō Hojitsu Zenshō* (Complete Treatise on Naval Artillery) about 1847.

But Schwartz was also figuring in Chinese dress. In the course of his campaign, “...”

The technique of artillery (hao phao) was invented in China, and European people did not know of it. At the end of the Yuan period4 an Jhi-erh-man5 person (i.e. Aleman, German) named Su-Er-hi-Tsou6 (i.e. Schwartz) started to imitate the art, but hardly attained the right way of managing it. During the Hung-Wu reign-period7 of Ming, Ti-Mo-Er-hi Wang8;9 (i.e. Timur Lang or Tamerlane) of Sa-Ma-Er-hi Han10 (i.e. Samarkand) was very powerful in the Western countries; some Europeans enlisted in his army, and afterwards returned home taking gunpowder and cannon (hao yao phao)11 with them. They got to know the whole technique of it, changing and improving its methods, so that they developed the “bird-gun” (miao chiu hong)12 musket, and used it in a multitude of battles to gain innumerable victories. And they built great ships to sail all the seas, so that they appropriated vast territories such as Siberia and Malaya, including the Indies and all the islands of the South Seas. Their victories criss-crossed the four quarters, and now they own more than ten (Eastern) countries.

All this was ingenious, but Tamerlane will not work, because the first of the Timurid emperors, Amir Taimur Sāhiba Qirān, was not born till +1336 and did not set out on his conquests till +1370, by which time gunpowder weapons had been known and used in Europe for more than forty years.8 Still, this voice from East Asia was echoing the conviction of Louis de Gaya long before that Schwartz had been a transmitter, not an originator. It was not given to Hsi Chi-Yü to know that in fact he had no real existence at all, but since this is indubitably the case we shall now dismiss him into the realm of legend, and speak no more of him in our history.

Meanwhile, all kinds of unacceptable accounts of the origins of gunpowder and firearms were circulating in China. For example, both Gauqil (12) and Amiot (2).9 Jesuits working there in the +18th century, adopted the persistent legend that gunpowder had been known in the +3rd century and had been used by the Captain-General of Shu, Chuko Liang, for constructing land mines (ti lei). Then in the +15th century the Ming book *Wu Yüan* (Origins of Things) by Lo Chhi1 averaged that guns (cheung2) were first made by Lü Wang in the +11th century,3 and sticks of fire-crackers (pao chang) invented by Ma Chün in the Wei Kingdom (in the +3rd century). Lo Chhi also said that emperor Yang Ti of the Sui dynasty (in the +6th century) had used gunpowder for fireworks and miscellaneous amusements;14 while Liu An (Hui Nān Tzu), the naturalist-prince of the +2nd century, first prepared saltpetre (shen hui).15 These sayings were all reproduced and elaborated by Tung Sueh-Chang1 in his *Kiang Po Wu Yüan* (Enlargements of the ‘Records of the Investigation of Things’) of +1607.16 Feng Chi-Sheng rightly dismissed such claims as legendary, putting them in the same category as those of Europe which attributed the invention of gunpowder to Marcus Graecus, Albertus Magnus or Berthold Schwartz, if not Roger Bacon.17 He agreed with Hallam’s idea that gunpowder was discovered accidentally by several people rather than invented by any individual.18 As far as the legend that guns were introduced by Lü Wang, it was obviously self-service.

+ Amor Taimur (Tamerlane) died in +1405 at his capital, Samarkand, having conquered Kandahar, all Persia, Bagdad, Delhi and Cairo. He was the enemy of the Ottoman Turks under Bajazet, whom he defeated in +1402, and consequently friendly with the Byzantine emperors, especially Manuel Palaeologus. It was one of his descendants, Bahr, who founded the Mogul (Mongol) empire centred on Delhi. His extraordinary career stirred two English plays, one by Christopher Marlowe in +1596 and another by Nicholas Rowe in +1709.
+ We translated a long passage on the life of this remarkable engineer in Vol. 4, pt. 2, pp. 39 f. Bamboo crackers he perhaps could have known, but crackers containing gunpowder, no. Attempts have been made in recent times to substantiate Ma Chün’s connections with gunpowder, as by Wang Yü (3), but it cannot be done.
+ Pig. 52. Whatever firework was made by the Chinese before (cf. p. 196 below) they did not contain gunpowder, but a knowledge of saltpetre on the part of Liu An is impossible, as we shall see (p. 196 below).
+ Suppl. vol. I, p. 479.
contradictory, since in the next breath saltpetre was attributed to Liu An some eight centuries later. By +1780 there had come the first serious sinological discussion of the history of fire-weapons in China; it was in the 'Supplément' which de Videlou & Garland added to the famous Bibliothèque Orientale de Barthélémy d'Herbelot. They knew of the naval battle of Thang-tao island between the J/Chin and Sung fleets in +1519, and thought that the 'hoa phat' (huo phao) might have been cannon, especially firing red-hot shot, though they also recognized hao chien rightly as incendiary arrows. They acutely remarked on the failure of terminology to adapt, pointing out that tormentum in Latin was just like phao, the thing fundamentally changing (trebuchets to cannon) while the old name continued in use. They knew that there was nothing on gunpowder to be found in Thang sources, but they also knew of the novel fire-weapons (whatever they were) invented by Fêng Chi-Shêng4 in +670 (cf. p. 148 below), by Thang Fu5 in +1000 (p. 149 below), and by Shih Phu6 in +1002 (p. 149 below); realising that gunpowder was involved, but not being able to say whether as incendiary, propellant or explosive. It is clear to them, however, that the chên thien leí (heaven-shaking thunderer) used by the J/Chin army when defending Khaïfeng against the Mongols in +1292, was an explosive bomb or mine, though here also they did not feel they could exclude cannon.7 By this time they were getting very near the bone. They also knew about the hao huo chhiang7 (fire-sputting lances) invented and introduced in +1259 at Shou-chhun8 in Anhui,9 and being well aware that some kind of tube was involved, they believed that these might have been true cannon. Again, they were not far wrong, though today we would call them erupors or fire-lances with co-axiavite projectiles. Finally, they quoted from the Mêng Shîh4 the reply of an emperor in response to a courtier who said that firearms had led to cowardice: 'No, the use of firearms has always been

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30. THE GUNPOWDER EPIC

of one of the prerogatives that China has had over all other nations!' Such was the first serious sinological approach to the history of gunpowder weapons in China.

It was just about this time (+1774) that the witty but iconoclastic Cornelius de Pauw4 came into collision with the witty and much better informed Chinese Jesuit Aloysius Ko (Kao Lei-Ssu)10 who replied in +1777. Finding nothing about gunpowder in the San Tzu Ping Fa, and taking a poor view of the matchlock muskets still used in China, de Pauw wrote off all the Chinese gunpowder evidence, including the events of +1292 (p. 171 below), but the Jesuit knew a lot of +970, +1002 and many others as well, successfully defending the authenticity of Chinese historiography.

The nineteenth century saw a great intensification in the history of gunpowder weapons and artillery, but the pitfalls were many, and many historians fell into them. Thus Reinaud & Favé (2) in 1849 were convinced (quite rightly) from the descriptions that the 'heaven-shaking thunder' (chen thien leí), used from +1231 onwards, was some kind of explosive. Meyers (6) in 1870 thought, on the other hand, that gunpowder went to China either from India or Central Asia in the +5th or +6th century, but that the Chinese were the last to realise its full implications, and only during the first quarter of the +15th century did they make use of its propellant power. H. A. Giles fell into the misunderstanding that firearms were first used by the Chinese when the Ming general Chang Fu defeated the Annamese in +1407;6 while Gelli, conceding the invention of gunpowder to China, maintained that cannon were cast only under foreign influence. On the other hand, Greener (1) was prepared to credit China with a far too early knowledge of the properties of saltpetre, saying that 'the Chinese and Hindus contemporary with Moses are thought to have known even the more recondite properties of the compound'. Then at the beginning of this century (1902) Schlegel (12) well argued the case for the origin of gunpowder in China, but interpreted the term chên thien leí wrongly as referring to cannon. His conclusion that 'the Chinese ... knew and employed fire-arms, cannon and guns, as early as the 13th... century', turned out however to be quite justified.

There were fierce controversies too. Some of these arose over the nature of Greek Fire; others concerned the interpretation of the earliest evidence for guns and cannon in Europe.4 On gunpowder history in India, Oppert (1) was duly

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1 The legends could be pursued in collections such as the Yuan Shih Lin Kuang Chi and the Chihng Ko Chih Ch'ing Yuan, if anyone were sufficiently interested.
2 (1), Suppl. p. 117, "De l'invention des Canons en Chine".
3 This is described in the biographies of the two Sung commanders Li Pao (Sung Shih, ch. 370, p. 44; WHKT, ch. 358, pp. 191-2, 195-6) and Wei Shêng9 (Sung Shih, ch. 368, pp. 114,154). The former mentions only fire-arrows (hoa chien), but the latter speaks of hau shih phat, which must mean trebuchets casting incendiaries and stones. Hau phat at this battle are also mentioned in the biography of the J/Chin admiral, Chêng Ch'ing10 (Chih Shih, ch. 15, p. 164), who jumped into the sea and was drowned when all his fleet was set ablaze. Cf. Fêng Chia-Shêng (2), p. 59; Lu Mou-Tê (1), pp. 30-1; Wang Ling (1), pp. 156, 169. There may well have been gunpowder in these bombs, but at that time it would probably have been low-nitrate incendiary rather than high-nitrate explosive.
4 The description of these affairs is in Chih Shih, ch. 113, p. 196; cf. Fêng Chia-Shêng (2), p. 80; Lu Mou-Tê (1), p. 32.
5 Mod. Shou-hien.
7 They gave the reference as ch. 72, p. 51, but we have not been able to locate the passage.
8 Fêng Chia-Shêng (2), p. 72, "The legendary origin of the salute of fire and smoke at the Yucheng宴会", "Foxen, Cheng 1902 (1902) 702.
9 "The legendary origin of the salute of fire and smoke at the Yucheng宴会", "Foxen, Cheng 1902 (1902) 702.
12 In the previous year an anonymous article in Harper's Magazine (Anon. 196) had got it somewhat more right than this, though still accepting that gunpowder was known in the San Kuo and the Sui. We shall mention W. E. Meyers again on p. 172 below, in connection with his recognition of the fire-lance, a weapon which so many other scholars did not understand. Dr Clayton Breth tells us that Mayers' files and papers still exist, and are preserved along with other material from the old British Legation in Peking at the Public Record Office at Kew.
14 E.g. Lalamme (1, 2) and Quatremer (2) against Reinaud & Favé (1, 2, 3) in the forties of the last century; here the question largely was whether it had contained saltpetre or not.
15 E.g. Larboire (1); Bonaparte & Favé (1), also in the forties.
16 "The legendary origin of the salute of fire and smoke at the Yucheng宴会", "Foxen, Cheng 1902 (1902) 702.
17 Epigraphs of the San Tzu Ping Fa, and taking a poor view of the matchlock muskets still used in China, de Pauw wrote off all the Chinese gunpowder evidence, including the events of +1292 (p. 171 below), but the Jesuit knew a lot of +970, +1002 and many others as well, successfully defending the authenticity of Chinese historiography.
18 On the other hand, Greener (1) was prepared to credit China with a far too early knowledge of the properties of saltpetre, saying that 'the Chinese and Hindus contemporary with Moses are thought to have known even the more recondite properties of the compound'. Then at the beginning of this century (1902) Schlegel (12) well argued the case for the origin of gunpowder in China, but interpreted the term chên thien leí wrongly as referring to cannon. His conclusion that 'the Chinese ... knew and employed fire-arms, cannon and guns, as early as the 13th... century', turned out however to be quite justified.
19 On gunpowder history in India, Oppert (1) was duly
exploded by Hopkins (2). Then came in the German writers, remarkable military historians, but liable to get into trouble by claiming too much for Teutonic abilities. On the +15th century European fire-book writers, Berthelot (4–7) was better, and on the +14th-century bombardment Brackenbury (1) and Clephan (1–5) produced histories still useful today. In 1895 von Romacki (1) made a gallant effort to identify the origin of gunpowder weapons in Asia, with results satisfactory as far as they went, but he was impeded by little access to the original texts, and dependent on the work of the Jesuits and the earlier sinologists, not always reliable guides. Still, he did correctly interpret the thu hao chiang of +1299 as a gunpowder flame-thrower with what we should call co-axiative projectiles, though of course he knew nothing of the actual dated true Chinese hand-guns and cannon going back as far as +1290.

In the early years of the present century much uncertainty continued. For example, Gohle (1) believed that gunpowder originated in China, but that the Chinese did not arrive at making metal gun-barrels, nor did the Arabs, though he could not be quite sure what the mird of was. According to him, firearms appeared almost simultaneously in several European countries, and it was not possible to determine the place, nor the person who first invented them. Next Pelliot and Chavannes were able to prove that the Chinese thu phao of the +12th century was a kind of bomb and not a cannon. In 1915 there appeared a little-known monograph on the history of artillery by Colonel Henry Hime (2), who believed that in all probability gunpowder was not invented, but discovered accidentally, by (Roger) Bacon. At the same time he refused to accept the evidence brought forward by the +18th-century Jesuits on the origin of gunpowder, saying that the invention of gunpowder was probably carried from the West to China, by land or by sea, at the end of the +14th century or the beginning of the +15th and was falsely adopted as an old national discovery before the arrival of the Portuguese and the Jesuits in the +16th. This was quite courageous of Hime, seeing that he had no access whatever to any of the original Chinese sources. One might say that until the end of the Second World War the theory of a European origin of gunpowder continued to hold its ground. In 1925, for example, Rathgen could write about the exclusively European origin of Indian gunpowder weapons.

Forty years ago, however, decisive advances began to take place. One can see that the history of fire-weapons and gunpowder during the previous two centuries had been a welter of mistakes and misunderstandings, mistranslations, legendary traditions, allegations unsupported by sources, false attributions and cultural prejudices. In the fifties and sixties this log-jam came under fire from two battles of exceptionally heavy artillery, as it were: the writings of Feng Chia-Shêng (r–9) from 1947 onwards, and Partington (5) in 1960. Feng and Partington1 swept it all away, or rather amassed it in heaps and critically sifted it, rejecting the nonsense and formulating some reasonably sure conclusions. Of course, some of these are today not beyond criticism, and there was much which Feng and Partington never knew—indeed a great deal still remains to be found out. For instance, if only we knew the exact composition and physical character of the gunpowder in each of the many and various fire-weapons used in China from +900 onwards we would be much better off; as it is, we can only guess.

These heavy batteries were heralded and supported by lighter, but still extremely effective, field-guns. The new approach was pioneered by Wang Ling (1) and Goodrich & Feng Chia-Shêng (2). Abundant evidence from Chinese historical sources and the descriptions of gunpowder and firearms in the Chinese military compendia came to light. For example, Davis & Ware (1) studied some of the many firearms described in the Wu Pei Chi. All of them came to the conclusion that gunpowder originated in China, a conclusion that Partington cautiously accepted, elucidating the part played by the Arabs in the transmission of the knowledge of gunpowder to Europe. In Japan Arimo Seiho (1) produced an interesting book on the origin and diffusion of cannon, in which he expressed the same view regarding the origin of gunpowder in China and drew further evidence from actual surviving examples of old Chinese cannon. Such guns, dated +1332, +1351 and +1372 were also cited by Wang Jung (1) to testify to the existence of bronze cannon in +14th-century China. Indeed most of the best work since Partington’s book has appeared in Chinese and Japanese. In 1968 a Japanese explosives chemist, Nambo Heiho (1) wrote an important monograph on the development of fire-arms, gunpowder and firearms in East Asia, and their transmission to Europe, partly through the Arabs.

1 I had the honour of being personally acquainted with this inspiring scholar both in New York and in Peking; he was always most amiable in answering our many queries.
2 Partington had been an engineer officer and a staff member of the Ministry of Munitions in both world wars, so besides being like Berthelot outstanding both as a chemist and a historian of chemistry, he knew about blowing things up in actual practice. He was not, as I was, an ignorant and inexperienced Adviser to the Feng Kang Shu during the second world war. Thus in July 1946, Wang Ling and I enjoyed a conference with him of several days’ duration, in which [with his coming book in mind] we went over all the evidence about China and gunpowder which we then had, and learnt a great deal from him as to how the history of the subject should be written.
3 Two of Feng’s papers, (2) and (3), were devoted to critiques of earlier Western histories of fire-weapons and gunpowder.
4 Wang Ling (Wang Ching-Ning) was already engaged in this when I first met him in 1944 at the History Institute of Academia Sinica, at that time evacuated to Luching in Szechuan. He had, I think, been stimulated to take up the subject by that eminent scholar Fu Shu-Nien. Feng Chia-Shêng worked with Carrington Goodrich before returning permanently to China.

5 Similarly Davis & Chao Yen-Tsung made a great contribution to the history of gunpowder fireworks in China.

6 Partington’s book has been much appreciated by later writers, e.g. J. E. Smith (1).
7 One thinks of Chou Hsia-Hua (7), Liu Hsien-Chou (2), Wei Kuo-Chung (1) and Wei Chi-Hsien (7).
8 The English translation of this (8), however, contains many errors, and must be used with caution.
The progress of enlightenment can be traced in the comprehensive and synthetic study of Sarton (1). When he published his second volume in 1931 he thought that gunpowder had been found out in Western Europe or Syria towards the end of the +13th century; Chinese origins were not excluded, but unproven. The first guns did not come until the second half of the +14th. Sarton realised that the machines of the Hsiang-yang siege were trebuchets, but did not recognise them as counterweighted. When he finished his third volume in 1947 he knew about Walter de Milamete, and he was able to draw upon Wang Ling (1) and Goodrich & Feng (1), so he knew of the Chinese cannons of +1356 and +1377. Although he did not admit China’s priority in so many words, and was evidently loth to give up the legend of Black Berthold, his accounts clearly show that he moved a long way towards the standpoint which we now adopt.

It is interesting to read the following judicious comment from two Russian scholars, Vilinbakhov & Kolmovskaja (1) concerning Western writings.

Although much of this work made great contributions to the study of the history of gunpowder and firearms, it was characterised by very slight knowledge of Oriental sources, especially those in Chinese. The statement by Western scholars that gunpowder weapons were known in China only after they had been introduced thither by Europeans, does not correspond at all with what actually occurred. The fire-weapons of mediaeval China pursued an independent course of development, the logical culmination of which was the invention of metal-barrel weapons making use of the propellant force of gunpowder.

With this we entirely agree.

The conclusions to which we come in our gunpowder epic are generally similar to those arrived at by Feng Chia-Sheng, Partington, Wang Ling, Goodrich, Arima Seihõ, Nambô Heizô, and Okada Noboru. We have, however, incorporated a study of the Chinese military compendia on a scale that has not been attempted before; and the results of recent archaeological findings in China have also been included.

It now remains only to direct the reader’s attention to the most useful books on the nature and properties of gunpowder itself. Here our standby has been the work on the chemistry of powder and explosives by Tenney Davis (17), finalised in 1956. Since in modern times gunpowder has taken a back seat, as it were, to the nitrate and other organic compounds which give true molecular detonations with a supersonic rate of burning, the most interesting modern books, such as that of Urbanaski (1), which deal only with these, are not very useful in the present context. On the other hand, it may not be desirable to go back too far, though there are books of value dating from before the first world war. The two volumes of Marshall (1) in 1917, and the three of Faber (1) a couple of years later, we have found quite helpful, while those belonging to the second world war period, such as the very practical book of Reilly (1) which includes accounts of slow and quick match, and Weingart (1) on military pyrotechnics in general, may also be mentioned. This was the time when the historian of alchemy, John Read (3) gave an instructive popular exposition of the subject. As for civilian pyrotechny, we have used Brock (1, 2).

Lastly, in the following pages we shall be giving many accounts of battles in China in which gunpowder weapons were used between about +900 and +1600. It is therefore desirable to have at hand a comprehensive history of the campaigns of East Asian warfare so that one may gain some idea of the strategic background of these engagements. Fortunately we now have the valuable compilation of Chhien Thing-Yuan & Li Chen (1) in sixteen volumes, abundantly illustrated with maps and plans.

(3) Ancestry (I): Incendiary Warfare

In traditional Japan, fire, together with earthquakes, thunderbolts and paternal power, were regarded as the four most fearful things in life. The awe-inspiring and destructive force of fire led to the deployment of incendiaries in warfare among all ancient people; and incendiaries of various kinds were assuredly the predecessors of gunpowder. Assyrian bas-reliefs dating back to the -8th century depict torches, lighted tow, burning pitch and fire-pots thrown at the siege engines of troops attacking a city. In -480 the Persians used arrows tipped with burning tow to capture Athens, and the first recorded use of incendiary arrows by the Greeks was in -429 at the siege of Plataea during the Peloponnesian war.

Technologically speaking, the Greeks seem to have advanced more quickly than any other ancient people in the warlike employment of incendiary substances. In -424, according to Thucydides, the Boeotians besieging Delium made use of a long iron tube, moved on wheels and carrying a vessel containing

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a. For example Bockmann (1) in 1880; Kededy (1) in 1909.
b. Accounts of a somewhat similar kind can be found in the older literature, such as that of Hu Lin-I (1), but this is by far the most modern and complete.
c. A striking passage on the subject was written by Shibô Kôkan late in the +18th century, and translated by Waley (28), pp. 193-4.
e. Herodotus, Histories, vi. 52.
f. Thucydides, History, ii, 75.
g. Cf. Finó (1).
h. Cf. Kededy (1).

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burning charcoal, sulphur and pitch, behind which was a large bellows which blew the flame forwards. This recalls the bellows described in China by the 4th-century Mohist military writers which blew toxic or irritating smoke into the enemy’s sapping tunnels. In the early 2nd century Apollodorus described a similar apparatus using powdered charcoal and intended as a kind of fire-setting device against fortifications with stone walls. A description of a similar apparatus was given by Heron of Byzantium as late as the 1st century. About 390, Aeneas the Tactician gave the composition of fire ships as a mixture of pitch, sulphur, pine-shavings and incense or resin filled into pots for throwing on the wooden decks of enemy ships or at wooden fortifications. Hooks on the containers helped them to stick fast.

In those ancient ages the use of expendable animals also figured tactically from time to time. We have an example of this in a text of early Jewish history, dating from about 530. It concerns the wars with the Philistia. So Samson went and caught three hundred foxes, and setting them tail to tail, took torches and bound them to each pair of tails. And when he had lit the torches he loosed the foxes and let them go free, so that they entered into the standing corn of the Philistines, and burnt up both the shocks and the grain, and not only that but vineyards and olive groves too.

This is particularly interesting because, as will later be seen, expendable animals appear in all the medieval Chinese military compendia, continuing on as a means of delivery of gunpowder as incendiary and later as explosive. Indeed the winged rockets of China almost certainly derived their inspiration from the wings of birds made to carry incendiaries or explosive weapons.

Fire-arrows were naturally part of the equipment of Roman armies. They were mentioned by Vergil (70 to +19) and Livy (59 to +17). There were also the mailed or ‘little hammers’, a type of fire-arrow that could only be distinguished by sand but not water, mentioned by Ammianus Marcellinus about +590. The inflammable material attached to the arrow consisted of sulphur, resin, bitumen and tow soaked in oil, according to Vegetius, writing about the same date. After the invention of non-torsion catapults (arcuballista and gastrogripes) under Dionysius of Syracuse in -390, and of torsion catapults by Polydus of Thessaly under Philip II about fifty years later, this artillery was often employed, when need arose, to project pots containing incendiary material. Fire-ships and resinous torches had been used at the siege of Syracuse in -413; and the Phoenicians also used fire-ships to burn the works on the mole made by the Macedonians at the siege of Tyre in -332. After -323, the year of the death of Alexander the Great, the use of incendiary missiles became common practice among all troops of the Mediterranean cultures. In -304 fire-ships and resinous torches were again employed in the siege of Rhodes. Burning spears (ardentes hastae) hurled by catapult artillery were described by Tacitus (c. +60 to +120). And so it went on, down to the conclusion of the Gothic wars.

‘Automatic fire’ (pyrr automaton, ἀυτόματον) was also used in antiquity, but how much military value it had is doubtful, for it depended on the spontaneous inflammation of quicklime mixed with combustibles such as sulphur and petroleum when wetted. The heat evolved is enough to fight the incendiary mixture. The term itself was first used by Athenaeus of Neukratos about +200.

According to Vielmond’s edition of the Kestoi of Julius Africanus (c. +225), as interpreted by Parrot, it consisted of equal parts of native sulphur, rock salt, incense, thunderbolt stone or pyrites, all ground in a black mortar in the midday sun and mixed with equal parts of black sycamore resin and liquid Zakynthos asphalt to make a greasy paste. Some quicklime was then added and the mass stirred carefully at noon, the body being protected as the composition was liable to take fire quickly. It had to be kept in bronze boxes tightly covered until it was needed. It was to be smeared on the ‘engines’ (hopla, ópata) of the enemy and when the morning dew wetted it, all would be burnt. Automatic fire recipes also appear in the Liber Ignium and in De Mirabilibus Mundi, +13th-century works already discussed (p. 49 above). One may conclude that mixtures of quicklime with combustible materials, if stowed away secretly in unexpected places, might produce some mysterious conflagrations, but the technique can never have been of much use either on land or sea; in the latter case (provided means were used to prevent the material from sinking) the combustion would have been mild, quiet and harmless, apart from some element of surprise.

Fire-weapons were also used in the -1st millennium in India. The Mahabharata epic often mentions the use of inflammable materials such as resin or tow in

3 Thucydidcs, Histery, vii. 55. 4 Arrian, Exped. Alexander, u. 17. 5 Diodorus Siculus, ix. 86. 6 Historv, iv. 25. Parrot (5) calls these ‘fire-lances’, but in view of what is to come, the term would be very misleading here. 7 Ammianus Marcellinus (c. +590), xxii, iv. 14, 15. 8 Many have tried to repeat this but not everyone has been able to do it. Marshall (1), vol. i, pp. 79-93 could not make it work, but Parrot’s friend Richardson (2) fully succeeded. 9 Talking about the tricks of one Xenophon the Wonder-worker; a conjurer. 10 (3), p. 8. 11 In § 4, cals an extina, Parrot (5), p. 47. 12 Parrot (5), p. 85, text and translation. 13 Cf. Xenophon (1). We shall hear later on (p. 165) of a famous Chinese naval battle of +1161 at which quicklime was used in bombs of some kind, as also other examples of the same, but this seems to have been because of its irritant properties when dispersed in smoke rather than as an igniter of incendiary substances.
battles. There are many recipes for incendiary mixtures, toxic smokes and similar devices in the Arthaśāstra, including showers of firebrands, and fire-pots hurled from catapults of some kind. The troops of Alexander the Great encountered fire-weapons in India in 326. The Oxydracae, a people of the Punjab, were particularly renowned for this. When Apollonius asked why Alexander the Great had refrained from attacking them, he was told that these truly wise men dwell between the rivers of Ganges and Hyphasis. Their country Alexander never entered, deterred not by fear of the inhabitants but, as I suppose, by religious motives, for had he passed the Hyphasis he might doubtless have made himself master of all the country round—but their cities he never could have taken, though he had a thousand men as brave as Achilles, or three thousand like Ajax; for they come not out into the field to fight those who attack them, but rather these holy men, beloved of the gods, overthrow their enemies with tempest and thunderbolts shot from their walls. It is said that the Egyptians Hercules and Bacchus, when they invaded India, attacked this people also, and having prepared warlike engines attempted to conquer them; they in the meantime made no show of resistance, appearing perfectly quiet and secure, but upon the enemy's near approach they repulsed them with storms of lightning and flaming thunderbolts hurled upon their armour from above.

This was a remarkable description of incendiary warfare. The element of 'thundering', which occurs not only here in the words of Philostratus (d. +244), but in the many accounts of Crusade battles a thousand years later, has deceived many into supposing that true explosions or detonations of gunpowder were meant; but in fact the forced draught during the rapid aerial trajectory of large containers of combustibles is enough to produce the effect.

Much confusion also has been caused by Sanskrit terms such as agni astra, which undoubtedly meant 'fire-arrow' in the classics, but was later given the meaning of 'cannon'. The word satāgun t 'killer of hundreds', also appears in the Sanskrit classics, and led some scholars into believing that gunpowder was known and used in India before the end of the 1st millennium, a conclusion which cannot be sustained. Again, it has been said that the battle of Bīyanagar in 1368 the Hindus used 'arabah against the Muslims. The modern meaning of this word is certainly 'gun-carriage', but originally it meant simply a cart as such. Hime saw that the historian Firishtha (d. c.1611) fell into this trap by interpreting the passage to imply field-artillery unjustifiably, and other historians did the same.

In an abortive attack on the fortress of Rantambhor in 1290 the sultan Jalāl al-Dīn ordered maghribiīhā machines (i.e. trebuchets) to be erected, but later the besieged forces constructed their own. When the fort was successfully besieged in 1300 the Hindus inside collected fire in each bastion; and every day the fire of those infernal (machines) fell on the light of the Muslims. As there was no means of extinguishing it they filled bags with earth and prepared entrenchments... Later the royal army made vigorous attacks, rushing like salamanders through the flames that surrounded them...

During the siege of Bhetnāīr in 1398 the Hindus 'cast down arrows and stones, and (incendiary) fire-works' upon the heads of the assailants. The elephants in the army of the sultan Mahmud, which Timur defeated at Delhi in 1399, carried throwers of grenades (rād-āndāzān), fireworks (ātīt bāzī) and launchers of rockets (takh-āndāzān). By this time of course explosive gunpowder bombs would have been not only available, and rockets as well, but the second weapon mentioned looks like the old incendiary fire-pots.

In China fire as an arm of war has been recognised at least since the classical 4th century military handbook, the Sun Tzu Pīng Fa, where ch. 12 is entirely devoted to it. Apart from incendiary methods to set alight the enemy's weapons stores or provisions, the most interesting reference is to 'dropping fire' (chāi hau—'), a phrase which has caused a lot of trouble to commentators through the ages, but which is most plausibly interpreted, as since the Thang it has been, to mean fire-arrows shot into the enemy's camp. The use of fire in

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1 Hime (1), p. 8o. Partington (5), p. 216 shows that copyists and eighteenth-century translators of Firishtha were very unscrupulous in their use of words connected with guns and artillery.
2 I.e. machines of Western origin. The Maghrib included all the western regions of the Arabic culture-area in North Africa and Spain. But, as we saw above (Vol. 5 p. 96), the siege-principle embodied in the trebuchet and mangonel was much older in China than in Europe. That, however, the Muslims in India did not know.
4 Timur's autobiography, the Maqāmāt, in Eliot (1), vol. 5, p. 422; cf. Partington, loc. cit.
5 The same work, in Eliot (1), vol. 3, pp. 438 ff. (cf. Partington, loc. cit. 6 See the translation of Giles (11), pp. 150 ff. and Griffith (1), pp. 141 ff., as well as the transcription into modern Chinese done by Kuo Hua-Jo (1). A number of variant versions of the book and parallel texts have been found in recent years (see Anon. (270) pp. 86 ff). Most of them have something about attack by fire.
7 The texts all write 火 (division or battalion) but 炮 was assumed since the characters are often taken as interchangeable. Unfortunately the newly discovered Early Han text has a lacuna at this point, but WCTCC, ch. 11, pp. 194, 4 opts for the first form and makes correct. The character could also be 炮, which would suggest an underground mine passage, unlikely here.
8 Amiot, the eighteenth-century Jesuit, misled by tradition (cf. p. 59), attributed incendiary 'bombs' filled with weak gunpowder having the effect of Greek fire, to Master Sun (12), p. 146, Suppl. p. 337; cf. p. 16, fig. 37, explanation, p. 361. Here he was unquestionably wrong.
9 孫子兵法
10 陳火
11 陳火
12 陳火
battle is also mentioned in a Chhin and Han military handbook, the Liu Thao\(^4\) (Six Quivers), which has the semi-legendary Chiang Shang\(^2\) as its putative author.\(^5\) Two famous early battles deploying incendiaries are often retold in Chinese history. The first is the ingenious use of fire and expendable buffaloes by Thien Tan\(^6\) in -279 when he defended the last stronghold of Chi\(~i\) State and repelled the superior invading force from the State of Yan\(^7\). After winning this decisive battle Thien Tan recovered more than seventy Chi\(~i\) cities which had previously fallen into enemy hands.\(^8\) The other is the complete destruction of Tshao Tshao's\(^8\) Wei fleet by fire at the Battle of the Red Cliff in +208 by the forces of Shu\(^9\) and Wu under the combined command of Chuko Liang\(^1\) and Chou Yü.\(^9\) Fire-ships (Fig. 5) were indeed very important in Chinese naval engagements through the centuries, for example the Po-yang Lake battles of +1365 in which Chu Yuan-Chang and his admirals overcame all their adversaries.\(^10\) Incendiary arrows using burning tow are described in all the military handbooks, such as the Thang That Pat Yin Ching\(^9\) written by Li Chih-\u0101\~uan\(^10\) in +779,\(^11\) and the Sung Hu Chhien Ching\(^9\) of +1004 by Hs\~u Tung.\(^12\)

Incendiary weapons in the form of projectiles hurled towards the enemy lines, or let down from city-walls over besiegers, are described in the Wu Ching Tsang Yao of +1044. For example, it speaks of two of the second sort as follows:\(^13\)

On the right is a drawing of the 'swallow-tail incendiary' (lit. torch, yen wei chu\(')\).\(^14\) Straw is fastened together in a divided shape like the two parts of a swallow's tail, and soaked in oil and fat. After ignition it is let down on the enemy approaching the city walls so that it destroys their wooden structures (scantlets, etc.) by fire.

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\(^{a}\) Cf. WPC, ch. 3, p. 224. Alternatively, Li Wang.\(^12\)

\(^{b}\) A number of texts on incendiaries carried by expendable animals were collected in Pflimlmaier (98), p. 6.

\(^{c}\) WPC, ch. 29, pp. 78, 84; Giles (11), p. 91, translating a Sun Tzu commentary.

\(^{d}\) Amiot also ascribed the use of explosive land-mines to Khung-Ming\(^10\) (i.e. Chuko Liang), saying that he had set off earth-thunderer (s\textsuperscript{t}\textit{m\~u} ch\textit{h\~u}) about +200 (3). Suppl., pp. 321–2, 326. Indeed he was better at this than any other general of his time: 'On sait d'aill\eres, \~a ne pas en douter, que dans leur mani\~ere de combattre par le feu, ils employoient le salp\~etre, le soufre et le charbon, qu'ils meloient ensemble en certain proportion; d'o\u il resul\~te qu'ils savoient faire le poudre \~a tirer, bien des s\~edes avoient m\~eme qu\'on se doutat en Europe que cette invention exist\~oit.' Amiot was justly criticized by H\~ene (1), p. 90, for not appreciating the difference between an explosive and an incendiary. But on the main issue he was quite right, albeit for the wrong reasons. Cf. Parcotton (5), pp. 238–9, 251–2. Amiot reproduced many drawings in copperplate form of fire lances, bombards, mines, etc., from Chinese books that we know well and use in this Section (cf. pl. 15, figs. 67–71, pl. 16, figs. 72–80, pl. 29, fig. 176, this last the wheelbarrow rocket-launchers).

\(^{e}\) Cf. Wiggers (1), vol. 1, p. 827; WPC, ch. 26, pp. 213, 224.

\(^{f}\) See Dreyer (2).

\(^{g}\) E.g. ch. 33 (ch. 4), p. 28, ch. 38 (ch. 4), p. 83. The first of these accounts describes how arrows were first sent over having guards of oil attached which on breaking spread it about over the houses, towers and wooden structures of the enemy; then later volleys of burning arrows ignited it all. The second says that aeshottling shooting with a range of 300 paces should be used.

\(^{h}\) E.g. ch. 54 (ch. 6), p. 32, ch. 56 (ch. 6), p. 144.

\(^{i}\) WCTYICC, ch. 12, pp. 59a, 61a. For the yen wei chu and fen chu see also WPC, ch. 190, 234a, b, 244a,b.

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Fig. 5. Fire-ships, from WCTYICC, ch. 11, p. 28a.

The 'flying incendiary' (\textit{fei ch\~\~iu}) is shaped like the swallow-tail incendiary, and let down on an iron chain from a swape lever set up on the city wall. These will burn enemy troops even when attacking in great numbers.

The significance of the swallow-tail shape is not evident unless one realises that battering-rams and other offensive machines were brought up under cover of temporary wooden structures with wheels and ridged roofs; the incendiary device would rest astride these and set them on fire (Fig. 6). Another page describes a projectile.\(^8\)

\(^{*}\) WCTYICC, ch. 12, pp. 64a, 65a.

\(^{*}\) WPC, ch. 5, p. 254. Alternatively, Li Wang.\(^12\)
The 'igniter ball' (yin huo chien) is made of paper round like a ball, inside which is put in between three and five pounds of powdered bricks. Melt yellow wax and let it stand until clear, then add powdered charcoal and make it into a paste permeating the ball; bind it up with hempen string. When you want to find the range of anything, shoot off this fire-ball first, then other incendiary balls can follow.

Such a blazing projectile would certainly have set the enemy’s huts or trebuchets on fire, as well as giving an idea of the distance at which your own trebuchets would have to aim (Fig. 17). But in the Wu Ching Tsung Yau there are not so many of these specifications, since most of the incendiary projectiles by this time contained low-nitrate gunpowder, as we shall see in the appropriate place (p. 149 below).

(4) NAPTHA, GREEK FIRE AND PETROL FLAME-THROWERS

Among all the combustible substances which would be used in war, naturally occurring mineral oils came to take more and more importance. The knowledge of petroleum and its congeners goes back in all nations to high antiquity. Already we have discussed it in relation to China in more than one place, but we have to concentrate on its use in war. Seeppages of natural oil were made use of in both east and west for many purposes, varying according to its composition, whether heavy oil, sulphurous or waxy, or the lighter, lower boiling-point, fractions that got the name of naphtha.

A Greek physician at the Persian court, Ktesias of Cnidus, writing in the neighbourhood of -398, reported a story about an oil derived from a gigantic worm (scolex, arctiopf) living in the Indus River, an oil which was capable of setting everything on fire. The tale was repeated by Aelian (d. +140) and Philostratus (d. +244). The latter said that the white worm was found in the Hyphasis River in the Punjab, and that the oil made by melting it down could be kept only in glass vessels; when once set on fire it could not be extinguished by any ordinary means. Naturally occurring naphtha was most probably the basis of the legend.

Persian naphtha, which the Greeks called 'oil of Media', was well known in the time of Alexander the Great when he captured Babylon in -324. Pliny wrote about an 'inflammable mud' called meltha found at Samosata on the Euphrates. Petroleum was described at length by Vitruvius, and 'white naphtha' was prob-

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*Here the studies of Forbes (20, 21) are important guides.


c See McCrindle (4) and Parlington (5), pp. 209, 211.

1 De Nat. Animalium, v. 3.

2 Life of Apollonius of Tyane, ii. 1.

3 Here the view of Parlington, loc. cit., has general assent.

4 The word itself is of Iranian origin. The great oilfields of巴士 and Baku must have been the origin of the material and the stories.


6 De Architecuta, viii, 3.
ably petroleum purified by filtration through fuller's earth. These substances were all used as incendiaries in warfare, as for example against Maximinus when he captured the town of Aquileia.a They found employment more and more, as by Genseric, king of the Vandals, to destroy a Roman fleet in +468,\(^b\) and in +551 when Petra in Colchis was being defended by the Persians.\(^c\) By this time the composition was getting more complicated, sulphur, resins, bitumen and tow being mixed with the incendiary oil; as we know from the recipe that Vegetius gives\(^3\) for fire-arrows about +385.

From the beginning of the Arab conquests their armies acquired particular skill in the use of naphtha as a war-weapon. Special corps of *naffatin* in fireproof suits were formed to handle it. Already in +712 at the siege of Alor in India the Muslims used *disch baz\(\dagger\)*, or incendiary projectiles developed on the basis of what they had seen in use by the Byzantines and Persians. They threw *hussab\(\dagger\) baz\(\dagger\)*, probably naphtha pots,\(^e\) at the howdahs on the elephants, making them rush away in panic.\(^i\) In +904, at the siege of Salonika, they used earthenware grenades filled with pitch, oil, quicklime and other materials.\(^j\) When Jerusalem was attacked in +1099 the Saracens hurled flaming balls of pitch, wax, sulphur and tow against the machines of the Crusaders.\(^k\) When the Turks were besieged in turn in Nicara they took similar defensive action.\(^l\) At the siege of Assur, all in the same year, the Turks set ablaze a tower using iron stakes wrapped in tow soaked in oil, pitch, and other combustible substances, and it was said that the fire could not be extinguished with water.\(^l\) During the Second Crusade (+1147 to +1149) the Arabs again used naphtha. In +1168 Shawar employed 20,000 barrels of petroleum to burn down the city of Fustat (Cairo) to prevent its recapture by the Franks.\(^m\) At the time of the Third Crusade (+1190, +1191) during the siege of Acre, "boiled naphtha" and other incendiaries contained in copper pots (*narmite*) were thrown at the attack towers of the Christians, successfully destroying them by fire.\(^m\) Thundering tubs of incendiaries thrown from trebuchets were used in all the battles of the Seventh Crusade (+1249), when St Louis of France and the Sieur de Joinville were there to record it.\(^n\) Such was the character of incendiary warfare down to the very century when the knowledge of gunpowder was making its way to the Arab and European cultures.\(^a\)

Petroleum is called in Chinese *shih yu\(\dagger\)*, presumably as an abbreviation of the old term *shih nua yu\(\dagger\)* (mineral-brain oil).\(^b\) Natural oil seepages were already being used in China in late Chou times (\(-5^{th}\) century onwards). Thang M\(\dagger\)eng described one about +190 in the district of Yen-shou,\(^c\) calling it *shih chih\(\dagger\)* (stone lacquer), because it was dark to begin with and gradually got darker.\(^d\) A similar account was given in one of the commentaries on the *Hai Han Shu*, which says that south of Yen-shou among mountain rocks there oozes out a liquid looking like uncoagulated fat. When burnt it generates an intense brightness, but it cannot be consumed as food (or used for frying). The local people call it *mineral lacquer*.\(^d\)

Not long afterwards Chang H\(\dagger\)ua recorded an event of about +270 when stores of oil in an arsenal caught fire, suggesting that petroleum was included in China army supplies.\(^e\) In Thang times natural petroleum was still a wonder. T\(\dagger\)au Ch\(\dagger\)h\(\dagger\)ieng-Shih\(\dagger\) had an entry for it in his *Yi-Tong Tsu Tsu* finished about +600.\(^f\)

Mineral lacquer is found in Kao-nu *ch\(\dagger\)* (they call it) *rock-fat liquid* (*shih chih sh\(\dagger\)*). It floats on the surface of the water like lacquer (i.e. dark in colour). People use it for greasing their cart axles, and when burnt in lamps it gives a bright flame.

Petroleum was produced at many places in China. Li Shih-Chen wrote:\(^g\)

Mineral oil (*shih yu\(\dagger\)*) is not found only in one location. In Shensi province it comes from Su-chou, Fu-chou, Yen-chou and Yen-chang,\(^h\) while many places in Yunnan and Burma produce it, as well as Nan-hsiung\(^i\) in Kwangsi. It flows out from the rocks and mixes with the spring water, gushing and gurgling. It is oily like the juices of cooked meat. The local inhabitants sop it up with straw and put it in earthenware pots. It is black in colour, rather resembling fine lacquer, and has an odour of realgar and sulphur. Many local inhabitants use it for burning in lamps, which shine brightly. When water is added, the flame only becomes more intense. This oil is inedible, but it gives a thick smoke. When Shen Tzun-Chung\(^j\) (i.e. Shen Kua) was an official in the west he...
collected the soot to make ink with; the product was black and lustrous like lacquer, and superior to that made from pinewood-lamp black.

Petroleum was discovered in different parts of China at different times in history. Li Shih-Chen quotes an example from the sixteenth century when oil was found in Chia-chou (in modern Szechuan). He says:

"During the last year of the Chêng-Tê reign-period of the present (Ming) dynasty (i.e. 1521) oil was accidentally found during the process of digging salt-wells. When used for illumination at night it gave twice the brightness (of ordinary lamps). When water was sprinkled over it the flame became more intense than before, and it could only be extinguished by stilling it with ashes. It gave off an odour of realgar and sulphur, so that the locals called it hsiung-huang yu and also liu-huang yu. Several more wells have recently been opened and they are all managed by the government. This is also shih yu (petroleum) only it comes from wells.

Chinese scholars also noted the occurrence of petroleum in other countries. For example, quoting from a late Buddhist tractate, the Chhiu Shêng Khu Hai, Chao Hsieh-Min says:

Burma (Mien-Tien) also produces shih yu, which is the same as shih niao yu. It flows out from crevices in the rocks, and has an unbarreable pungent smell. It is black in colour. It can be used to apply to sores, and is good for treating boils.

This was not surprising, in view of the great oilfields worked in Burma in modern times. And many other similar statements could be quoted.

There can be little doubt that naturally occurring petroleum obtained from seepages or wells was used in China through the centuries for military incendiary purposes. But a different chapter opens when the phrase meng huo yu (fierce fire oil) makes its appearance, for while native petroleum, shih yu, had been known for so long, the new appellation is found only from the beginning of the sixteenth century onwards. We think that wherever it occurs it means preparations like Greek Fire.

What then was the difference between natural mineral oil, petroleum, as such, and the artificial inflammable gasoline that was called Greek Fire? The answer can today be given in a few words, because Partington demonstrated (in so far as it is ever possible to prove anything in the history of chemistry) that Greek Fire was essentially petroleum distilled. This liquid rectified petroleum would have been unlike the volatile petrol which everyone is familiar with today, and consisted of the low boiling-point fractions containing relatively short-chain hydrocarbons which come over when petroleum is distilled. Undoubtedly many of the later accounts of naphtha 'grenades' had to do with its use in such breakable bottles. But we know that the Byzantines (who first invented it) used it in 'siphons' (σηφών), i.e. projector-pumps or flame-throwers. As Partington reflected, petrol alone would float, still fiercely burning, around enemy hulls, but it would dissipate rather quickly, and carry only a short distance; for these reasons (as the texts show) it was thickened with resinous substances dissolved in it, and perhaps sulphur also.

The significance of the distillation of petroleum in the Greek world is very considerable. At an earlier stage we described the four classical still types (the Chinese, Mongolian, Gandhāran and Hellenistic), and we know now that all of them were about equally effective from the physico-chemical point of view. The distillation of oils is not at all prominent in the Alexandrian-Byzantine Corpus Alchemiae Graecorum, perhaps not even detectable, but there was no reason whatever why some daring experimenter should not have tried it by the middle of the seventh century. Indeed, like gunpowder itself, it was almost bound to come.

Greek Fire is one of those inventions which can be dated rather exactly. Theophanes, who finished his Chronographia in +815, described how the Arabs continually attacked Byzantium from +671 to +678. But they finally gave up, a major factor in their defeat being the chemical process introduced a few years earlier by an architect-engineer named Callinicus who came from Heliopolis.

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1 This was the word that had been used for the double-acting force-pump for liquids invented by Ctesibius in the +2nd century and improved by Hero of Alexandria. Cf. Vol. 4, p. 114, 115, as also Vitruvius, De Archit. x, vii, and Neuburger (1), p. 299, Usher (1), 1st ed., p. 86, 2nd ed., p. 135. We generally call siphons as understood today examples of the 'true siphon'.

2 Hence the name 'sea-fire' (thalassia per, paladin et nis) in Théophraste.

3 Closely similar reasoning led in contemporary times to the invention of 'napalm' (the word deriving from naphthenates + palmate). This is essentially petrol or gasoline thickened to a jellylike consistency by the incorporation of a mixture of aluminium soaps. Its extremely controversial use in incendiary anti-personnel bombs need not be enlarged upon here.

4 One of the greatest controversies of controversy has been whether or not Greek Fire contained saltpetre, as many, e.g. Lalanne (1, 2), Reinard & Faye (1), Berthelot (9), (10), (9), (12), (14), Mercier (1), Oman (1), p. 546; Brock (1), pp. 233-23; Forbes (22), have thought that it did. But the history of saltpetre makes this quite impossible. Von Romorck (1), vol. 1, p. 7, stood out against the idea even when it was most prevalent—but unfortunately he himself fell for quicklime.

5 See Vol. 4, p. 4, p. 80 f.

6 Butler & Neddham (1).

7 Berthelot & Ruelle (1).

8 On the distillation of essential oils, turpentine, pitch, etc. in Roman times, see Partington (5), pp. 30-1.

9 Among further sources of information on Greek Fire (unenlightened by Partington's insight) we may mention Oman (1), vol. 4, p. 46 f; Forbes (21), pp. 36 f, (40), pp. 46 f, (89) f, (unpublished on China); Dols (1), pp. 108 f; von Lippmann (22), pp. 131-2; Hine (1), pp. 37 f. In 1904 Hine (2) had been an adherent of quicklime, but abandoned it in favour of calcium phosphate, an even more inapplicable idea.

10 The exact date is not clear, but it would have been in the neighbourhood of +675. Also it seems that the invention was perfected by Callinicus after his arrival in Byzantium.

11 Whether that in Syria or in Egypt is uncertain. But in either case he would have been well in the Hellenistic proto-chemical tradition, described in Vol. 5, pt. 2 and 4.
The defending ships of the Romans (as the Byzantine Greeks spoke of themselves) were now all 'siphon-bearing' (σφήνωσθα τοίς σιφονωσθοι) and they systematically set the enemy craft on fire, as well as burning those aboard them. Further information on these petrol-throwing devices comes from many sources, for example The Tacita of the Emperor Leo, written in the 8th or 9th century. He tells us of the iron shields protecting the men working the bronze flame-thrower pumps, and of the rumbling thunderous noise made by the blazing jets, a notice which indicates that the apparatus must sometimes have been of considerable size, though others were hand-held. One account says that the pumps were worked by compressed air, which could mean that the petrol was forced out of the tanks by some sort of piston-bellows. Another implies that flexible pipes formed part of the apparatus. It could be directed to left or right at the will of the operator, or even at a howitzer trajectory to descend on enemy ships from above. The mouths of the tubes were often given the shapes of animal heads.

A graphic account of the use of Greek Fire in a sea-fight between the Byzantines and the Persians in 910, based on Anna Comnena's book, is given by Oman in his second volume, and it is worth reproducing here because it gives us some idea of what the Chinese flame-throwers themselves might have been like in practice. By her time these had been standard army equipment in China for a couple of centuries.

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4 This leads one to propose a question whether all the medieval tales of fire-breathing dragons may not derive from the Byzantine petrol-thrower. For example, the Anglo-Saxon epic poem Beowulf has a rather graphic description of flame as a weapon during the last combat of this Swinburne hero with a fire-breathing dragon or 'wild worm'; cf. Morris & Wyatt tr., pp. 172 ff., esp. p. 132; Ebbutt (1). Although the oldest MS. of the poem is of the late 11th or early 12th century, and the historical characters referred to belonging to the 5th or 6th, the composition itself must be of the early 9th, cf. Klerke (1), p. 305. As is well known, the Scandinavians were long in close touch with Michaelis (Byzantium), and would at least have heard of Greek Fire 'siphons'.

It is true that the ancient Greek gun-master Typhonos, who fought against Zeus, was said to send forth fire from eyes and mouth (Hom. H. 2, 545; Hesiod, Thg. 336, Ren, Finder, Fed. 4, 13. Acharn. Ps. 355). But Rother's Livius takes him to have been a personification of volcanic flame. Significantly, he was a son of Gaia and Tartarus. A man named Callinicus may have been responsible for a considerable amplification of the fire-breathing dragon motif. Thanks are due to Prof. Charles Brink for discussing this question with us.

5 Depending on his identification, whether Leo III the Baurian (r. 775 to 791) or Leo VI the Armenian (r. 886 to 911).

6 Cf. p. 68 above. It does not imply detonation.

7 Tacita, xix, 6, 51-7.


9 Leo says this, as does Anna Comnena (b. 1048), daughter of Alexius I Komnenos, in her biography of her father (Alexii, x, 10). Cf. Rose (1).

10 Recently a tapered bronze pipe, possibly part of a 'siphon' pump, has been found in the underwater excavation of a 7th-century Byzantine ship, the 'globe' wreck, west of Bodrum and north of Cos. See Frost (1), pp. 196-7, 173.

11 Apart from the military 'flameweeders' usual mines in the Germanic world, and by the Americans in the second world war, the chief line of descent of the device is the humble blowtorch or blow-lamp, which emits the flames of methyl alcohol under pumped air-pressure, for burning off paint and suchlike uses.


13 Perhaps they were, but the writings have not come down to us. Cf. pp. 41 ff. above.

14 Laptrand, Historia epiqae Legatio ad Nigeram Phanum, v. 6, cf. von Roscoek (1), vol. 1, p. 15.
leum fractions, and by then it was passing over to the Arabs too. Or rather, it was getting widely known there, for already by about +900 there had been directions for the distillation of naf in al-Razi’s work Kitâb Sirr al-Asrâr (Book of the Secret of Secrets). But by +1200 references are numerous, for example in the writings of the pharmacist Ibn Muhammad al-Shaizari al-Nabarawi (d. +1193), again in the work of the agriculturist Ibn al-Awâmî about +1230, then twenty years or so later in the mineralogy of Zakariya ibn Mahmûd al-Qazwini, and the pharmacy of Ibn al-Baitâh, finally in the cosmography of Shams al-Dîn al-Dimashqi (d. +1327). This looks as if it was kept rather dark in the +10th and +11th centuries before becoming widely known in the +13th, just as it was about to be replaced by the perhaps more dependable and controllable weapon of gunpowder, first incendiary, then explosive, finally propellant.

When Richard I of England was sailing from Cyprus to Acre in +1191, he captured a Saracen transport ship laden with not only the same kinds of armaments, including an abundance of Greek Fire petrol in bottles, which a witness had seen put aboard at Beirut. Later the historian ‘Abd al-Latif al-Baghdádi described a great parade held in Baghdad in +1228 on the occasion of the reception of a Mongolian ambassador; there were ’soldiers with glass flasks of nafî, who filled the whole plain with fire’. The nafâsîn troops certainly had now something else in their armours than ordinary unprocessed mineral oil, and thence the line ran straight and quick not only to the Liber Ignium (p. 39 above) but also to the book of Hasan al-Rammâh (p. 41 above), towards the end of the +13th century.

If we are right in our identification of mêng huo yu, Greek Fire came into China by about +900, just the time when various Byzantine emperors were writing about it in their military treatises (p. 78). How it came we shall consider presently. So far as we know, the very first mention of the ‘fiery fire oil’ occurs in connection with a gift from a southern Chinese State to a prince of the Chhi-tan Liao Tartars up in the north; and the date was +917. In his Shih Kuo Chhun Chhiss (Spring and Autumn Annals of the Ten Independent States between Thang and Sung), Wu Jen-Chhen says:

In that year the king of Wu-Yêî sent an envoy with fierce fire oil to the Chhi-tan. He said that when they attacked cities they should use this oil to start fires, which would burn the buildings and the watch-towers. If the enemy poured water on it, it would burn all the more fiercely. The ruler of the Chhi-tan was delighted.

The fullest version of this occurs, naturally, in the Liao Shihi (History of the Liao Dynasty), but it is preferable to translate the somewhat less diffuse text edited for a later historical work. In this we read a rather amusing story:

The ruler of Wu State (Li Pien) sent to A-Pao-Chi, ruler of the Chhi-tan (Liao), a quantity of furious fiery oil (mêng huo yu) which on being set alight and coming in contact with water blazed all the more fiercely. It could be used in attacking cities. Thoi Tsu (A-Pao-Chi) was delighted, and at once got ready a cavalry force thirty thousand strong with the intention of attacking Yu-chou. But his queen, Shu-Li laughed and said: ‘Whoever heard of attacking a country with oil? Would it not be better to take three thousand horse and lie in wait on the borders, laying waste the country, so that the city will be starved out? By that means they will be brought to straits infallibly, even though it takes a few years. So why all this haste? Take care lest you be worsted, so that the Chinese mock at us, and our own people fall away.’ Therefore he went no further in his design.

Here we can see how the nomadic traditions of cavalry strategy found it hard to absorb the new-fangled siege weapon.

So far nothing has been said about any siphon-like projector-pump. But sure enough it appears only a few years later, in fact in +919. The Wu Yuâi Pei Shihi (Materials for the History of the Wu-Yêî State in the Five Dynasties Period), written by Lin Yu, only a few decades later, gives us an extremely interesting passage. The Wên-Mu King (Wên-Mu Wang) was in command at an important naval battle when with more than five hundred dragon-like battleships he attacked the men of Huâi at a place called Lang-shan Chiang (Wolf Mountain River). This was Chhi-hien Yuan-Kuan, the seventh son and later (+932) the successor of the Wu-Su king (Wu-Su Wang), Chhi-hien Chhiu. They won a great victory over the other side’s forces ‘because fire oil (huo yu)’ was used to

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* Yet as late as the early nineteenth century in England there was great uncertainty about the effects of heating and distilling on all kinds of oils, animal and vegetable no less than mineral. This clearly appears from a legal case analysed in fascinating detail by Fullmer (1).

The ‘cracking’ of the long hydrocarbon-chain oils of petroleum into shorter molecules is of course something else again. It was a characteristic discovery or invention of the modern petrochemical industry, not put into practice industrially until about 1913 (Sherwood Taylor (4), pp. 270–1, 420). It involves high temperatures and high pressures, as well as the use of metallic catalysts, a field pioneered by Russian chemists such as V. N. Ipatiev (1867 to 1925).


* Ruska (14), p. 221.

* Wiedemann (20); Wiedemann & Grohmann (1).

* Wiedemann (25); Leclerc (1).

* Mehren (1). All these references were assembled by Forbes (20).


* Vos Somogyi (11), p. 119.

* Ch. 2, p. 16a. The passage was quoted by Feng Chia-Sheng (2), p. 17. Tr. auth.

1. 猛火油
2. 十面春秋
3. 吴任贤
4. 壬戌史
5. 李异
6. 吴越备考
7. 阿支德
8. 阴州
9. 瑞藤
10. 夏州
11. 汴州
12. 青藤
13. 武观王
14. 藤长
15. 火油
16. 蒙古
17. 真金
18. 宋史
19. 貞元
20. 青州
21. 蜀州
22. 韩州
burn them up'. Then the author's commentary goes on: 2

What is 'fire oil'? It comes from Arabia (Ta-Shih Kuo1) in the southern seas. It is spouted forth from iron tubes, and when meeting with water or wet things it gives forth flame and smoke even more abundantly. Wu-Su Wang used to decorate the mouths of the tubes with silver, so that if (the tank and tube) fell into the hands of the enemy, they would scrape off the silver and reject the rest of the apparatus. So the fire oil itself would not get into their hands (and could be recovered later).

And the text goes on to say that in this battle more than seven thousand men were captured and over four hundred naval ships destroyed in the conflagration.

The reason why this passage is of such signal importance is that it probably implies the first use of gunpowder in warfare in China. For just over a century later we come upon the only surviving description of a Greek Fire flame-thrower pump, in the Wu Ching Tsung Yao of +1044, and there gunpowder (hau yao2) makes its first appearance on the stage, used as a slow match to ignite the petrol when pumped forth. This description of the flame-thrower, which constituted a double-acting double-piston single-cylinder force-pump for a liquid, has already been given earlier, in Section 29, 3 but the translation of the passage in Tseng Kung-Liang's text is so essential for our argument that we must repeat it here (Fig. 7). 4

On the right is the petrol flame-thrower (lit. fierce fire oil shooter, fang ming hao yao pi5). The tank is made of brass (sha theung7), 6 and supported on four legs. From its upper surface arise four (vertical) tubes attached to a horizontal cylinder (sha theung') above; they are all connected with the tank. The head and the tail of the cylinder are large, (the middle) is of narrow (diameter). In the tail end there is a small opening as big as a millet grain. 7

The head end has (two) round openings 3¾ in. in diameter. At the side of the tank there is a hole with a (little) tube which is used for filling, and this is fitted with a cover. Inside the cylinder there is a (piston-) rod packed with silk floss (tsa suu theung8), the head of which is wound round with hemp waste about 3 in. thick. Before and behind, the two communicating tubes are (alternately) occluded (lit. controlled, sha'), and (the mechanism) thus determined. The tail has a horizontal handle (the pump handle), in front of which there is a round cover. When (the handle) is pushed in (the pistons) close the mouths of the tubes (in turn). 8

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1 Ch. 2, p. 46, b, tr. auct., adjug. Wang Ling (1), p. 167. An abbreviated quotation was given by Feng Chi-Sheng (2), p. 17.
2 Vol. 4, pt. 2, p. 145. We refrain, however, from repeating the explanations of the mechanism of the pump, for which the reader is referred to pp. 147 ff. there.
3 Ch. 10, pp. 60a. 61b. tr. auct. This flame-thrower was, I think, first introduced to Western scholars in the paper of Wang Ling (1), pp. 166 f. I like to remember that the text describing it was copied out for me more than forty years ago by a great scholar, the late Dr Pu Sau-Nien, long before I possessed a copy.
4 This interpretation is fixed by T.K.W., ch. 8, p. 4a, ch. 14, p. 7a, etc., and other later Ming sources; cf. Chang Hung-Ch'ao (3), p. 22. The practical use of brass at this date may be noted.
5 If this is not the hole in the back wall through which the pump-rod passed (and for this purpose it seems rather too small), we cannot explain it.
6 Reading shwa for shwa. 7 Like slide-valves.
8 大火枪 (da hao jang) is a broad-bronze tube with a slide-valve, and can be used for several shots, whereas the gun mentioned above is short and can be used only once. It is called '金锁' (jin su).
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Whereupon the oil (the petrol) comes out through the ignition-chamber and is shot forth as blazing flame.

When filling, use the bowl, the spoon and the filter; for igniting there is the brand-iron; for maintaining (or renewing) the fire there is the container (tuan)\(^1\). The brand-iron is made sharp like an awl so that it may be used to unblock the tubes if they get stopped up. There are tongs with which to pick up the glowing fire, and there is a soldering-iron for stopping-up leaks.

[Comm. If the tank or the tubes get cracked and leak they may be mended by using green wax. Altogether there are 12 items of equipment, all of brass except the tongs, the brand-iron and the soldering-iron.]

Another method is to fix a brass gourd-shaped container inside a large tube: below it has two feet, and inside there are two small feet communicating with them.

[Comm. all made of brass, and there is also the piston (tiao su chang)\(^2\). The method of shooting is as described above.

If the enemy comes to attack a city, these weapons are placed on the great ramparts, or else in outworks, so that large numbers of assailants cannot get through.

And he goes on to say that in the defence of cities rolls of blazing straw should first be thrown down from the walls on to the assault bridges. The burning petrol does immense damage to enemy personnel, and water will not put it out. In naval fights it will burn and destroy floating bridges as well as wooden battleships. Also if directed upwards, matting fragments and chaff and any dry vegetable matter should be thrown up first into enemy towns or camps; this will quickly catch fire and give rise to conflagrations.

As we pointed out before, piston-pumps for liquids were not a characteristic constituent of Chinese engineering traditions, though the piston syringe was known and used in Han times, and bamboo had always been available for cylinders. Moreover the double-acting piston-bellows goes back as far as the 4th century in China. One might for a moment, therefore, be tempted to think that this flame-thrower pump was a direct technical loan from Byzantium through the Arabs. But its design was too original, and if the 'siphon' pump gave forth a continuous jet, as most probably it did, that was assuredly accomplished rather by a combination of two cylinders in a Ctesibian force-pump system of true Graeco-Roman style. Even more original was the presence of a gunpowder slow-match in the ignition chamber of the petrol flame-pump, identified all but infallibly by the term huo yao. Coarse twine impregnated with saltpetre and slowly burning will of course also do, and it touched off many a round during the first three hundred years of gunpowder weapons in the West, but very low-nitrate

gunpowder would work in the same way, and that presumably is what we are dealing with here. And if this may be considered established for +1044 there is good reason to suppose that gunpowder slow-match was also used in the projector-pump of +919. After all, the earliest evidence of the composition goes back to about +850 (p. 112), so the historical sequence is quite reasonable.

There is one passage referring to events earlier than +919 which may be significant for the first use of gunpowder in war, but it is somewhat ambiguous. In his Chiun Chao Chi\(^1\) (Historical Memoir on the Nine States, in the Wu Tai period) Lu Chen\(^2\) about +1064 wrote a series of biographies of the notable men who had served those warring principalities. Chêng Fan\(^1\) was a general of Wu, and Lu Chen relates that:

at the beginning of the Thien-Yu reign-period (+904) ... in the course of the attack on Yu-chang (mod. Nan-chang) Chêng Fan's men let off flying fire machines (fu chi fei huo)\(^3\), which burnt the Lung-Sha Gate; then leading a troop of brave soldiers he entered the city, but was himself badly burnt by the flames. For this he afterwards received promotion.\(^4\)

The difficulty here is to interpret the description. The phrase 'flying fire', which must have come naturally to the pens of chroniclers, is as troublesome here as anything that Joinville had to say about Crusader battles. Hsü Tung\(^\ast\), who started writing his military treatise Hu Chhien Ching\(^6\) (Tiger Seal Manual) in +977 and finished it by +1004\(^b\) has a brief note on fei huo\(^5\) in which he says that 'flying fire is the nature of the treasure called 'bombs' (huo phao) and incendiary arrows (huo chien).\(^6\). This has led several writers to suppose that what Chêng Fan used were incendiary projectiles fired from arcuballisteis or trebuchets, and these could of course by this date have contained gunpowder, even if probably low in saltpetre.\(^6\) But the possibility also seems open that what he and his men employed were Greek Fire (distilled petroleum) flame-throwers,\(^7\) and if the Wu-Yüeh people in +919 were using the gunpowder slow-match in the ignition chambers of their pumps, then Chêng Fan might well have done so too. But the incident remains ambiguous, though gunpowder in one form or another was probably involved.\(^8\)

That the flame-thrower was fully in use in the first years of the +11th century appears from a story in which certain officials were laughed at for being more expert with it than with their writing-brushes. The Chhing Hsiang Tsa Chi\(^\ast\) mentions two Sung officials Chang Tshun\(^\ast\) and Jen Peng\(^\ast\) who gained promotion

\(^1\) This must have been a jar in which glowing charcoal was kept, or else perhaps the glowing composition.
\(^2\) It is seen at the top of Fig. 8, taken from the San Tshao Tsa Hui encyclopedia (+1606). That details about the Greek Fire petrol flame-pump were still being given as late as this is remarkable in itself.
\(^3\) This must describe some other design for a double-acting force-pump, but the account is too brief to allow of any visualisation or reconstruction.

\(^1\) Ch. 9, p. 134 (p. 29), tr. auct.
\(^2\) It seems to have been based on drafts by earlier writers going back to +991 (Feng Chi-Sheng (1), p. 46).
\(^3\) Ch. 6 (ch. 31), p. 44 (p. 44), tr. auct.
\(^4\) Ch. 6 (ch. 31), p. 44 (p. 44), tr. auct.
\(^5\) Feng Chi-Sheng (1), loc. cit.; Tshao Yuan-Yu (4), p. 156.
\(^6\) Though the date is rather early for Chinese-distilled petrol (cf. p. 76 above).
\(^7\) We shall return to the incident, p. 148 below.

\(^1\) 丘敏之
\(^2\) 徐耀
\(^3\) 黄遵
\(^4\) 登飛行火
\(^5\) 勤州之火
\(^6\) 青塘之火
because of their expertise in using weapons such as the flame-thrower. Wu Chhu-Hou1 says:2

In the Ching-Tè reign-period (+1004 to +1007) all the Ho-shuo scholars with Chü-jen (degrees) obtained official positions because of their services in defending cities. After Fan Chao3 became the Optimus Scholar (Chuang-yuan)4 in the State examinations (his friends) Chang Tshun and Jen Ping both received promotion though they had very much neglected their studies. Whereupon a certain (writer who styled himself) Anonymous-Master (Wu Ming Tsu5) composed an irontic poem about them, which included the lines: 'Chang Tshun knows only how to shoot with the whirlwind trebuchet (hsuan feng phan),6 and all that Jen Ping can do is to set off the fierce fire oil-flame-thrower (meng huo yu).7' But afterwards (Chang) Tsun rose as high as Secretary of State (Shang-shu)7 and (Jen) Ping became Inspector of Military Colonies and eventually Governor of Yauchou, in which office he died.

From this it is clear that the petrol-flame-throwers were very familiar military equipment about +1000, even though the technicians who used them tended to be despised by the Confucian scholars.

At this point let us think about the route by which Greek Fire (distilled petrol) came into China, and how long it was before it became indigenous there. The impression grows that South-east Asia was the way-station, and that the fierce fire oil travelled along with Arabic merchants by the sea route. From an important passage in the Wu Tai Shih Chi8 (Hsin Wu Tai Shih9) we learn of a presentation of it by the King of Champa in +958 to the imperial court of the Later Chou dynasty (+951 to +960) which had its capital at Khai-feng in the north. The text reads:10

Champa (Chan-Chhêng)11 lies by the south-eastern sea... In the 5th year of the Hsien-Tè reign-period the king of that country, Yin Tê-Man11 (Sri Indravarman III) sent an envoy named Pho-Ho-San12 (Abu'l Hassan) with a tribute gift of 84 bottles of fierce fire oil (mêng huo yu) and 15 bottles of rose-water. The letter of presentation was written on large palm (lami) leaves, and enclosed in a box of fragrant wood. (It was said that) the

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fierce fire oil could be used for sprinkling over things,12 and when in contact with water it would burst into flame. The rose-water was said to come from the western regions, and if it was sprinkled over clothes the perfume would still remain even when they became old and worn-out.

Thus here again the petrol came up from the south.

One can follow this association of Greek Fire petrol, or 'naphtha' fighting, with south-east Asia all through the centuries. During the last few years of the +13th century, Chou Mi13 was writing his Kuei Hsin Tsâ Chih14 (Miscellaneous Information from Kuei-Hsin Street, in Hangchow) with its various parts and supplements. This contained a graphic passage on sea-fights in the south seas, but as it has dropped out from nearly all of the editions of this work we quote it from the Yu Chih Thang Than Wei15 (Thicketts of Talk from the Jade-Mushroom Hall), a Ming collection or anthology gathered together by Hsi Ying-Chhü16. The text runs:17

Most of the countries of the south seas have what is called 'mud oil' (mu yu). Nowadays their people who sail in shallow-draught vessels (chhien fang chhaun) are all keen at it, and when they encounter another ship they fight with it, if they think they are the stronger of the two. This is called ping chhuaan,18 a 'ship-collision.' When this happens, four men hoist up the mud-oil into the crow's-nest. Little bottles are filled with it, and a roll of betel-nut husk (jin-tung phii)19 is used as a stopper. When this is lit it acts like a fuse. Then the bottles are thrown down on to the enemy's deck, and when the mud-oil (bottles) hit the deck of the other ship (they break) and burst into flames which spread everywhere and continue to burn. If water is thrown on it, it blazes all the more fiercely, and nothing but dried earth and stove ashes will put it out.

Nowadays our official naval ships do not like to approach these shallow-draught barbarian vessels, because of this fearsome weapon.

This would have been written in the neighbourhood of +1298. The expression 'mud oil' for distilled petroleum is at first sight somewhat mysterious, but there are several possible explanations. The most obvious one would refer back to the appearance of petroleum at the natural seepages themselves, but another suggestion would see in the term a reference to the thick oil or sludge remaining in the retort after the distillation of the low boiling-point fractions. There must have been some tradition here other than that which gave rise to the commoner term 'fierce fire oil' (mêng huo yu). At any rate the description shows that people were talking about the same thing. What is to be noticed here, however, is that there is no flame-thrower or projector pump, just the throwing of naphtha...
grenades, as among the Arab troops in the contemporary time of Hasan al-Rammah.

Just about the same time that Hsü Ying-Chhiu was assembling his collection, the navigator and geographer Chang Hsien¹ was writing about the mēng hua yu still in use for sea-warfare in south-east Asia. In his Tung Hsi Yang Kiao² (Studies on the Oceans East and West) of +1618, he wrote:³

San-Fo-Chhi (Palambang in Sumatra) ... is situated in the south-eastern seas ... Originally (the people) belonged to a special tribe of southern barbarians intermediate between those of Cambodia and Java ... Later it was defeated by the Javanese, and its name was changed to Chiu-Kang⁴, which is still in use now .... It produces the furious fiery oil (mēng hua yu⁵), which according to the Hua I Kiao is a kind of tree secretion (sha chin⁶), and is also called mud oil (niyu yu⁷). It much resembles camphor, and can corrode human flesh. When ignited and thrown on water, its light and flame become all the more intense. The barbarians use it as a fire-weapon and produce great conflagrations in which sails, bulwarks, upperworks and oars all catch fire and cannot withstand it. Fishes and tortoises coming in contact with it cannot escape from being scorched.

Late in the following century, Chao Hsiêh-Min⁸, who quoted the passage in abbreviated form⁹ thought (wrongly) that this oil was a reference to natural petroleum (shih yu¹⁰). But from one of its names¹¹, he went on, “it is obvious that “mud oil” cannot be any sort of vegetable exudate. In the (Tung Hsi) Yang Kiao (Chang Hsien) he made a mistake about this.” Here again there was no talk of projector pumps, so it was probably a matter of breakable bottles with fuses once more.

These texts have surely demonstrated that the use of Greek Fire petrol or naphtha in war went on till quite a late date in south-east Asia, and that the distilled petroleum reached China through that region in the first place rather than over the land route. But now, before drawing all the threads together in a coherent picture, we must fill it out by one or two more accounts of the techniques in use in China itself. For example, going back to the +10th century, petrol flame-throwers were prominent on both sides in the suppression of the

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⁴ Ch. 3, pp. 174, 174, ir. auct.
⁵ Cf. Gerini (1), passim.
⁶ Here he must have been referring to the Hua I Hua Ma Niao Shoo Chen Wan Kiao¹¹ (Useful Examination of the Flowers, Trees, Birds and Beasts found among the Chinese and Neighbouring Peoples), written by Shen Mou-Kuan¹² in +2981. Shen’s ideas of precision in the natural sciences were none too exacting, as Wylie (1), p. 123 noted.
⁷ Pin Tsao Kang Ma Shih I, ch. 2, p. 65b. In the same entry he quotes eight other sources, all about natural petroleum, including Chu Pin-Chang’s¹³ Ko Wu Hsin Chih¹⁴ (What One should Know about Natural Phenomena), a late Chihli book. This repeats the stories about the fishes and the ashes, saying that these mineral oils can be kept only in glass vessels, and that they burn when floating on water so that water will not put them out.

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Southern Thang dynasty (+937 to +976) by the great Sung, established in +960. We have descriptions of the naval battle on the Yangtze in +975 near Nanking (Chinling), its capital,¹ which sealed its fate. In his Tiao Chi Li Than¹ (Talks at Fisherman’s Rock) Shih Hsü-Pai² wrote:³

Chu Ling-Pin⁴ (admiral of Nan Thang) was attacked by the Sung emperor’s forces in strength. Chu was in command of a large warship more than ten decks high, with flags flying and drums beating. The imperial ships were smaller but they came down the river attacking fiercely, and the arrows flew so fast that the (Nan Thang) ships were like porcupines. Chu Ling-Pin hardly knew what to do. So he quickly projected petrol from flame-throwers (fu chi hua ju) to destroy the enemy. The Sung forces could not have withstood this, but all of a sudden a north wind sprang up and swept the smoke and flames over the sky towards his own ships and men. As many as 150,000 soldiers and sailors were caught in this and overwhelmed, whereupon (Chu) Ling-Pin, being overcome with grief, flung himself into the flames and died.

The sailors of Byzantium would have felt very much at home in this battle. Then from another “History of the Southern Thang Dynasty”, that of Ma Ling, we hear more about another admiral, Tshao Pin⁵, in this case on the imperial side.⁶

In the 8th year of the Khai-Pao reign-period (+975), Tshao Pin⁶ came down upon Chinling. He had large ships furnished with (bundles of) reeds saturated with thick oil, with the intention of taking advantage of the wind to start conflagrations; these were called ‘rock-oil’ devices (shih yu chi). But in urgent situations, then they used the machines to shoot the fire-oil forwards to resist the enemy (hua yu chi chien chi⁷).

This was a clear mention of Greek Fire flame-throwers. Finally, rather more than a century later, Li Kang¹¹ brought them into action when trying to prevent the crossing of the Yellow River by the Chin Tartars before the siege of Khaifeng in +1125.⁸

Here we need not follow the petrol flame-throwers very far beyond the gunpowder era, but one reference imposes itself. When the Mongol ruler, Hulagu Khan, was setting forth in +1253 for the conquest of Persia,¹ couriers were sent to Cathay to bring from thence a thousand men skilled in war machines (trebuchets), naphtha throwing (or projecting), and crossbow (or arcaballista) shoot-
ing, with their families... And as late as +1600 the San Tshai Thu Hui encyclopaedia gave a full account of the flame-thrower (Fig. 8), with illustrations.6

Perhaps the most curious story about the petrol occurs in the Tso Meng Lu7 written by Khan Yu-Chih8 about +1137, a book which, as its title indicates, 'Dreaming of the Good Old Days', was written in the south after the victory of the Tartars, and recalls life in the former capital of the Northern Sung.9 Khan had some rather wild ideas about the origin of distilled petroleum, but he remembered the way it was stored in the arsenals of the north-west in Northern Sung times,4 and vividly sketched manoeuvres with the use of it against enemy encampments. What he said was as follows:7

Near the Wall Defence Arsenal (Fang Chhieh Khu9) at the northwest frontier Wall (the military engineers) used to dig out earth and make a large reservoir more than ten feet square in order to store 'fierce fire oil' (meng hua yu10). In less than a month the surrounding earth would turn orange in colour, so further reservoirs were dug and the oil transferred to them; if this had not been done fire would have broken out and set light to the pillars supporting the roof (of the shed over the reservoir).11 I have heard that this fierce fire oil comes from a region several thousand li east of Korea.6 When the sun begins to shine with all the strength of full summer, it makes the stones so hot that this oil oozes out from them. If it comes into contact with anything else it bursts into flame. It should only be stored in real glass vessels.

West of Chung-shan Fu12 there was a large body of water called Ta-po Chhiah13 (Big Wave Pond), so large that the local people called it a 'lakelet' (hai tsu14). I myself still remember the district commanders coming to it to study (and practise with their troops) water-combat, and to test the fierce fire oil. The opposite bank of the lake represented the fortified camp of the enemy. Those who were in charge of the oil sprayed it about, and as it was ignited it broke into a sheet of flame, so that the (fictive wooden) fortifications of the enemy were all in a short time completely destroyed. What is more, the oil had a secondary effect on the water, for all the water-plants were killed, and the fishes and turtles died.

\[\text{Footnotes:}\]
2 Chhia yung sect., ch. 3, pp. 186-187, Greek Fire petrole also appears in the Wu Fu Chih of +1628, ch. 162, p. 218, but in connection with an eruption (cf. p. 186 below).
3 There is a good account of the book in SKCSTT(I), ch. 143, p. 79. The editors knew the passage in the Lan Shih (p. 9 above), but doubted whether anyone knew much about Greek Fire petrole before the capture of Li Lin6 (or Yin Li-Lin6). We have not been able so far to unearth any information about this character, who might be of considerable interest for this history.
4 One would like to know what measures were taken to reduce evaporation losses.
5 In SF, ch. 21, pp. 213, 214 (ch. 34, p. 146), also reproduced in Kuang Pu Chuhua Hauh Hau, vol. 4 (pp. 105a-3), and in Ku Chhia Shou Hau, whence it was kindly brought to our attention by Dr Werner Eichhorn in 1956. It is also quoted in Fang Chhia-Sheng (2), p. 138.
6 We have not been able to think of an explanation for these phenomena, but unless the reservoirs were broken the surrounding earths would certainly have become wastefully saturated.
7 Curiously, this was diametrically opposite to the real point of origin.
8 The present Chhia-tie (50).
To recapitulate, it seems quite clear that Greek Fire petrol (distilled petroleum) reached China by about +900 or rather earlier, and that it came by the intermediation of Arab merchants along the sea-route, and then up through East Asia from the south to the north. Of Chinese–Arab contacts a great deal has already been said, and it is only necessary to assume that the invention of Cullinicus passed to the Arabs by the middle of the +9th century. We have seen how the petrol was handed on from Wu-Yüeh State in the south to the Chhi-tan Liao Tartars in the far north in +917 (p. 80). It was not long before there were diplomatic contacts between the Liao State and the Arabs direct; there were embassies in +1019, +1021 and +1027, and in the same decade the Liao despatched the daughter of a nobleman as spouse for an Arabian prince. It seems most probable that in due course the know-how of distillation was conveyed along with the product, in which case there is a close parallel with the gunpowder formula which reached Roger Bacon together with the gift of explosive crackers (p. 48 above). At first, no doubt, the product was supplied alone, but at some time during the +10th century the Chinese must have started distilling petroleum themselves. By +1060, certainly by +1040, the petrol flame-thrower pump was standard armament equipment in China (p. 82), and it is quite impossible to believe that the incendiaries depended on imported petrol distilled in Byzantium or Baghdad. It has already been shown that distillation with the Chinese still-type would have been perfectly possible—with adequate precautions—using natural petroleum as the starting material. This is borne out by the Sung Hui Tso Chi Kao, which mentions, not indeed the ‘fire oil’ by name, but oil itself as a supply material delivered to arsenals for working up.

Much stronger evidence comes from the Tung Ching Chi (Records of the Eastern Capital), written by Sung Min-Chhiü, some time before his death in +1079. In that he wrote:

Apart from the Offices of the Eight Workshops (Pa Tsao Saü), there are also other government factories, notably the Workshops for General Siege Train Material (Kuang Pi Kung Chhêng Tso), and now both of these, Eastern and Western, are under the authority of the arsenals administration (Kuang Pi Li Chhi Chhi Chien). Their work comprises ten departments, item, the gunpowder factory (huo yao tu), item, the pitch, resin and charcoal department (li chhêng tu), item, the fire-and-foam laboratory (meng hao yu tu), item, the metal shop (chun lu), item, the incendiaries plant (hao lu), item, the box design for timber large and small (la hiao ma tu), item, the foundry for stoves large and small (la hiao lu tu), item, the leather yard (phi tu), item, the hemp rope works (ma tu), item, the brick and pottery kilns (yao tu).

All these have their regular specifications and procedures, so that those in charge can learn them by heart. But it is absolutely forbidden to divulge the text to outsiders.

This is certainly a vital text both for the petroleum distilleries and the gunpowder mills of the Northern Sung in the +11th century. It is, moreover, confirmed by several passages in the Sung Shih itself, which verifies in so many words the precautions about security when speaking of the arsenals administration (Chhi Chhi Chien). The eight government arms factories (Tung Hsi Pa Tsao Saü) were operated by a War Office department named Chiang Tso Yuan, and the.

As quoted by Wang Té-Chhien in his Chhinh (Conversations on Historical Subjects), prefaced in +1125, ch. 1, pp. 46-47. It is reproduced in Fêng Chhi Shih (-), ch. 12. See also Passim; (1), cf. Tung Hsi 22-25.

This is an emendation by Fêng Chhi Shih (+), ch. 13, for the original text has chhi chêng yu, a redundancy with the tenth workshop.

Although these workshops may have had much else to do also, the function of both indicate the preparation of equipment for making molten iron (chhi chhêng) for assuialing the enemy and his wooden structures. This procedure is attested for many centuries in Chinese military history. In the beginning it was probably mainly a matter of pouring vessels of the hot metal on besiegers from above (as was proverbial in Europe), but already in the Thu Pê Yung Chih of +759 (ch. 4, p. 49) 'bombs' (phêng) filled with iron hurled (phêng) from trebuchets. The We Chhêng Tung Chih of +1044 (Chhien chi, ch. 10, pp. 598, 620, E) gives more detailed specifications of the refractory clay containers (huo tu), projectiles breaking on impact; and a similar account is in the We Pê Chi of +1658 (ch. 133, pp. 149, E). Both these describe and illustrate the 'mobile furnace' (kung lu) for filling them, which could be drawn back and forth along city-walls. In considering all this it should be remembered that the melting-point of cast iron is 1130°C, some 400° lower than that of pure iron, but as was pointed out in Neddiham (32), pp. 14, 19, early Chinese cast iron (which long preceded cast iron anywhere else in the world) probably contained up to 3% of phosphorus, and this reduces the melting-point still further, to about 940°C. Of course, as an incendiary and offensive weapon this would be quite bad enough. That it was habitually used in medieval Chinese warfare appears from many texts, for example the Mongol general Bayan (Po Yen) besieging Ying-chêng in +742 (mod. Wu-chiang in Hupeh) about +1280 with trebuchet-launched molten-metal 'bombs' (chih khan). Cf. Lu Mou-Té (1), p. 37, Fêng Chhi Shih (-), p. 47.

Aid. ch. 165, p. 221: "The people in the Arsenals Administration have designs of military equipment handed down, and no person below a certain rank was ever allowed to see them or copy down texts. Thus the secrets were not divulged."
numbers of artisans and craftsmen who worked in them are discussed in yet another place. So the Chinese were doing their own distilling.

The reason why we have considered Greek Fire so carefully is not just that as an incendiary weapon it was a predecessor of gunpowder. Its focal importance in the whole evolutionary story is that in the Chinese petrol projection-pumps its ignition took place by means of a gunpowder slow-match. The 'siphon' provided the occasion for the first use of the mixture; this is firmly established for the neighbourhood of +1040, and by implication to earlier dates such as +1004 back to +919. Such was the first appearance of gunpowder on the practical stage of war, after its invention and elaboration by the Taoist alchemists of the +9th century, perhaps about +830, in their search for life-elixirs. And just as their work took place in China alone, so also exclusively Chinese was the practical use of the explosive mixture, even though as yet only in glowing and smouldering low-nitrate form.

And then, a whole millennium later, gunpowder and Greek Fire met together once again in a strange reincarnatory partnership—but what that was will be told in its place. As for that partnership which we have been examining between the Byzantines and the Chinese—if one might figuratively call it so—the saying of the Persian Sharaf al-Zamān Ṭāhir al-Marwārizi about +1115 was exceedingly apposite:

The people of China are the most skilful of men in handicrafts. No other nation approaches them in this. The people of Rūm (the Eastern Roman Empire) are highly proficient (in technology) too, but they do not reach the standards of the Chinese. The latter say that all men are blind in craftsmanship, except the men of Rūm, who however are one-eyed, that is to say, they know only half the business.

(5) Ancestry (II): The Recognition And Purification of Saltpetre

The pre-requisite of the discovery of gunpowder was the recognition and purification of saltpetre (potassium nitrate); and before saltpetre could be used in any gunpowder composition, techniques had to be developed to extract it from its sources. It happened that medieval and pre-medieval chemical knowledge in China was in many ways more advanced than it was in Europe; and thus it is possible to trace the first uses of saltpetre from there eastwards leading back to their origin in East Asia. In fact the early history of saltpetre is much more fully documented in China than in any other civilisation.

Broadly speaking, the word 'saltpetre' has been used to refer to potassium nitrate or sodium nitrate, or even calcium nitrate. But its primary significance was potassium nitrate, the most singular ingredient of the gunpowder mixture. In nature potassium nitrate (prismatic saltpetre) is usually found mixed with sodium and magnesium salts. It needs the right climatic conditions to form, namely a sufficiently high temperature and a suitable humidity in which organic matter, especially excreta, can decompose; these conditions existed in Arabia, India and China, but not so much in Europe. For example, before the discovery of the nitre source in Chile, the Ganges valley was the greatest source of supply of saltpetre to England in the +18th and early 19th centuries. The nitre from Chile, sodium nitrate (also known as cubical saltpetre), is far inferior to the potassium salt as an ingredient for gunpowder because it readily absorbs moisture, but it can be converted to potassium nitrate by treatment with strong solutions of potassium chloride. As for calcium nitrate, it is commonly found forming in the earth and on walls, together with many impurities, but again it can be converted to potassium nitrate by ionic exchange with potassium carbonate. These are, of course, modern techniques; in the early pre-gunpowder centuries, the problem was to distinguish it from other salts such as sodium or magnesium sulphate.

At an earlier stage we gave a rather thorough account of the recognition and isolation of saltpetre in China, so we must not repeat it here. In the previous paragraph the word 'nitre' was used, coming naturally enough, but historians of chemistry know well what multifarious meanings were attached at different times to that term, originating as it did through Greek and Latin from ancient Egyptian nīrī or nātron. This was sodium carbonate, mixed with the sulphate and common salt, together with a little bicarbonate, occurring naturally in desert regions; and it was known in China too, as chien or shih chien. 'Nitre' could mean almost anything, generally soda, more rarely potash, and often mixed with the chloride. Its parallel term in Chinese was hsiao or hsiu, but instead of translating this in ancient and medieval texts as nitre it is better to use a word of equivalent vagueness, such as 'solve'. This is suggested not only by the etymology of congeneric characters and usages but by the facts that potassium nitrate acts

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1) See Mellor (1), pp. 309 ff.
2) C. E. Ray (1), and ed. p. 200; Mothafar (9).
4) Although several scholars have believed that they could establish a consistent semantic difference between the use of the water radical and the stone radical in Aria, this has not been our experience. We fear that these were used indiscriminately both by the alchemists and the pharmacists in Chinese texts.
5) C. E. Vol. 5, pt. 4, p. 5.
strongly as a flux in smelting, and participated in the procedures for bringing insoluble mineral substances into solution.⁴

The most characteristic name for saltpetre in Chinese texts was *hsiao shih*¹ (solve-stone), but to be sure of the identification of what they were talking about it is always necessary to see what they said about its properties. Hence the significance of other names such as *yen hsiao*² (blaze-solve), *hsiao shih*¹ (fire-solve), *khu hsiao*³ (bitter-solve), *sheng hsiao*⁴ (natural solve),⁵ and *ti shuang*⁶ (ground frost).⁷ In China potassium nitrate was never confounded with sodium carbonate, as in the West, but rather with sodium sulphate and magnesium sulphate. The first of these generally went by the name of *phu hsiao*⁷ (crude-solve), the second was *mang hsiao*⁸ (prickle-solve)—Glauber’s Salt and Epsom Salt respectively. In Tang and post-Thang texts, however, this last term came often to be applied to saltpetre;⁹ and indeed it must be emphasised in general that none of the names can be taken as entirely reliable by themselves; always the description of the product must be examined in order to be sure what it was that the alchemical adepts or the pharmaceutical natural history writers had in hand. Already the name *hsiao shih*⁹ appears in the *Chi Ni Tsü¹⁰* book of the 9th century in its list of drugs and chemicals, but without details of its properties.¹¹ Then in the *Shen Nung Pín Tshao Ching¹²*, the first of the pharmacopoeias, a couple of centuries later, it occurs again, but mainly in a medical and macrobiotic context.¹³ Next comes the *Li hsien Chuan¹⁴* (Lives of Famous Hsien), datable about the 2nd century, where a famous adept achieved immense longevity by ingesting solve-stone as an elixir ingredient.¹⁵ For the extraction of saltpetre is already made in a list of seasonal prohibitions occurring in the *Hou Han Shù* (History of the Later Han Dynasty).¹⁶

From the day of the summer solstice onwards strong fires are forbidden, as well as the smelting of metals with charcoal. The purification of saltpetre (*hsiao shih*) has to cease altogether, until the beginning of autumn ....

This would have referred to the +1st and +2nd centuries, and shows that the practice must have been quite widespread, for otherwise the government would hardly have issued an order interdicting it at this time of the year. But the turning-point is reached in +402, when Thao Hung-Ching¹⁷ described in his *Pín Tshao Ching Chi Chu*² (Collected Commentaries on the Classical Pharmacopoeia of the Heavenly Husbandman) the purple potassium flame test given by the solve-stone,¹⁸ together with its strong deflagration on charcoal. Since this and the closely related work of +510, *Ming I Píh Lü¹* (Additional Records of Famous Physicists on Materia Medica),¹⁹ recorded so much +3rd-century knowledge, it is likely that the flame test and other criteria such as the flux effect went back to that time; in any case it is surely by far the oldest reference to the potassium flame in any civilisation.²⁰

After that there are many references to the purple potassium flame, the deflagration, and the properties of flux and solubilisation. The *Hsin Hsia Pín Tshao*²¹ (Newly Improved Pharmacopoeia) of +695 repeats them,²² and soon afterwards, in +664, we have the ‘Hsing alchemical text about the wandering monks.²³ Here in the *Chin Shih Pu Wu Chiu Shu Chiah²⁴* (Explanations of the Inventory of Metals and Minerals according to the Numbers Five and Nine) we read about the Saka or Sogdian monk Chih Fa-Lin²⁵, who recognised the presence of saltpetre in northern Shansi and knew of its properties. Probably belonging to the same century is another alchemical book, the *Huang Ti Chiu Ting Shan Ten Ching Chiah²⁶* (Yellow Emperor’s Canon of the Nine-Vessel Spiritual Elixir, with Explanations) which has an important passage about saltpetre.²⁷ And then, not later than about +850, there is a further text in the *Chen Yuan Miao Yao Yao Lüè²⁸*.

⁴ Vol. 5, pt. 4, pp. 167 ff. See now also Butler, Gildewell & Needham (1), Li Shih-Chen, in *PTKM*, ch. 11, p. 305, who quotes the *Pín Tshao Ching* text (cf. 167) as saying that saltpetre can ‘dissolve and soften the five metals, and bring the seventy-two minerals into aqueous solution’. Though saltpetre is mentioned there several times (e.g. ch. 11, p. 88, ch. 16, pp. 73, 94), this passage seems not to be there now, but it certainly referred to the liquefaction of siliconic gangues by a flux, and to the solution of inorganic substances normally very insoluble, like cinnabar.

⁵ In 16th-century Europe a significant parallelism with gunpowder was constituted by the ‘black’ or ‘deflagrating’ flux, so often described by the metallurgist Lazarus Ercker (1) in 1574. Here saltpetre was mixed with ‘argol’ (potassium tannate) and charcoal, giving, upon ignition, potassium carbonate, carbon and nitric oxide. This flux was used for smelting and purifying silver (Stasio & Smith (2), pp. 44, 81), gold (110), copper (pp. 207, 215), bismuth (p. 275) and tin (p. 990). We should like to thank Prof. Cyril Stanley Smith for bringing this to our remembrance.

⁶ Chiang Hung-Chao (1), p. 241, recognised all these names as synonyms.

⁷ As in all countries, saltpetre was at first scraped from the surface of the ground as a white crust or powdery efflorescence; cf. Kovda (1), pp. 121–2. As it happens, China possesses rather substantial areas of saltpetre solonchak soils in Honan province yielding more than 30,000 lbs. of saltpetre per acre p.a. cf. K. C. Hou (1) and Yoneda (1), together with Wei Chao-Yuan (1), pp. 460–9 and Torgasheva (1), pp. 306 ff. It is now more than thirty-five years since I first heard about these deposits (which produce sodium nitrate too) from Dr Wu Ching-Lieh of the 2nd Arsenal at Lu-hsien.

⁸ Presumably because of the shape of the crystals.

⁹ Cf. what Su Ching (Su Kung) says about mang hsiao and *hsiao shih* (+650) in *PTKM*, ch. 11, p. 265. Li Shih-Chen abbreviated the passage, as one can see from *HHPT*, ch. 3 (vol. 1, pp. 119–22).


¹² 耕石¹³ 搶磷¹⁴ 火硝¹⁵ 黃硝¹⁶ 生硝¹⁷ 胭脂¹⁸ 神農本草經¹⁹ 列仙傳
before, may contain the earliest appearance of the phrase huo yao, afterwards so universal as the appellation for gunpowder. But it occurs as a sub-title, i.e. a ‘method for subduing chemicals by fire’ (fu huo yao fa). The experiment required white alum, potassium nitrate, sodium and magnesium sulphates, and mercury, so far as we can tell, producing in the end a purple sublimate. In general, Chu Sheng suggests that the procedures of ‘subduing by fire’ (fu huo) were worked out by the alchemists of the Chin and Liu Chiao periods in their search for elixirs, precisely for the purpose of avoiding those deflagrations and proto-explosions which the military afterwards found so useful. For example, if the crude salt-petre contained much carbonaceous material, as it may well have done, heating it would produce potassium carbonate, something reasonably innocuous. Many mishaps were probably wrapped in silence, and the first actual record of such ‘calamities’ is in the Chen Yuan Miao Tao Yoo Lish, which we shall speak of below (p. 111).

A rather clear statement was that given by Ma Chih in the Khai-Pao Pen Tsuan (Pharmacopoeia of the Khai-Pao Reign-Period) in +973. He wrote:  
"It was because salt-petre can dissolve (hsiao shih) and liquefy (lit. change, huo) minerals that it was given the name of solve-stone (hsiao shih). When it is first boiled and refined it crystallises in small prickly (mang) shapes, and in appearance resembles cudred-solve (fu hsiao) therefore it has the synonym of prickle-solve (mang hsiao). . . .

Solve-stone (hsiao shih) in fact a ‘ground frost’ (ti huang), an efflorescence of the soil. It occurs among mountains and marshes, and in winter months it looks like frost on the ground. People sweep it up, collect it, and dissolve it in water, after which they boil to evaporate it, and so it is prepared. (The crystals) look like the pits of a hair-ornament. Good ones can be as much as five jin (about half an inch) in length. Thao Hung-Ching said all sorts of things (about these salts) because he did not know the facts. . . .

Actually solve-stone is produced among the rocks and cliffs in the mountains west of Mou-chou in Szechuan. The size of the pieces (after purification) varies, but its colour is bluish-white, and it can be collected at all seasons.

It should be borne in mind that this was written some three hundred years before the Arabs and the Franks knew anything about salt-petre at all. For Ma Chih, solve-stone was unquestionably a substance different from crude-solve and prickle-solve, though the latter term could be applied to it as a synonym. In a moment we shall give some more detailed accounts of the manner of its purification.

One of the most interesting accounts of the whole subject, indeed remarkable
for its insight, was that of Li Shih-Chen\(^1\) in his *Pen Tshao Kang Mu*, published in +1596. His words were these:\(^2\)

Ever since Chin and Thang times,\(^3\) the different (substances) the names of which contain the term 'solve' (*hsiao*) have been the subjects of guesswork by most writers (on pharmaceutical natural history), who simply named them at random, with little justification. Only Ma Chih in the *Khai-Pao Pen Tshao* recognised that solve-stone was refined from 'ground front', while prickle-solve and horse-tooth solve (*ma ya hsiao*) were for the most part refined from crude-solve. His statements ought to have cleared up all the doubts and hesitations of these people. It was because solve-stone (*hsiao shih*)\(^4\) was often given the synonym of prickle-solve (*mang hsiao*)\(^5\), and because crude-solve (*phu hsiao*)\(^6\) had the synonym of crude-solve-stone (*hsiah shih phu*), that the pundits got their names mixed up, and could not decide how to express the situation.

What they did not know was that the solves (*hsiao*) can be divided into two classes,\(^7\) one aqueous (*shui*) and one pyriac (*hua*).\(^8\) Although their outward appearances are similar they differ completely in their nature (*hsiang*)\(^9\) and their chhi. Only the two items under crude-solve (*phu hsiao*) and solve-stone (*hsiah shih*) as set out in the *Pen Ching*\(^10\) are correct. The rest, like prickle-solve (*mang hsiao*) in the *Ming I* *P'ien Lu*,\(^11\) or horse-tooth-solve (*ma ya hsiao*) in the *Chiao-Yu Pen Tshao*,\(^12\) or natural solve (*sheng hsiao*) in the *Khai-Pao Pen Tshao*, were the outcome of unnecessary distinctions. I have therefore put them back where they ought to belong.

Now the crude-solve (*phu hsiao*) of the *Pen Ching* is an aqueous solve (*shui hsiao*).\(^13\) It is of two types. After the solution is evaporated by boiling, the crystalline produce appearing like prickles is called *mang hsiao*, and that appearing like horse teeth is called *ma ya hsiao*. Crude-solve (*phu hsiao*) is the solid which finally settles at the bottom (of the vessel); it has a salty sapidity and is (pharmacologically) cooling (*hua*).\(^14\)

But the solve-stone (*hsiao shih*) of the *Pen Ching* is a pyriac solve (*hua hsiao*).\(^15\) This is also of two types. After the solution is evaporated by boiling, the crystals which appear like prickles are also called *mang hsiao*, and those which look like horse teeth are called *ma ya hsiao*. They are also named natural solve (*sheng hsiao*). What settles as a

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\(^{1}\) A Yang property.

\(^{2}\) I.e. Glauber's and Epsom salts.

\(^{3}\) A Chinese abbreviation for 'magnesium carbonate'.

\(^{4}\) Chang Hung-Chao (*I*), pp. 241 ff., reported in 1927 the analyses of seven contemporary traditional samples of *mang hsiao* from different localities, finding varying proportions of Na, Mg, Ca and K sulphates. The first named was always preponderant, the second did not exceed 7%, the third 1% and the fourth 4%. Up to 5% of common salt could also be present. Yet a Thang specimen (+756) turned out to be almost pure magnesium sulphate (*Vol. 5, pt. 4, p. 301*).


\(^{6}\) An abbreviation for 'fire'.

\(^{7}\) Faithful to the *Pen Ching*.

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### 30. THE GUNPOWDER EPIC

Solid on the bottom is the solve-stone (*hsiao shih*). Its sapidity is acrid and bitter, and it is very heating (to warm) medically.

Both the solve classes give rise (during processing) to *mang hsiao* and to *ya hsiao*. For this reason the old prescriptions (of the Chin and Thang periods) took the salts as interchangeable, but since the Thang and Sung the prickle-solve (*mang hsiao*) and tooth-solve (*ya hsiao*) have been of the aquoue class (*shui hsiao*).\(^1\)

Thus it would seem that Li Shih-Chen distinguished rather clearly, and very justifiably, between the 'watery', aqueous, sulphates, and the 'fiery', pyriac, nitrates. What he was really saying was that the traditional Chinese terminology of solves (*hsiao*) had often depended as much on crystal form (none too accurately observed) as on other properties. He was also clear that the same salt could crystallise in more than one form; and by his time it was becoming evident that similarity of crystal shape could easily be very confusing.\(^2\) It was because of the needle-like and other crystal forms that the name *mang hsiao* had got transferred both to saltpetre and to different sulphates at various times. Only the chemical properties themselves—and Li Shih-Chen knew them well—could really distinguish the salts. After all, he was writing in the century of Paracelsus and Agnolo, no more able to attain modern scientific knowledge than they could, yet in distinguishing so well between the sulphates and the nitrates he reminds one of Paracelsus preparing his series of coloured metallic chlorides.\(^3\) Both were early steps in the recognition and preparation of distinct chemical classes of salts.

One might not suppose that so great a naturalist as Li Shih-Chen would have anything to say about the military, but he has. A couple of pages later,\(^4\) he is ruminating upon medicinal properties, and says that since *phu hsiao* is a Yin or aqueous substance, cold and salty, it tends to go downwards, and so can soothe and clean the intestinal tract, expelling malign pyriac chhi (*hsieh huo chhi*)\(^5\) from the three coctive regions (*san chiao*). Conversely, *hsiao shih* is a yang or pyriac substance, hot and sulphurous, so it tends to go upwards and can cure stasis of Fire in the three coctive regions as well as dispersing all kinds of accumulations. Then we read:

Now the military technicians (*ping chia*) when making fire-weapons (lit. beacons, cannons and suchlike machinery, *ping huo tung chiu ting wu*)\(^6\) use compositions containing...
saltpetre; so they fly up high, as if straight to the clouds and the Milky Way. For it is their very nature, as we know, to go upwards. . . .

Here was a prescience, one might feel, of that escape from Planet Earth which Chinese rockets in their mature development would permit.

The passage puts us in mind of two things—first al-Juwayni saying, about +1260, that the
trebuchet artillerymen of Cathay could with a stone missile convert the eye of a needle into a passage for a camel, and couldfasten the woodwork of their trebuchets so firmly together with sinews and glue that when they aimed from the nadir to the zenith the missile did not return.4

But secondly, and more seriously, Li Shih-Chen’s Aristotelian conviction of upward tendency reminds us of the Paracelsians theories of ‘aerital nitre’, that ‘volatile saltpetre’ somewhere up above us. In +16th- and +17th-century Europe this played a considerable part in physiological as well as meteorological speculation; for on the one hand it was appealed to as the element in the air essential for respiration and muscular motion, while on the other it was thought to be the cause of thunderstorms and lightning. After all, for Paracelsians such as Joseph Duchesne and Robert Fludd, the atmosphere was the medium through which the heavenly and starry influences had to pass to reach us, so it was not hard to suppose that ‘Sophic fire’ or ‘vital nitre’ was generated by them there.

The gunpowder theory of thunder and lightning lasted on well into the +17 century, and the vital nitrous element led directly to John Mayow’s classical work on the nature of respiration (+1668). Once again the quasi-mystical speculations of the Paracelsian tradition helped to generate modern science,5 and once again the thoughts of Chinese naturalists of +1590 strangely recall the ideas of their contemporaries in Europe, isolated from each other though they were.

Lastly, what detailed accounts of the practical preparation of saltpetre for the gunners can we find in Chinese literature? We translate two, both from the neighbourhood of +1630, and first the indispensable passage from the Diderot of China in his technological book, Thien Kung Khai Wu1 (Exploitation of the Works of Nature), about saltpetre. Sung Ying-Hsing2 wrote:4

Saltpetre (solute-stone, hsiao shih) is found both in China and in the lands of neighbouring peoples, all have it. In China it is chiefly produced in the north and west. Merchants who sell (saltpetre) in the southern and eastern (parts of the country) without first paying for the official certificate are punished for illegal trading. Natural saltpetre has the same origin as common salt. Subterranean moisture streams up to the surface, and then in places near water (e.g. the sea), and where the earth is thin, it forms common salt, while in places near the mountains, and where the earth is thick, it forms saltpetre. Because it dissolves (hsiao) immediately in water it is called solute-stone (hsia shih). In places north of the Yangtze and the Huai river, after the mid-Autumn fortnightly period, (people) just have to be at home and sweep the (earthen) floors on alternate days to collect a little for purifying. Saltpetre is most abundant in three places. That produced in Szechuan is called chhuan hsiao; that which comes from Shansi is commonly called yen hsiao; and that found in Shantung is commonly called thu hsiao.

After collecting saltpetre by scraping or sweeping the ground ([Comm.] as also from walls) it is immersed in a tub of water for a night, and impurities floating on the surface are skimmed off. The solution is then put into a pan (fa). After boiling until the solution is sufficiently concentrated, it is transferred to a container, and overnight the saltpetre crystallises out. The prickly crystals floating on the surface are called mang hsiao5 and the longer crystals are ma ya hsiao. ([Comm.] The amount of these varies with the places where the raw material has been collected.) The coarse (powder or crystals) left at the bottom as a residue is called phu hsiao6.

For purification the remaining solution is again boiled, together with a few pieces of turnip, until the water has evaporated further. This is then poured into a basin and left overnight so that a mass of snow-white (crystals) is formed, and this is called phen hsiao. For making gunpowder this phu hsiao and phen hsiao have a similar effect. When saltpetre is used for making gunpowder, if in small quantity it has to be dried on new tiles, and if in large quantity it should be dried in earthenware vessels. As soon as any moisture has all gone, the saltpetre is ground to a powder, but one should never use an iron pestle in a stone mortar, because any spark accidentally produced could cause an irretrievable catastrophe. One should measure out the amount of saltpetre to be used in a particular gunpowder formula, and then grind it together with (the right amount of) sulphur. Charcoal is only added later. After saltpetre has been dried, it may become moist again if left over a period of time. Hence when used in large coggins it is usually carried separately, and the gunpowder prepared and mixed on the spot.

Here we are back again in the terminological morass of the different ‘solves’, just like ‘nitrates’. If Sung Ying-Hsing thought that sulphates, chlorides or other salts would do instead of the nitrate, he was far astray, and may have been confused by his informants; but surely he was not so artless. He may not have been entirely wrong in what he said, for potassium nitrate does crystallise in two different forms, and in his time these may well have had different names. The salt is dimorphous, giving both rhombic crystalline plates and needle-like rhombohedral (trigonal) crystals isomorphous with those of sodium nitrate. So crystals or crystalline precipitates that looked different may all have been nitrate.

Of course the definitive identification and isolation of inorganic salts had to await the coming of modern chemistry, but Debus has shown* how great an

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5 On this whole subject see Debuc (9, 10), (18), pp. 32, 115f., 154; also Guerlac (1, 2); and Partington (9ff)
6 TKW ch. 15, pp. 56, 8, 74 (Ming ed. ch. 3, pp. 324, 8, 334); tr. auct. adjviv, Sun & Sun (1), pp. 450, 371.
7 天工开物
8 宋應星
9 陶石
interest there was in late medieval Europe in the nature and composition of spa and mineral waters before the time of Robert Boyle. Here, besides such great names as Paracelsus and Agricola, advances were made by Edward Jorden (+1569 to 1632) and Gabriel Platten (fl. +1639). Jorden was interested in salt-petre, and said that only when pure will it 'shoot forth needles.' Indeed, Debus can say that all modern chemical analysis developed from dry metallurgical assays and wet analyses of mineral waters.

Another element of much interest in Sung Ying-Hsing's account, and one which we shall see even more prominently in the following text, is the use of colloidal organic material for clarifying the solution of the salt before crystallisation. Thiduchum (Is), Thudichum Bk. This (is), This (is), Ying-Hsing is mentioned below. The Chinese salt-petere used the soluble constituents of turnip slices, and also, as we shall see, glue, but a great variety of other substances found employment in the Chinese table-salt industry, as we note at length in Sect. 37. For example, the briners there used ground soap-bean pods and millet chaff, but also hen’s eggs, bodhi-seeds and ground whole soya-bean suspensions. European salt-broilers in their turn used the blood of bulls, calves and bucks, together with ale or beer (in moderation), as Agricola tells us in his De Re Metallica, finished in +1550. This was still going on in the nineteenth century, but Dutch briners used sweet whey and many English ones egg-white. Bull’s blood was used too in sugar-refining, while in culinary techniques egg-white reigned supreme, as for the making of clear consommé and aspic from thick broths and meat-extracts. Since all these methods belong to a time long before modern industrial chemistry, it would take a special research to elucidate their origin, but they must surely go back well into the Middle Ages, both in China and in Europe.

As for the explanation of the effect, we doubt if the simple coagulation of proteins by heat, and the mechanical entanglement of the substances causing the inorganic or organic turbidity, will suffice to account for it. It seems more likely that the mutual precipitation of oppositely charged colloids plays a large part. The recognition of the electric charges on colloidal particles was one of the foundation-stones of colloid chemistry, and in this clearing or clarification of salt solutions we must have one of the earliest empirical applications of it.

Let us look now at the last of our accounts of saltpetre making and testing; it comes from the military compendium Phing Phi Pai Chin Fang (The Wasehman’s Precious Salve; Appropriate Techniques of Successful Warfare), edited by Hui Lu at some time not long after +1626. He says:

Take half a pan (ka) of crude saltpetre (in water) and boil it until the salt dissolves (completely). Then take one large red turnip, cut it up into four or five slices and put them into the boiling liquid. Remove the turnip (slices) when they have become cooked (and turn soft). Then mix the white of three eggs with two or three bowlsful of water, and pour it into the pan while stirring with an iron spoon. Remove all the solid material (chu) floating on the surface. Then take about two ounces of the best clear liquefied glue, and pour it into the pan. After bringing to the boil again 3 to 5 times the contents of the pan are poured into a porcelain basin and then covered. The (precipitated) solids should not be allowed to flow out together with the water. The basin must not be moved or else the chhi may leak away. It is put into a cool place overnight.

If the needle-like crystals (chhiang), lit. spears, which form look extremely fine and lustrious, (the salt-petre) is fit for use. If the crystals are not fine, or if they still have a salty taste, the chemical is not ready for making (gun)powder; and the above process should be repeated to refine (the salt-petre) once more.

Next Hui Lu mentions three methods of testing the nitrate. He says:

There are only three ways to test solve-stone (saltpetre). The needle-like crystals should be extremely fine, the colour should be very lustrous and the taste should be insipid. If the product is white and without lustre, the impurities have not all been removed. If one can test the crystals with the tip of the tongue and still finds them salty and tart, that is a sign that the salt has not all been removed. These two factors very often give rise to confusion and much harm can be caused as a result. However, saltpetre manufacturers often think in terms of profit and consequently it is very difficult to obtain purified saltpetre. But we can test the saltpetre by asking the manufacturer himself to hold the saltpetre (which he claims to be pure and genuine) on the palm of his hand and ignite it.

1. (18), p. 28.
2. (Turnip tissue is also referred to by Li Shih-Chen in the preparation and purification of Pn hoii, PTKM, ch. 11, p. 168. Probably Dracena roja.)
3. This was a convenient property as it enabled crystallisation to start on the bottom and at the sides of the vessel.
4. Glue and ‘edishes’ were mentioned by d’Incarrville (1) in +1765 in his account of the making of pure salt-petre in China.
5. Gledictis aiassic; cf. p. 115 below.
7. (Zapadae malvaceae). Glcier rite; cf. Vol. 6, pp. 2, 512 E.
10. Thudichum (1), pp. 155, 266. Also, of course, for clarifying wine.

* Cf. Hardy (1, a. g).
* Ch. 4. p. 44, b. The passage is almost identical with an earlier one in the Ping Lu of +1606 (ehi, p. 351). On the title see p. 35 above.
* It is interesting to note the term used here to denote the needle-like crystals of salt-petre. Obviously there was no technical term for these, and Hui Lu borrowed the word chhiang for this purpose. We have not found any dictionary which gives it the meaning it has here. In the Ping Lu the word chhiang is written with the ‘metal’ radical.
* Ch. 4. p. 514: tr. auct.
One should only (buy and) keep the saltpetre when it is found to burn on the palm without the hand becoming hot. Who would want to risk physical injury by thinking only about profit? This is (the third method) of testing saltpetre.

This passage has a distinctly more professional air than that of Sung Ying-Hsing, as might perhaps be expected. On the glue as well as the turnip extractives we have already remarked. The test of the hand, however, is something new, and must have been very widespread, since we meet with it again in +17th-century Syria, but China may well have been its home, like saltpetre itself, and now we shall give no more quotations in this sub-section, concluding it with a few words on India in comparison with the Arabic culture-area.

At what time saltpetre was first recognised, isolated and crystallised among the people of India remains obscure. At a guess, in view of their proximity to China, it can hardly have been later than the beginning of the +13th century, when the Arabs first understood the matter. On the other hand, the transmission of the knowledge from the Portuguese at the end of the +15thth seems much too late. The Chinese text of +664 about the wandering Šaka monk, just referred to, indicates clearly that saltpetre was well known and produced in quantity by that time in Wu-Chiang, i.e. Udyāna, a region of the high Indus valley near Gandhāra and Tokharestan; and by this time a Kushan or Šaka principality. But that is not really evidence for India.

Many years ago, Berthelot, translating a Latin MS. entitled Liber Secretorum Bubmacar, probably of the +13th century, conjectured that the 'Indian salt' named in a list of salts was saltpetre. Berthelot rightly identified the author as the great Abu Barkr ibn Zakariyā al-Rāzī (hence the title), and it was in fact more or less a translation of his systematic chemical treatise Kitāb Sīr al-Arār (Book of the Secret of Secrets), written about +910. When we look at the direct translation of this from the Arabic by Ruska, we find that in fact two salts are mentioned—'Chinese salt' as well as 'Indian salt'—if one remembers the date, either, or indeed both, of these, could have been saltpetre; but the descriptions

are not promising, for the Indian salt is 'black and friable, with very little glitter', while of the Chinese salt al-Rāzī said that 'all we know about it is that it is white and hard, and has a smell like that of boiled eggs'. On the whole, then, this suggestion of Berthelot's leads to a dead end.

And so does all the other evidence examined by Partridge, who carefully weighed the legendary attributions, the undatable books, and the earliest Indian technical terms of problematical meaning. There is no word in classical Sanskrit for saltpetre, thuraka being derived from the Persian sharāj. By +1526, the beginning of the Mughal (Mogul) Empire, there were plenty of guns and cannon in India, and therefore saltpetre for the gunpowder too, but that is much too late for our purpose; and before that time there seems to be little positive evidence for firearms other than Greek Fire and incendiaries. The crucial period, where future research will have to concentrate, lies between +1200 and +1400. In the meantime the obscurity remains.

All this indicates that between about +200 and +1200 the Chinese alchemists and pharmacists were slowly and painfully working out methods of isolating and purifying inorganic salts of many kinds, particular progress being made after the time of Thao Hung-Ching in +500, so that recognisable fairly pure saltpetre was available for the first gunpowder mixtures in the middle of the +9th century. By contrast the oldest Arabic mention of saltpetre occurs in the Kitāb al-Jāmi' fi Ad-Dhawāji yā Majrada (Book of the Assembly of Medical Simples) completed by Ibn al-Baitārī about +1240, after which many other mentions soon follow. There is, however, some reason to place the first knowledge of saltpetre among the Arabs in the first decades of that century, while the earliest account of its use in war, especially for making gunpowder, belongs to the last decades of the
same; this is the book of Hasan al-Rammāh which we have already described (p. 41 above). The passage of knowledge of saltpetre to the world of the Franks and Latins must have taken place quite soon after its first appearance among the Arabs, for as we also saw, Roger Bacon about +1260 knew of it, and the Liber Ignium followed on before the end of the century. The Westerners may not have called it 'Chinese snow', but the Arabs certainly did (thulūl al-Sin), and with great justice, for clearly it was recognised and prepared there long before anywhere else. This reason alone goes far to explain why China was the original home of all chemical explosives, starting with low-nitrate gunpowder.b

(6) Gunpowder Compositions and Their Properties

The word 'gunpowder', widely defined, should include all mixtures of saltpetre, sulphur and combustible material; but any composition not containing charcoal, as for example those which incorporated honey, may be termed 'proto-gunpowder'. Our word gunpowder arises from the fact that Europe knew it only for cannon or hand-guns. In China, however, prototype mixtures were known to alchemists, physicians, and perhaps fireworks technicians, for their deflagrative properties, some time before they began to be used as weapons. Hence the Chinese name for gunpowder, huo yao, literally 'fire-chemical' or 'fire-drug'.e One also has to note that although a couple of centuries of the earlier stage of proto-gunpowder occurred in China, it never appeared in Europe at all—this in itself is an argument of some weight for diffusion from Asia.

All the conditions necessary for the first discovery of gunpowder were present in China by Han times. Saltpetre, as we have seen, was then already known, and fully recognised by +500. Sulphur too appears in the +2nd-century Shen Nung Pên Tsiao Ching2 (Pharmacopoeia of the Heavenly Husbandman),d and in the natural history of Wu Phu3, the Wu Shih Pên Tsiao4 of about +235.e Charcoal was a substance commonly used in China from high antiquity. Alchemists there were also, busy from Chhin times onwards in the search for life-elixirs, which naturally involved the putting together of chemical products in all combinations and permutations. The only question is, when exactly these three substances were first mixed, and the incendiary or explosive property of the mixture realised. Since substances used in early time could not have been very pure, especially in the case of saltpetre, and also to some extent sulphur, one would rather expect the first Chinese mixtures to have been incendiary rather than explosive. But it is time to define our terms more clearly.f We may reasonably draw up a scheme of combustible substances on the following criteria, depending on the character of the combustion.

(1) Slow burning. The old incendiaries: oils, pitch, sulphur, etc., used doubtless on the earliest incendiary arrows, as well as by other methods of delivery. See pp. 75 ff. above, on shīh yu and the like.

(2) Quick burning. Distilled petroleum or naphtha (Greeek Fire, mēng huo yu), either hurled in breakable pots with fuses or projected from mechanical flamethrowers. Still basically incendiary, though more effective against personnel.

(3) Deflagration. Low-nitrate powders, containing (a) combustible material, or (b) charcoal as such. To deflagrate is to burn with a sudden and sparkling combustion, producing a 'whoosh' like a rocket; and indeed the nitrate proportion is increased these mixtures become suitable for rockets, as also for Roman candles, fire-lances (huo chhiang) or 'eruptors', as we shall call them when of large dimensions. They could project incendiary balls, poisoned smoke-balls, and pieces of broken pottery and metal; though again essentially incendiary, they were as flamethrowers still more offensive against enemy troops, though not very prolonged in action. But here enters in the beginning of gunpowder's propellant property, since it carried the rocket huo chien retroactively to its destination.g

(4) Explosion. This occurs with mixtures having higher proportions of nitrate, best with sulphur and charcoal alone as combustibles, but also sometimes in the presence of other substances such as arsenic. This may be termed 'weak explosion', giving the 'explosive puff', but if the firing is done in a closed space a considerable amount of noise can be produced, in fact a 'bang', and thin-walled containers of cast iron or other metal ('bombs', huo phao) can be broken by the explosion.

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a Cf. pp. 48, 39, above.
b As J. F. Davis well saw, (1), vol. 3, pp. 8 ff.
c We must not anticipate arguments the proper place of which is with transmissions (p. 508 below), but here it is impossible to overlook the fact that the earliest names for gunpowder in Europe, names which lasted long in the Germanic languages, denoted a plant-drug, i.e. (Germ.) krūt, (Dan.) krød, (Flem.) crép, etc. This was noted by Partington (5), pp. 93 ff., but he offered no comment on it. That the earliest European gunners (+1325 onwards) should have used a word meaning plant or plant-drug seems a coincidence passing strange unless it was a direct translation of yao. This might be considered a reason for thinking that some transmission came overland rather than by way of the Arabs. Cf. Nielsen (1), p. 208; Falk & Torp (1), pp. 513, 585.
d Ch. 2 (p. 57).
e PTKM, ch. 11 (p. 62). On sulphur-production methods in mediaeval China see Chang Yün-Ming (1).

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* What follows is based upon a conference which two of us (J. N. and W. L.) had with the late Professor J. B. Partington on the 18 and 19 July 1956. A somewhat more condensed version was published in Partington (5), p. 266.

† This is the point at which proto-gunpowder (in our terminology) turns into gunpowder.

‡ A typical composition might be (in percentages of saltpetre, sulphur and carbon) 60:10:30 (Malina). Blasting powders also belong in this region, a famous French formula having saltpetre as low as 40:30:30 (Davis (2), p. 48).

§ Throughout this volume we give percentages in the following order: N for saltpetre, S for sulphur, and C for carbon. This is the normal usage of explosives chemists (Partington (5), p. 374). It differs from that of the organic chemists, who use the order C:N:S for the ratio of the elements in organic compounds.

†† 火藥  ❄️ 銷礦本草  ❄️ 吳普  ❄️ 蘇氏本草
Detonation. When the nitrate content reaches the level of 'modern gunpowder', i.e. a suitably prepared mixture of saltpetre, sulphur and charcoal in the proportions 75:15:10, a 'bristling' explosion results upon firing. Metal containers burst with a loud noise, tearing and scattering, but leaving debris, and holes are blown in earth or masonry. The gunpowder is now a full propellant for projectiles launched from metal-barrel cannon or guns with walls of adequate strength (hao thang, hao chang). It is much too 'fast' for use in rockets.

The proportions of the components just given are those of 'service gunpowder', which has great propulsive force, but the 'theoretical' percentage figures are considered to be 75:13:12. This mixture, gradually attained through some ten centuries from a probable starting-point of equal quantities of the three constituents, constituted the first chemical explosive known to man. An explosion may be defined as a loud noise accompanied by the sudden going away of things from the places where they were before. An explosive substance of this classical type is something capable of giving rise to a sudden release of its own energy and a vast increase of its own volume; in black powder the nitrate, which constitutes built-in oxidizing power for the combustion, produces suddenly 3000 times its bulk of gas, giving off white smoke and including nitrogen, the oxides of carbon, and many salts of potassium in particular form. The temperature reached in the explosion is of the order of 3860°C. The intrinsic energy may of course be liberated without explosion, since black powder will burn when uncompressed or unconfined; in fire-crackers for instance the rupture of the container because of the evolved gases makes the noise that shocked Roger Bacon so much, not strictly the explosion of the powder. Indeed, in comparison with high explosives, some of which are not combustible at all, gunpowder always essentially burns, but it can do this at so fast a speed that it can generate veritable explosions.

In gunpowder it is the sulphur which lowers the ignition temperature to 250°C, and on combustion raises the temperature to the fusion point of saltpetre (335°C); sulphur also helps to increase the speed of combustion. The more the saltpetre the quicker the ignition and combustion are, and later on (p. 342) we shall document a continuous increase in the nitrate proportion which took place between the first warlike use of gunpowder in China in the 11th century, when the saltpetre hardly exceeded 50%, up to the 'theoretical' figure of 75%. Thus the development was consistent from the slower and less vigorous effects to the maximum explosive power. As for the charcoal, its physical state, grain size, degree of aggregation and surface area, all turned out to be of much importance. Often quoted is the aphorism of John Bate in +1654: 'The Saltpeter is the Soul, the Sulphur the Life, and the Coales the Body of it.' But still in his time the optimal nitrate content was only just being approached in Europe.

Proto-Gunpowder and Gunpowder

The legend of Berthold Schwartz was in China no legend. There really were at least six centuries of alchemic experimentation before the first gunpowder explosion, and here we must take a look at some of the records which have come down to us from these times. The climax of this alchemic prelude is found in one of the books in the Taoist Patrology (Tao Tsang) entitled Chen Yun Min Tao Yoo Lueh¹ (Classified Essentials of the Mysterious Tao of the True Origin of Things). This work details thirty-five elixir formulae or procedures which the writer considered wrong or dangerous, though some of them were popular in his time. At least three concern saltpetre, treated with quartz or blue-green rock³:

1. 水银
2. 火药
3. 炮竹

¹ p. 48 above.
² In Chinese fire-crackers the nitrate of the mixture is usually low, e.g. 86.6:16.4:6.8; Davis (17), pp. 111 ff. Of its ubiquity in Chinese culture we need say little; cf. Brewer (1), pp. 95-97.
³ Many attempts have been made to represent the explosion of gunpowder in a single, if complex, chemical formula, but we need not engage on this here; perhaps the best known is that of H. Debus in 1890. Several alternatives are possible, which is why there cannot be any definitive theoretical set of proportions, only a certain range.
⁴ Comparison is made on p. 330 below between Chinese and Western theories of gunpowder explosion.
⁵ We gave a fuller account of it in Vol. 3, pp. 5-9, but did not translate the key passages.
30. MILITARY TECHNOLOGY

Salt, and then the text goes on to say:

Some have heated together sulphur, realgar, and saltpetre with honey, smoke (and flames) result, so that their hands and faces have been burnt, and even the whole house (where they were working) burned down.

Evidently this only brings Taoism to discredit, and Taoist alchemists are thus warned clearly not to do it. These words are of local importance for our history, and their approximate date is therefore of much importance. The book is attributed to Chêng Yin (Chêng Ssu-Yuan) who lived between +220 and +300, the putative teacher of the prince of alchemists, Ko Hung, but very little of it can seriously be attributed to him. One modern scholar has placed it about the middle of the Wu Tai period, which would mean the neighbourhood of +930, but in view of military descriptions which we give elsewhere (pp. 80, 81, 85) this must be too late. Perhaps therefore the best date for our passage would be c. +850, and this we shall retain.

It so happens that we have a circumstantial account of an alchemical disaster, quasi-fictional though it may be, just about contemporaneous with the foregoing fundamental deflagration statement, or even a little earlier. Li Fu-Yen was a scholar from Kansu who was living and writing in +831, and in his Hsien Kuai Hsi Lu (Continuation of the Record of Things Dark and Strange) he tells the story of a young man named Tu Tzu-Chhung, a story which was taken up and reprinted in the Thai-Phing Kuang Chi collection. Tu was rescued from poverty by a strange old alchemist, in return for which he was called upon to help him in his elixir experiments. While the reactions in the stove were going on, he had to take certain drugs and meditate in front of a blank wall, but terrifying nightmares superimposed, including the apparent death of his own son, and although he

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1. The book also gives a text for saltpetre.
2. P. 30, tr. auct. Fêng Chia-Shêng was the first to notice the passage. (1), p. 42. (5), p. 38. That was in 1947, but our collaborator Tshao Thien-Chinh discovered it independently while working in Cambridge in 1950.
3. Arsenic disulphide.
4. The drier the honey was allowed to become the better it would be as a source of carbon in this experiment.
5. Perhaps not surprisingly, identical prohibitions occur in Europe, but in the late 1+13th century, not the 9th. As Berthelot (14), p. 604 pointed out, some versions of the Marcus Graecus text have the warning: ‘Caveas ne flamma tangan doctum vel tectum’ (Beware lest the flames set the house and roof on fire!). And there is another statement: ‘Hac autem sub testo fiet prohibenter quidam periculum imminens’ (It is forbidden to make this (mixture) under a roof, because of the danger). Such parallels are very noteworthy; cf. Partington (5), p. 45.
7. Pu-Tung-Wên (i). Besides Chang historical references, he discovered quotations from Yun Lo Tzu (the Smoky Vine Master), whose juan was Wu Tai, +936 to +943. But these could have been later interpolations. Apparently also there was a Chêng Ssu-Yuan in the +10th century. But he was not necessarily the real author. The doubts of Ong are shared to some extent by Kuo Chêng (1) and Wang Hui-chy Kho & Chu-Shêng (i).
8. TPK, ch. 16, pp. 118. (vol. i, pp. 132-3). We gave an fuller account of the proceedings in Vol. 5, pt. 3, p. 490, but we did not enlarge on the final explosion. It was Fêng Chia-Shêng (i), p. 45, who first saw the significance of it.

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30. THE GUNPOWDER EPIC

had been strictly warned not to make any sound.

as he awoke from his terrible visions near daybreak he cried out ‘alai!’, and then saw purple flames already enveloping the house. Fierce flame burst forth from the chemical furnace (yao lu), and set light to all the rooms around the courtyard. The foreign Taoist jumped into a water-butt and disappeared. Previously he had said that whatever the emotion and temptations the young man should say absolutely nothing, but in the end he had not been able to contain himself.

So again this seems like an account of some deflagrative composition. Perhaps the Taoist had been mixing saltpetre, sulphur and some source of carbon.

When could we find the earliest account of saltpetre and sulphur together in an alchemical process? The answer could be in the neighbourhood of +300, for the Pao Pha Tzu book of Ko Hung, already mentioned, has this in one of his purificative procedures. It is worthwhile while giving the recipe in full, since we have not before done so. The text reads:

Child's-play Method for making alchemical Gold (Hsiao erh tsu huang chihn-fa);

Prepare one iron cylinder 12 in. in diameter and 12 in. deep, and another smaller one 6 in. in diameter and highly polished. Grind and sieve 1 lb. of (dry) red bole clay, saltpetre (hsiao shih)?, mica, red haematite and calcareous spar, and mix them with 1 lb. of sulphur and 4 oz. of laminar malachite. Make the powder into a paste with vinegar. Then coat the interior of the small cylinder with it to a thickness of 6th of an inch. Take 1 lb. of mercury and 1/2 lb. each of cinnabar and lead amalgam… Mix these thoroughly together with the mercury until (globules) are no longer visible, then place the material in the smaller cylinder and cover over with mica, closing it with an iron lid. Place the smaller cylinder within the larger one, set them both on a stove, and pour in enough molten lead to cover the smaller container and reach within 1 in. of the brim of the larger one. Then heat over a raging fire for three days and three nights. What forms is called 'purple powder' (tsu fen).

Seven inch-square spatulae of this, used for projection, will immediately turn 10 lb. of molten lead into gold; but the lead must have been held in the liquid state for 20 days beforehand in an iron vessel, and transferred to a copper vessel for the projection. Again, three inch-square spatulae of the same purple powder will at once turn heated mercury in an iron vessel to silver.

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* There are plenty of accounts of alchemical explosions in the literature, but of course one can never be sure that mixtures of the gunpowder type were concerned, though very probably they sometimes were. For example, in a book entitled Kui Tung (The Control of Spirits), written by a Mr Shen probably about +1185 but not printed till +1218, there is a discussion between a doughty soldier Wei Tzu-Tung and his friend Tsan Kung-Chuang about ghosts and apparitions, weird animals, and Taoist alchemical laboratories in caves, such as those of Thoai-pai Shan, where they were talking. The story was that a certain Thang alchemist had experienced an explosion in which the furnace was blown asunder by the blast (yao ting pao hou). If the tradition was trustworthy it could well have been someone playing about with saltpetre, sulphur and sources of carbon.


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What was really happening here is anyone's guess, and only a repetition under laboratory conditions could decide. Of the 7½ lb. of reactants, only 1 lb. were nitrate and sulphur, and although some carbon would have been present in the form of the carbonates of calcium and copper, it is unlikely that any fireworks would have resulted. Too many other elements were present—aluminium, silica, and iron, with probably small amounts of chromium and manganese. The lead would have held the temperature between 325°C and 1900°C, while the heated mercury would have been below 360°C. What the purple powder was remains uncertain, but one thing is certain—sulphur and saltpetre were both ingredients in an alchemist's formula at the beginning of the 14th century. If this was to be pursued, the spagyrical masters would infallibly hit one day, "accidentally" it would be said, upon the inflammable nature of proto-gunpowder.

But more still, we can find in the "Pao Phu Tsu" book a combination of the three essential constituents, nitrate, sulphur and carbonaceous material. This occurs in a process for getting elementary metallic arsenic, the passage on which, misunderstanding by all translators so far, has now been elucidated by Wang Khuei-Kho & Chu Sheng (i). After saying that reaglar (hsiang huang), arsenic sulphide, can at need be consumed in hot water or wine, Ko Hung goes on to direct three treatments, with recrystallised saltpetre (hsiao shih), with (dried and powdered) large intestine of the pig (chu tung) heated in a red clay stove, and finally with pine resin (sung chik). Then come the words: "If you transmute with this three things, (arsenical vapours) will arise like wisps of cloth, and (arsenic) sublimes as white as ice". Two separate points arise here also, first the earliest question of the preparation of pure metallic arsenic, but second, more important for us here, the fact that the three gunpowder components are present all at once. No mention of a deflagration, or the possibility of one, is made by Ko Hung, but perhaps the presence of that danger was why he may have done it in three steps. Saltpetre oxidises the sulphide to arsenious oxide, "white like ice", and then the carbonaceous materials reduce this to volatile elementary arsenic. Perhaps it might not be too far-fetched to trace back the persistent inclusion of arsenic in later Chinese gunpowder compositions to ancient experiments of this kind.

We must next come down to a period between Ko Hung and the Taoist who warned of the danger of the proto-gunpowder mixture. The Chu Chia Shen Phin "Tan Fa" (Methods of the Various Schools for Magical Elixir Preparations) is a collection made at some time during the Sung (i.e. after +960), but it assembled many recipes of much earlier dates. No name of principal author or compiler is given. Here in one place we find a "Process in the Elixir Manuals for the subduing of Sulphur" ("Tan chang nei tzu liu huang fa"). It reads as follows:

Take of sulphur and saltpetre (hsiao shih) 2 oz. each and grind them together, then put them in a silver-melting crucible or a refractory pot (sha kwan). Dig a pit in the ground and put the vessel inside it so that its top is level with the ground, and pack it round with earth. Take three perfect pods of the soap-bean tree (tsao chik), uneaten by insects, and char them so that they keep their shape, then put them into the pot with the sulphur and the saltpetre. After the flames have subsided close the mouth and place 5 lb. of glowing charcoal on the lid; when this has been about one-third consumed remove all of it. The substance need not be cool before it is taken out—it has been "subdued by fire" (fu huo).

What this meant was that chemical changes had taken place giving a new and more stable product. As we remarked when we first discussed the passage, this operation seems to have been designed to produce potassium sulphate, and was therefore not in itself very exciting, but on the way Sun Sun-Mo (or whoever it was) stumbled upon a truly deflagratory mixture, later to lead to veritable explosions.

The attribution is in fact a little difficult. The process as it stands is anomalous, but the one before it carries the name of Huang San Kuan-jen (His Excellency Huang Territius), about whom nothing is known, and the one before that is given the name of the great Sui alchemist and physician Sun Sun-Mo (+581 to +682). If Sun was responsible for the soap-bean pods the date of the receipt would be about + 650. The belief that he was is strengthened by another which...
appears on the previous page, attributed to the Holy Immortal Sun, almost certainly Sun Ssu-Mo. This mixes an ounce each of saltpetre and sulphur with half an ounce of borax (tincal, sodium borate, ophobic sulphur), a combination which would be inflammable though hardly deflagrative; here again simple laboratory tests would settle its properties. Even if Sun himself was not responsible for these sulphur-saltpetre contiguities, there were still two centuries to run before +850, and their rather archaic nature must place them then in the +8th or at latest early +9th century.

From this latter time there comes another instance of our theme, found in the Chhien Hung Chia King Chih Pao Chi Chheng4 (Complete Compendium on the Perfect Treasure of Lead, Mercury, Wood and Metal)5, compiled by Chao Nai-An7 about +808. In this work there is a 'Method of Subduing Alum (or Vitriol) by Fire' (fu huo fan fa)6; it involved mixing together 2 oz. each of saltpetre and sulphur with 0-55 oz. of dried aristolochia (ma lou ling)7. With the carbon present in such a form the preparation would have ignited suddenly, bursting into flames but not actually exploding—as indeed Fêng Chia-Shêng & Li Chhih-Ping were able to show by actual experiment. Thus one may say that the whole succession hangs together, from Ko Hung's use of saltpetre and sulphur mixtures (and probably some of the late Han alchemists had done it before him) through Sun Ssu-Mo and Chao Nai-An to the warnings of the mid +9th century, and then the application of the 'fire-drug' in war at the very beginning of the +10th, finally the printed compositions in the Wu Ching Tsung Yao dating from the early +11th.

Before examining these, however, we should take another look at the rather curious appellation 'fire-drug' (huo yao)6, for it has a background the significance of which has already been hinted at (p. 6). The word yao originally meant a drug-plant or plant drug, but medicines of mineral and animal origin were always included in the Chinese pharmaceutical natural histories, from the Shen Nung Pen T'ao Ching onwards. Hence it came to mean for the alchemists any chemical or 'fire-chemical' equally well. It indicates clearly that those who first occupied themselves with it, indeed those who discovered it, were Taoist alchemists and physicians rather than military men. Thus its appearance as a medicine in the Pen T'ao Kang Mu of +1596 was quite in character. Li Shih-Chen wrote.8

Gunpowder has a bitter-sour sapidity, and is slightly toxic. It can be used to treat sores and ringworm, it kills worms and insects, and it dispels damp chi and hot epidemic fevers. It is composed of saltpetre, sulphur and pine charcoal, and it is used for (making) various (incendiary and explosive) preparations (yao) for beacon-fires, guns and cannon (feng cui chung (fa-long) chi).9

There was thus no sharp line of distinction between medicines, drugs and chemicals; and the technical term betrays the centuries of medico-alchemical work which preceded the adoption of the mixture in war—in China, that is to say, since in the Western world gunpowder appeared full-fledged. Indeed, when physiological alchemy (net tan)7 tended in China to replace chemical laboratory alchemy (wai tan), the phrase huo yao was taken over in connection with the formation of 'inner elixirs' or enchyromas. Lastly, the alchemists' secrecy injunctions of those centuries have often been remarked on, and this must have operated with particular force when a dangerous substance had been discovered. And the relations of the Taoists with the military were quite close, as is shown, for example, by the authorship of the Thai Pai Yin Ching, by the titles of many military manuals in the bibliographies of the dynastic histories, and by the names of military formations which often conformed to Taoist cosmological lore.

(ii) The Sung formulae

It would have been around the year +1040, during the life of William the Conqueror, that Tsêng Kung-Liang and his assistants were writing down the first gunpowder formulae to be printed and published in any civilization, though evidence already given (pp. 80, 111) shows that the essentials of the mixture must have been known and used for at least a century previously. In the Wu Ching Tsung Yao there are three of these formulae, first for a quasi-explosive bomb to be shot off from a trebuchet (huo phao yao), secondly a bomb with hooks attached so that it would fasten itself to any wooden structures and set them on fire (chi huo chhiu), and thirdly a poison-smoke ball which would attack the enemy chemically (tuo yao yen chhiu). To these we can add a formula

1 The point was strongly made by Fêng Chia-Shêng (2), p. 31.
2 Ch. 11, p. 50a (p. 78), tr. auct.
3 On the last item see p. 96 below.
4 All, so often, in the form of powders.
5 This is fully explained in Vol. 5, pp. 2. It should be emphasised that this is the only context where the 'pyrrhotic drug' has any meaning other than gunpowder. Cf. p. 7 above.
7 These points were well put by Fêng Chia-Shêng (1), p. 43. Cf. p. 19 above.
8 Ch. 11, p. 50a (p. 78), tr. auct.
9 Ch. 11, p. 50a (p. 78), tr. auct.
for another poisonous mixture probably intended to accompany a gunpowder-containing missile, which would provide the flame necessary to dissipate it as a smoke. It has been suggested that the relatively high content of sulphur betrays the origin of these projectiles from simple incendiaries, but in fact the sulphur is not particularly prominent in them; carbonaceous materials other than charcoal form the main bulk, though charcoal itself is generally specified—what betrays the incendiary origin is surely rather the pitch and the various oils. Although we cannot deny the name of gunpowder to these compositions, it is still at a very low-nitrate level, deflagrative and incendiary rather than explosive. Later on we shall trace the rise in saltpetre content as the years and battles went by.

The first specification (Fig. 9) is called simply ‘Method for making the fire-chemical’ (huo yan fa), and it lists the following ingredients:

\[
\begin{align*}
\text{oz.} & \\
\text{Chin-chou sulphur}^a & 14 \\
\text{wu huan}^b (\text{perhaps nodular sulphur})^c & 7 \\
\text{saltpetre} (jen huan) & 40 \\
\text{hemp roots} (ma ju) & 1 \\
\text{dried lacquer} & 1 \\
\text{arsenic} (phi huan)^d & 1 \\
\text{white lead} (ping fu)^e & 1 \\
\text{bamboo roots} (chu ju) & 1 \\
\text{minium} (huang tan)^f & 1 \\
\text{yellow wax} & 0.5 \\
\text{clear oil} & 0.1 \\
\text{tung oil} & 0.5 \\
\text{pine resin} & 14 \\
\text{thick oil} & 0.1 \\
\hline
\text{total} & 82.2 \\
\end{align*}
\]

\*a Chao Thieh-Han (7), p. 10.
\*b WCTFH, ch. 12, p. 37; 20, 3 in. sunt.
\*c The original figures are given in chih (3.5 lb.); duan (1 lb.); kung (oz.) and fen (tenths of an oz.), but we reduce them all to ounces for the sake of uniformity and simplicity.
\*d In Sung times this was the name of a city in Shantung, where there are indeed good sulphur deposits.
\*e This seems to be a typographical error, for the phrase ‘nest yellow’ cannot be found in any dictionary or reference work. It seems that ‘chicken’s nest yellow’ (zi kuo huan) was a synonym of huan huan, realgar (arsenic disulphide), see JPTM, ch. 2, p. 84, but we suspect that some kind of sulphur was meant here.
\*f Probably one of the sulphides rather than one of the oxides.

Lead carbonate.
Lead arsenate; old lead.
From disulphides, ferric.

\*It will be noticed that the weight generally totals about 80 oz. (5 lb.)
The text then explains that the sulphur and saltpetre are to be pounded together and passed through a sieve, the arsenic, white lead and minium are ground together, the dried lacquer is pounded separately to a powder, the bamboo and hemp roots are slightly roasted and then comminuted to a powder, finally the yellow wax, pine resin, and the three sorts of oil are boiled together into a pasty mass. All the powders are then introduced into the thick soupy material, with constant stirring until evenly suspended. The resulting mass is wrapped into a ball with five layers of paper, tied up with hemp string, and covered with melted pine resin. The bomb is then ready to be discharged by a trebuchet (phao).

What did this mean in terms of percentage composition of saltpetre, sulphur and carbonaceous material? As in the other cases which we shall be examining, it depends upon what constituents (apart of course from the inorganic ones) are included. So we can tabulate the first formula as follows:

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>S</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ditto, assuming that ,oo Huang is sulphur</td>
<td>55.4</td>
<td>19.4</td>
<td>25.2</td>
</tr>
<tr>
<td>Ditto, assuming that</td>
<td>50.5</td>
<td>26.2</td>
<td>23.6</td>
</tr>
</tbody>
</table>

Some writers have obtained higher saltpetre percentages by noting the absence of charcoal, or by taking the plant roots as the only available carbon, but this is surely inadmissible. Others have followed the second alternative, while others again have avoided percentage calculations. In any case, the fact that there is no charcoal as such in the formula means that we must call it proto-gunpowder; and like all the others in the Wu Ching Tung Yao, its function must have been primarily incendiary, though no doubt it burnt with a fierce deflagration.

The second gunpowder formula (Fig. 10) is for 'thorny fire-balls' (chi li hou chiou or hou chii), which took their name from the calthrop or the water-calthrop, plants the fruits of which have spines or horns. Derivatively, the calthrop in military parlance is an instrument with four or more spikes disposed in a triangular form so that when three of them are on the ground the others will point upwards to wound the feet of horses and men. In the present case (Fig. 17) the spikes were shaped like hooks or arrow-heads, designed to catch on to

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* Nothing is said of a fuse, but there must have been one, for the artillerist to light before despatching the missile. The text says 'for attacking gates'.
* E.g. Chao Theih-Han (r), p. 10.
* Ho Ping-Yü (priv. comm.).
* Arima (7), p. 43; Partridge (5), p. 273; and ourselves formerly.
* Wang Ling (1); Davis & Ware (1), p. 294.
* WCTY/CC, ch. 12, p. 65a, b., tr. auct.
* Tribulus terrestris, R 664, Stuart (1), p. 441.
* Tribus patina, R 243; the ling or chi chi.
* Cf. Wang Chung-Shu (1), p. 123 and fig. 156.
objects and set them alight. The preamble says that the device has three hooks and six iron knives, inside the frame of which the gunpowder is enclosed in paper bound with hempen string, and finally eight iron calthrops are attached, each with fine backward-pointing prongs. At the time of firing a red-hot iron brand is thrust in, and as the ball begins to blaze it is shot off from a trebuchet. Furthermore, when all the constituents of the inner ball have been melted together, they are wrapped up in many layers of paper tied with hemp, and a coating of the second mixture plastered over it. Here are the listed ingredients:

<table>
<thead>
<tr>
<th>Inner ball</th>
<th>oz.</th>
</tr>
</thead>
<tbody>
<tr>
<td>sulphur</td>
<td>0.2</td>
</tr>
<tr>
<td>saltpetre</td>
<td>0.2</td>
</tr>
<tr>
<td>coarse charcoal powder</td>
<td>0.2</td>
</tr>
<tr>
<td>pitch (li chhing)</td>
<td>0.2</td>
</tr>
<tr>
<td>dried lacquer, pounded to a powder</td>
<td>0.2</td>
</tr>
<tr>
<td>bamboo roots</td>
<td>0.2</td>
</tr>
<tr>
<td>hemp roots, cut into shreds</td>
<td>0.2</td>
</tr>
<tr>
<td>tung oil</td>
<td>0.2</td>
</tr>
<tr>
<td>lesser oil (hsiao yu)</td>
<td>0.2</td>
</tr>
<tr>
<td>wax</td>
<td>0.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outer coating</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>paper</td>
<td>1.25</td>
</tr>
<tr>
<td>hemp (fibre)</td>
<td>0.1</td>
</tr>
<tr>
<td>minum (red lead)</td>
<td>0.1</td>
</tr>
<tr>
<td>charcoal powder</td>
<td>0.1</td>
</tr>
<tr>
<td>pitch</td>
<td>2.5</td>
</tr>
<tr>
<td>yellow wax</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Calculating the percentages we find the following figures:

<table>
<thead>
<tr>
<th>If inner ball alone considered</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>50-2</td>
</tr>
<tr>
<td>S</td>
<td>25-1</td>
</tr>
<tr>
<td>C</td>
<td>24-7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>If outer covering included</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>all carbonaceous matter being taken</td>
<td>54.7</td>
</tr>
<tr>
<td>taking charcoal specified alone</td>
<td>27.4</td>
</tr>
</tbody>
</table>

Here Chao Thieh-Han and Ho Ping-Yü, omitting all the non-charcoal carbon, obtained approximately the result on the second line, while Partington preferred

<table>
<thead>
<tr>
<th>Table 30.1: The Gunpowder Epic</th>
<th>oz.</th>
</tr>
</thead>
<tbody>
<tr>
<td>sulphur</td>
<td>1.5</td>
</tr>
<tr>
<td>blaze-solve (saltpetre, yen hsiao)</td>
<td>3.0</td>
</tr>
<tr>
<td>aconite (tsiao tung thou)</td>
<td>5</td>
</tr>
<tr>
<td>croton oil (pa tou)</td>
<td>5</td>
</tr>
<tr>
<td>wolfsbane (lang tu)</td>
<td>2.5</td>
</tr>
<tr>
<td>tung oil</td>
<td>2.5</td>
</tr>
<tr>
<td>lesser oil (hsiao yu)</td>
<td>2.5</td>
</tr>
<tr>
<td>charcoal powder</td>
<td>5</td>
</tr>
<tr>
<td>pitch (li chhing)</td>
<td>2.5</td>
</tr>
<tr>
<td>arsenic (phi shuang)</td>
<td>2</td>
</tr>
<tr>
<td>yellow wax</td>
<td>1</td>
</tr>
<tr>
<td>bamboo roots</td>
<td>1.1</td>
</tr>
<tr>
<td>hemp roots</td>
<td>1.1</td>
</tr>
</tbody>
</table>

the third, and Arima adopted the first, as we ourselves originally did. Since the function of the device was essentially incendiary, it may be that the third line is the best conclusion. Although the nitrate-content is in this case so low, the name of true gunpowder cannot be withheld because a considerable quantity of charcoal was present; and it would be reasonable to compare the figures on the first line with those established just above for the incendiary bomb of proto-gunpowder.

With the third formula we enter the field of chemical, or at least pharmacological, warfare, in its medieval manifestation. It is called ts u yao yen chhia (poisonous smoke bomb), and appears in the previous chapter, which has a section entitled huo kung (attack by fire). According to the preamble about ordinary non-toxic smoke bombs, the inner core weighing 3 lb. is to be of a gunpowder composition thickly plastered over with about 1 lb. of yellow hao tinder (huang hao i tu) as a wrapping. But the poison-smoke bomb core, after being thoroughly mixed and made into a ball tied up with 12.5 ft. of hemp string, is to have a different coating, as specified in the table, almost identical with that of the preceding formula. At the time of firing, the ball is ignited by means of a red-hot iron brand pushed in, and then quickly shot off. The ingredients are as follows:

<table>
<thead>
<tr>
<th>Inner ball</th>
<th>oz.</th>
</tr>
</thead>
<tbody>
<tr>
<td>sulphur</td>
<td>0.2</td>
</tr>
<tr>
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<td>3.0</td>
</tr>
<tr>
<td>aconite (tsiao tung thou)</td>
<td>5</td>
</tr>
<tr>
<td>croton oil (pa tou)</td>
<td>5</td>
</tr>
<tr>
<td>wolfsbane (lang tu)</td>
<td>2.5</td>
</tr>
<tr>
<td>tung oil</td>
<td>2.5</td>
</tr>
<tr>
<td>lesser oil (hsiao yu)</td>
<td>2.5</td>
</tr>
<tr>
<td>charcoal powder</td>
<td>5</td>
</tr>
<tr>
<td>pitch (li chhing)</td>
<td>2.5</td>
</tr>
<tr>
<td>arsenic (phi shuang)</td>
<td>2</td>
</tr>
<tr>
<td>yellow wax</td>
<td>1</td>
</tr>
<tr>
<td>bamboo roots</td>
<td>1.1</td>
</tr>
<tr>
<td>hemp roots</td>
<td>1.1</td>
</tr>
</tbody>
</table>

### Table 30.1: The Gunpowder Epic

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
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<td>1.5</td>
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<tr>
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<td>3.0</td>
</tr>
<tr>
<td>aconite (tsiao tung thou)</td>
<td>5</td>
</tr>
<tr>
<td>croton oil (pa tou)</td>
<td>5</td>
</tr>
<tr>
<td>wolfsbane (lang tu)</td>
<td>2.5</td>
</tr>
<tr>
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</tr>
<tr>
<td>lesser oil (hsiao yu)</td>
<td>2.5</td>
</tr>
<tr>
<td>charcoal powder</td>
<td>5</td>
</tr>
<tr>
<td>pitch (li chhing)</td>
<td>2.5</td>
</tr>
<tr>
<td>arsenic (phi shuang)</td>
<td>2</td>
</tr>
<tr>
<td>yellow wax</td>
<td>1</td>
</tr>
<tr>
<td>bamboo roots</td>
<td>1.1</td>
</tr>
<tr>
<td>hemp roots</td>
<td>1.1</td>
</tr>
</tbody>
</table>

### Notes:

1. This is again a mysterious item, but probably edible oil from small beans of some kind as opposed to soya beans.
2. This is from *Cochlium fischeri*, R. 353.
4. This is from *Cochlium fischeri*, R. 353, a composite allied to *Artemisia argyi*, the source of the celebrated moss tinder (cf. Burkhill 1, vol. 1, pp. 243 E., 247). Lu Gwei-Djen & Needham, p. 1, p. 170 f. Both these plants have hairless leaves of which contribute to the tinder texture when dried, powdered, compounded, and again dried to evaporate the oil. This was an ingenious device, for the glowing tinder would have acted as a fuse, igniting the gunpowder only when it was nearing its destination.
5. *Acacia fischeri*, R. 353.
8. In focuses on *Artemisia argyi*, R. 353.
be heated to boiling (or perhaps on a boiling water-bath) and filled into stoppered bottles or containers each holding about 20 oz. for storage and use. These were to be fired from trebuchets, and presumably along with one of the gunpowder mixtures to make the material into a smoke when the container broke on impact. The ingredients were as follows:

<table>
<thead>
<tr>
<th></th>
<th>oz.</th>
</tr>
</thead>
<tbody>
<tr>
<td>human faeces</td>
<td>24 oz.</td>
</tr>
<tr>
<td>powdered and</td>
<td></td>
</tr>
<tr>
<td>sifted very</td>
<td></td>
</tr>
<tr>
<td>fine</td>
<td></td>
</tr>
<tr>
<td>wolfsbane</td>
<td>8</td>
</tr>
<tr>
<td>aconite</td>
<td>8</td>
</tr>
<tr>
<td>croton oil</td>
<td>8</td>
</tr>
<tr>
<td>soap-bean</td>
<td>8</td>
</tr>
<tr>
<td>(pods, tsao</td>
<td></td>
</tr>
<tr>
<td>chiao)</td>
<td>8</td>
</tr>
<tr>
<td>arsenious</td>
<td>8</td>
</tr>
<tr>
<td>oxide</td>
<td></td>
</tr>
<tr>
<td>arsenic sulphide</td>
<td></td>
</tr>
<tr>
<td>cantharides</td>
<td>4</td>
</tr>
<tr>
<td>(fen ma)</td>
<td></td>
</tr>
<tr>
<td>lime</td>
<td>16</td>
</tr>
<tr>
<td>(shih hui)</td>
<td></td>
</tr>
<tr>
<td>tung oil</td>
<td>8</td>
</tr>
<tr>
<td>(Perilla oil,</td>
<td></td>
</tr>
<tr>
<td>fen yu)</td>
<td></td>
</tr>
</tbody>
</table>

The whole amount was thus 19.75 lb. The use of faeces as the vehicle was presumably to diffuse a disagreeable dust; the main content would have been indigestible material such as cellulose, but enough skatol and indol compounds could have been present to make it stink. One should remember that human manure had been used in Chinese agriculture from time immemorial, so the medium was not far-fetched—what mattered were the poisons. The description says that the furnes of the formula, good for use in attacking cities, would penetrate the chinks of iron or other armour causing severe irritation and blistering. If the artilleryists firing it off stuck black plums (wu ma)\(^a\) and Chinese liquorice (kuan tshao)\(^b\) they will be protected against the poisons.

It seems that the history of ancient and medieval poison-smokes has not yet been written, but it is easy to find a number of European 15th-century examples of gunpowder-smokes containing arsenic.\(^c\) Perhaps the nearest parallel to the Chinese use of plant poisons in toxic fogs occurs in the Arsacidae,\(^d\) but it must be old, though whether it was there in the oldest versions would be hard to say.

---

\(^a\) One chhing\(^a\), i.e. 15 lb.  
\(^b\) Glaucidia sinensia, R 387.  
\(^c\) Myristica echinata (R 29), not the same as the blister-beetle of Europe.  
\(^d\) If not from Alnus petraea (R 321), fen tung, this must be from Perilla nummifera (R 135), fen fen.  
\(^e\) Fruits of Prunus mume, smoked when half-ripe (Stuart (1)), p. 355.  
\(^f\) Glycerite galea, R 391.  
\(^g\) Partington (5), pp. 149, 158, 160. A formula of 1437 has 11.6% arsenic and 34.8% saltpetre, with sulphur, charcoal and much resin.  
\(^h\) Tr. Shamsabyn (1), pp. 441–2.
The recognition of gunpowder as a strategic war material already in the 11th century is reflected in the prohibitions of the export of the explosive and its raw materials to the Chihhian Tartars during the Northern Sung period. In modern terms one might say that the Sung government was apprehensive of the proliferation of gunpowder weapons. For example, the Sung Shi Hsueh tells us that in +1067 the people of the Ho-tung and Ho-pei prefectures were forbidden by edict to sell to foreigners any sulphur, saltpetre or t'ou kan shih. Similarly, in +1076 an order was issued banning all private transactions in sulphur and saltpetre, for fear of their being smuggled out across the border. This suggests the existence of a fairly large production by private enterprises, against which the government would have wanted to retain a monopoly. Curiously enough, some six hundred years later the attempt to deny sulphur and saltpetre to ‘foreigners’ was made again; in a time of troubles the Miao people in the South-west, it was memorialised that the constituents of gunpowder should be withheld from them. But the enlightened Chhian Hsi emperor would not agree, for he knew that they depended on gunpowder for their livelihood by hunting game, and such an embargo would only make matters worse.

Finally, Chang Yün-Ming (1) has brought forward evidence to show that the sulphur used in Chinese gunpowder in and after the +11th century was mostly not native, but rather that produced by the roasting of iron pyrites (tzu-jan thang), or ‘fool’s gold’), converting the sulphide to the oxide. There is a well-known illustration of the process in Thien Kung Kais Wu (+1637) showing how the ore was piled up with coal briquettes in an earthen furnace with a kind of still-head to send over the sulphur as vapour, after which it solidified and crystallised.

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* History repeated itself when in the +16th and +17th centuries the Papacy made great efforts to prohibit the export of gunpowder and metals to the Turks from Chemnitz. This was bitterly ignored by the English and the Dutch, as indeed also by Venetian and Genoese, more interested in trade than theology. Cf. Parry (1), pp. 225-6; Petrovich (1), p. 176.
* Ch. 86, p. 234; Flog Chia-Shing (1), p. 53.
* Mod. Shanghai and Hongkow.
* Hsi Tzu Chih Thang Chien Chihang Fuhe, Hsia-Ning reign-period, 16th year.
* Tsin Chia-Wu (1) has given us an interesting study of the trade between the Sung and the Liao (Chhian Tatars). In +1067, the export of sulphur and saltpetre to them was so preponderant that it had to be heavily taxed. In +1089 they had bought and translated many medical books; the sale of horses was prohibited in +1094 because they were reaching the Hsi-Hua people through the Liao, and in +1095 all export of copper and iron to the Uighurs was stopped. But Tsao Lin came and went freely, propagating a knowledge of wrestling—among other things.

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30. THE GUNPOWDER EPIC

In July +1719, John Bell of Antermony, a Scottish gentleman and a medical graduate of Glasgow, set out for China from Moscow as physician to the embassy from His Most Czarish Majesty to the Court of Peking which His Excellency Leof Vassilievitch Ismatol was undertaking. The account which Bell afterward wrote of his travels is one of the classics of the kind. It is relevant here because of certain conversations which took place during the residence of the embassy in Peking. Let us quote:

In January +1721, the [Khang-Hsi] Emperor’s general of the artillery, together with Father Friedel, and a gentleman, called Stadlin, an old German, and a watchmaker, dined at the ambassador’s. He [the general] was, by birth, a Tartar; and, by his conversation, it appeared he was by no means ignorant in his profession, particularly with respect to the various compositions of gunpowder used in artificial fire-works. I asked him, how long the Chinese had known the use of gunpowder? He replied, above two thousand years, in fire-works, according to their records; but that its application to the purposes of war, was only a late introduction. As the veracity and candour of this gentleman were well known, there was no room to question the truth of what he advanced on this subject.

The conversation then turned on printing. He said, he could not then ascertain, precisely, the antiquity of that invention; but, was absolutely certain, it was much an earlier than that of gunpowder. It is to be observed, that the Chinese print with stamps, in the manner that cards are made in Europe. Indeed, the connection, between stamping and printing, is so close and obvious, that it is surprising that the ingenious Greeks and Romans, so famous for their medals, never discovered the art of printing...

Next day, the ambassador and his train had a private audience of the Emperor, which lasted more than two hours. Khang-Hsi talking very affably and familiarly on many subjects, especially history, chronology, and inventions.

The Emperor also confirmed most of the particulars, mentioned above, concerning printing and gunpowder. It is from the holy scriptures, most part of which have been translated by the missionaries, that the learned men, in China, have acquired any knowledge of the Western ancient history. But their own records, they say, contain accounts of transactions of much greater antiquity.

Later, on the last day of January and the Chinese New Year on 1st February, the members of the embassy witnessed magnificent imperial firework displays,
which were much admired by John Bell. They far surpassed, he said, anything of
the kind which he had seen before, even though he had been present at perform-
ances exhibited by the best artists of Europe.

The following day, the Emperor gave the ambassador a private audience, and inquired
how he liked the diversions and fire-works. On this occasion, the Emperor repeated what
had been already observed concerning the antiquity of illuminations composed of
gunpowder; and added, that, although fire-works had been known in China for more than
two thousand years, he himself had made many improvements upon them, and brought
them to their present perfection.8

These fragments of conversation in eighteenth-century Peking may give us a
clue which is important here. They may indeed have been at the origin of that
persistent and erroneous cliché in the Western world already mentioned (p. 14),
which averred that gunpowder had been known in China for many centuries,
but used only for recreational purposes, before it was employed in war.9 And yet
the Chinese scholars of Kang-Hsi’s time were quite right in thinking that there
had been fire-cracker explosions ever since the Han period, that is to say, eight
centuries at least before the formulae of the Wu Ching Tsung Yao. The fact is that
in China there were explosions long before there were gunpowder explosions.

What depended on was the ubiquitous bamboo. Air is contained between
the septa of the stalk, and if it is thrown upon a fire, the segment will explode
with a loud report. Even if longitudinal slices are put in a fire they will emit
noisy cracks, but the explosion of the heated air between the nodes is what really
makes a fire-cracker.10 The packing of gunpowder into small containers,11 when it
came in, was simply a way of imitating the scaring sounds originally emitted
by burning bamboo. It must be remembered that in Chou and Warring States
times, before the invention of paper, writing was done on silk or on slips of
bamboo. The characters were first written on green bamboo, for easy erasure,
and then the bamboo was dried over a fire; this was the origin of the phrase sha
ching12, ‘killing the green’, applied to the making of documents. The phe-
omenon of the cracking of bamboo must therefore have been very familiar in
ancient China.

If the Shen I Ching13 (Book of the Spiritual and the Strange) was really written
by Tunfang Shuo14 in the 2nd century, then it might really be the oldest reference
to the use of decapitating bamboo, but its more probable author was
Wang Fou15 about +290. Nevertheless, what it recounts is so archaic as folklore

9 Even the percipient Bernal fell for this, (1), p. 237.
10 In the spring of 1968 we enjoyed a correspondence with Prof. Alfred Kubin of the Economics Department
of the University of Cincinnati, who had quite independently noticed the effect when making a basket of
bamboo in his garden.
11 Such as those which came into the hands of Roger Bacon (p. 48 above).
12 Feng Su Thang, quoted in Chua Huait Chih, ch. 28, and TPYL, ch. 66. The passage is reproduced in the
Centre Franco-Chinois ed., which includes the lost fragments, pp. 88–9.
13 楊清
14 鍾異編
15 東方朔
16 王洋

that it must be considered Han or even pre-Han. The earliest literary reference
would then be in the Feng Su Thang17 (Meaning of Popular Traditions and
Customs) written by Ying Shao18 of the Later Han in +175, but the passage,
which says that “the cracking of bamboo is like the roar of wild animals” is not
in most editions now. So we may turn to the Shen I Ching, and what it says is this:19

Deep in the mountains of the west there exist human-like creatures more than 10 ft. tall.
They go naked, and catch frogs and crabs to eat. They are not shy of men, and when
they see them halt to pass the night, they betake themselves to fires to roast their
frogs and crabs. They also watch the moment when the men are absent so that they
can steal their salt to eat with their food. They are called shan20 of the mountains (shan
shao)21, because this is the sound that they cry out to themselves. People cast lengths of bamboo on
the fire, which explode and leap out of it (pao22 pho erk chhu),23 thereby scaring these
sam24 away altogether. If an attack is made on them, they cause their assailants to catch fevers.
Although these beings have a human shape, they can take other forms by meta-
morphosis (pien hua), so they belong to the class of kuei and men25. Nowadays their
abodes occur everywhere in the mountains.

The background here is that the Shen I Ching was cast in the style of the much
older Shan Hai Ching, purporting to describe the strange beings, animals, gods
and goddesses, which a man might expect to encounter when venturing far into
the wilds. In this case the shan26 may have been either apes or neolithic tribal
forest-dwelling peoples, most probably the latter, since animals would hardly
want to cook their food.

One can see how the custom of scaring away mountain-spirits soon became
 POPULATED, from Tsung Lin’s27 Ching Chua Sui Shi Chih28 (Annul Folk Customs
of the States of Ching and Chhuh), written in the Liang dynasty about +550.
On New Year’s Day (he says) ... at first cock-crow, as soon as people get up,
bamboo crackers are let off with big bangs (pao29) in all the courtyards to frighten
away the mountain spirits and evil demons (shan sao o kuei).24 He then quotes
the passage from the Shen I Ching, and adds:

9 P. 34, tr. ought, adv. de Groot (3), vol. 5, p. 500. Li Shih-Chen quoted the passage, PTKM, ch. 51B,
p. 393, using the same sao.10
10 The word means ‘barking and binging’.
11 Probably a misprint for hiao.
12 Phu is a term especially applied to bursting bamboo.
13 The word means ‘rank-smelling’.
14 P. 14, tr. ought. Ching and Chhuh correspond to the modern provinces of Hupei, Hunan and Chuango.
15 TPYL has shau kiao here. As will be seen, the orthography of these spectro-names was very fluctuating.
It was discussed in the 14th-century Ne Ko Chih, p. 148.
16 Using shau20 for the spirits and pho22 for the explosions.
17 風俗通義
18 楊盛
19 山澤
20 山煞
21 山澤
22 山澤
23 山澤
24 山澤
25 山澤
26 山澤
27 譚賢
28 山澤
29 山澤
30. MILITARY TECHNOLOGY

The Yuan Huang Ching\(^a\) calls these spirits shan san kuei\(^b\). It is quite all right for the common people to make bamboo burst in the fire (pao chu\(^c\)) in the courtyards of their homes as a beacon-signal (tiao\(^d\)) for their families; but it is superfluous for rulers and officials (to carry out such) activities.

There speaks the sceptical Confucian scholar-bureaucrat, but the practice is fully established by his words. Indeed, it became universal in China at different times of the year, but especially at its beginning.\(^e\) For example, Li Thien\(^f\) (d. 1406) tells us in his Kai Wen Lu\(^g\) that each family would explode more than ten stems of bamboo on New Year’s Eve.

Moreover, the custom of exploding bamboo continued long after the introduction of gunpowder fire-crackers. At the end of the 16th century, Feng Ying-Ching\(^h\), in his Yüeh Ling Kuang \(^i\) (Amplifications of the ‘Monthly Ordinances’)\(^j\) remarked that

on the last night of the year bamboo is exploded in fires throughout the night until morning, in order to shake and arouse the Yang of the spring, and to remove and dissipate all evil influences (kišeh \(^k\)). Men in our time make a sport of it, and waste their money in attempts to outvie each other therein, so that the fundamental meaning of the matter is nearly forgotten.\(^l\)

And in Thang and later periods there are many references.\(^m\)

As we often note elsewhere (pp. 11, 22, 40), one great difficulty in pursuing the history of science and technology in China is that certain things changed fundamentally while the terminology for them remained the same. An obvious example is the use of the phrase huo chien\(^n\) (fire-arrow) first for incendiary arrows, and then for rockets (p. 147). But in other cases there does arise a change of appellation, and it does seem to mark a definite break in the continuity, in fact the appearance of something new. We have already had the example of shih jü\(^o\) (rock oil, natural petroleum or naphtha) giving place to mão huo jü\(^p\) (fiery fire oil), and it makes sense to assume that this new term meant only distilled petroleum or petrol, i.e. Greek Fire (p. 76). So with crackers; the term pao chu\(^q\) (exploding bamboo) or sometimes pao kan\(^r\) (exploding stem), is largely replaced after a certain time by pao chang\(^s\) (exploding crackers),\(^t\) and this coincides exactly with what we know of the origin and diffusion of gunpowder in China, i.e. it appears in the literature of the +12th century, and probably came into use in the +11th. Nevertheless, here again there was a tendency to use the old name loosely long after the new one had come in, so that when we meet with pao chu in Sung, Yuan, Ming or Ching, it is likely, though not certain (since bamboo continued to explode), that gunpowder fire-crackers are meant. Of course, if the context is specified, it is easy to be sure.\(^u\) Again, as we shall see (p. 133) pao chang and fire-crackers go together. The ancient name for these was yen huo\(^v\) (smoke-fires), and this appellation assuredly goes back much earlier than gunpowder; yet after the application of the explosive mixture for ‘feux d’artifices’ or true fireworks, the old name of ‘smoke fires’ still continued, indeed down to the end of the Ching.\(^w\) Coloured smoke and flame undoubtedly long preceded gunpowder fireworks, and so did gunpowder fire-crackers by some time also.

Positively the first appearance of the term pao chang seems to occur in that book which Meng Yuan-Lao\(^x\) wrote about +1148 describing life in Kaifeng during the first two decades of the century, before the fall of the Northern Sung capital to the Chin Tartars; he called it Tung Ching Meng Hua Lu\(^y\) (Dreams of the Glories of the Eastern Capital).\(^z\) Some time hard to fix between +1109 and +1120 the emperor visited the Pao-chin Lou pavilion to see a great entertainment given by the army, including fireworks of sorts. ‘Suddenly a noise like thunder (phi \(^{k3}\)) was heard, the setting off of pao chang\(^k\) (fire-crackers), and then the fireworks (yen huo\(^k\)) began.’\(^v\) These seem to have consisted almost wholly of dancers dressed in strange costumes moving about through clouds of coloured smokes, each act being separated by the resounding noise of fire-crackers. Thus the first act was called ‘carrying the gong’ (pao lo\(^k\)), the second ‘obstinate devils’ (ying kuei\(^k\)), the third ‘dancing judge of the ghosts’ (wu phan\(^k\)), and so on. Gunpowder was certainly here reference for fire-crackers, though not necessarily for the coloured smoke and flame.\(^k\)

Another +12th-century reference comes in the Hsi Hu Chih Yü\(^a\) of Thien I-heng.\(^b\) Although this book was written about +1570 it was based on local

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\(^a\) Other names for gunpowder fire-crackers were poem pao (whip bangs), chihens pao (linked bangs) and hao pao (spark bangs).

\(^b\) Then huo phau (spark canons) came also to be used; and especially hao ju.

\(^c\) Cf. Balss & Hershon (1), pp. 130-1.

\(^d\) It seems not necessary to enumerate all, but in the first there was fire-working by the actors, while the fourth had ‘drums panison’ and the eighth sword-juggling.

\(^e\) Feng Chia-Shing (6), p. 74, does the period +1150 to +1189 as the first appearance of yen huo, when during imperial inspections of the Sung navy by Hsiao Tsung, smoke balls of five colours (as yen phan)\(^k\) were shot off from trebuchets. This could have been but a further stage in their development.
records of the West Lake at Hangchow, and may therefore be worthy of credence here. It says:

In the 14th year of the Shun-Hsi reign-period (+1183), on New Year’s Eve, there were abundance of lanterns set out within the palace; and at the second watch of the night the emperor rode in a small carriage to Kuan-ao Shan⁴ hill outside the Hsiian-tê Men⁵ gate. As the night wore on, they let off more than a hundred fireworks (yen huo⁶) attached to frameworks, after which the emperor returned to his apartments.

Still another mention arises out of a famous court case when in +1183 the great philosopher Chu Hsi⁷ impeached a provincial governor Thang Chung-Yu⁸ for counterfeiting hsi tzü⁹ paper money, and other alleged misdemeanours.⁴⁹ Among the accusations was that since there was a man of Wuchow named Chou Su,³ who had a great reputation for making and managing fireworks, Thang Chung-Yu asked him to come to the city, and spent several thousand ounces of silver out of the public funds on the public performance of his displays.

In the +12th century the references to gunpowder fire-crackers and fireworks become more numerous. In +1275 Wu Tzu-Mu⁹ wrote his often-quoted book Ming Liang Lu¹⁰ (Dreaming of the Capital while the Rice is Cooking), a description of Hangchow towards the end of the Southern Sung, from about +1240 onwards.⁴

On New Year's Eve he says people all bought tchang shu¹¹ and small dates, and there were stalls selling fire-crackers (pao chang¹²) and fireworks (yen huo¹³) on frameworks, and that sort of thing .⁴⁹

Inside the palace the fire-crackers (pao chu¹⁵) made a glorious noise, which could be heard in the streets outside. All the boats (on the lake) were letting off fireworks and fire-crackers, the rumbling and banging of which was really like thunder. Ashore people sat around braziers drinking wine and singing songs and beating drums. It was called ‘Guarding the Year’ (Shou Suï¹⁴).

Interestingly, we read elsewhere that at the naval exercises following the ceremony of ‘watching the bore’ on the Chhiien-thang River, they practised firing off smoke balls (cf. p. 123) from trebuchets, and shooting hundreds of huo chien¹⁶, now almost certainly rockets, and setting targets on fire (shao hui¹⁶), probably with petrol flame-throwers.

³ Quoted in Maoshah’s dictionary (Chinese ed., vol. 5, p. 1809), tr. auct.
⁴ Hsi hien shen chi Wu Wen Kang Chi¹, ch. 18, pp. 178 ff., ch. 19, pp. 18 ff.
⁵ This was first noted in Wang Lung (1), p. 165.
⁸ Probably a misprint for the usual ching.
⁹ Ch. 6, p. 54 (b. 91).
¹¹ Ch. 4, p. 76 (p. 165). Parallel accounts of these naval displays, which included coloured signal smoke and smoke-screens, are in Wu Le Chi Shih, ch. 3, p. 114 (p. 371-2) and Ch. 7, p. 154 (p. 475).
¹³ The commoner phrase is yen huo⁹.
¹⁴ Ch. 3, p. 153, 144 (p. 383), tr. auct.
¹⁵ Ch. 3, p. 154 (p. 384). It is rather difficult to disentangle here the names of games from those of the various kinds of fireworks.
¹⁶ Ch. 3, p. 16 (p. 375).
¹⁷ Ch. 6, p. 390 (p. 406). There were shops where one could buy fireworks (ch. 6, p. 174, p. 453), and even one which specialised in gunpowder fires alone (ch. 6, p. 176, p. 452). For a special display of fire-crackers in +1491 see ch. 7, p. 119 (p. 473).
¹⁸ Tu Chi Ching Shih, ed. (p. 97).
¹⁹ In KCCF, ch. 50, p. 390. The book is not in any of the dynamic bibliographies.

The tale is continued in the Wu Lin Chia Shih¹⁰ and the Tu Chheng Chî Sheng¹². The former book (Customs and Institutions of the Old Capital) refers to events from about +1165 onwards, and was written by the eminent scholar Chou Mi¹ a century after that date.⁴ He said:

At the festival of the Year Remnant (Shui Chhü) from the 24th of the 12th month (Hsiao chieh ye²) to the 30th (Tsai chieh ye²) there were many fire-crackers (pao chang¹³), some made in the shape of fruits or men or other things . . . and between them there were fuses (pao hsin¹⁳) so arranged that when you lit one it set off hundreds of others connected with it. Pipes and drums were played too, to welcome the spring . . .⁴

Bamboo crackers (pao chu) were also let off. At the New Year on the West Lake many people went back and forth on boats with flags and picnics and singing . . . and fireworks (yen huo¹³). Some of these were like wheels and revolving things, others like comets ( louis hsiing¹¹), and others again shooting along the surface of the water (shui pao¹), or flying like kites—too many to mention. . . Young people competed in kite-flying . . .

Others let off fire-crackers on circular frames connected with long fuses, as an amusement. . . .

Chou Mi also mentions,¹⁴ as a precious fragment from those times, the names of two citizens of Hangchow who were renowned for making and displaying fireworks (yen huo¹³)—these were Chhen Thai-Pao¹⁵ and Hsa Tao-Tzu¹⁶. The second book (The Wonder of the Capital) was written rather earlier, in +1235, by a Mr Chao¹⁷, and it lists the same entertainments among skills (chiahia¹⁸) such as puppet-theatres and ball-play. There was the burning of fireworks (shuo yen huo¹³), and letting off fire-crackers (jong pao chang¹³), and performing fire-plays (hao hsi erh¹⁸), whatever these were at that time.⁴

To these references we may add one or two books from very little known. Wang Chhi¹⁹, probably in the Sung, wrote a Teng Wu Shih Pien²⁰ (Records of a Journey up to the Cities of Wu, i.e. Chiangsu, and he recorded that at Huchhiu Shan²¹, a hill resort near Suchow, there were at festival times masses of fire-crackers (pao chang²²) that took four men to carry. Again, in the Nung Chi²³, a
book of agricultural prognostications, it is said that one can foretell the future by the sounds, pleasant or unpleasant, made by the fire-crackers.

As for the continuing use of the term pao cha long after gunpowder had become general, it was probably a matter of literary elegance as opposed to common speech, since the ancient term had been consecrated by centuries of scholarly writing. Some made a clear distinction, for example, Shih Hsiu, in his book on the neighbourhood of Shao-hsing in Chekiang, Chia-Thai Kuei-Chi Chih, dating from soon after +1205, who says that on the last day of the year the sound of fire-crackers (pao cha) is everywhere heard, but that there are people who mix sulphur with other chemicals to cause even more violent explosions, and these are pao chang. Yet when in +1380 Chih Yu wrote a poem on a picture of the immortal demon-quelling scholar Chung Khuei, it included the lines:

At the sound of a burst of fire-crackers (pao cha)
People ran away in every direction..." which rather suggests the explosions of gunpowder. And many other examples of the elegant euphemism could be given.6

By the +14th and +15th centuries, fireworks were in full swing, gunpowder being now generally available, but there were very few detailed descriptions of them. The best, perhaps, were written in the close neighbourhood of +1593, in Shen Pang's Yuan Shu Tia Chi (Records of the Seat of Government at Yuan-shing, i.e. Peking), and in the other in Feng Ying-Ching's Yen Ling Kuang 15 (Amplifications of the 'Monthly Ordinances'). In the first of these we read:

Fireworks (yen huo) are made in many sorts.
Those which give a loud noise are called 'resounding bombs' (hsung phaen). Those which go up very high are called 'ascending fires' (chhi huo). Those which give several explosions in mid-air when let off are called 'three breaking waves' (son chhi lang). Those which don't make much noise nor go up high, but rush round and round (hsuan jao) twisting about on the ground, are called 'earth rats' (tia loo shu). Those fireworks which..."

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are packed loose or tight are of two kinds (releasing) many or few sparks (flowers), plants, and shapes like men, are known as 'flower children' (hua erh). Those which are enclosed in clay are called 'sand stone-rollers' (sha huo erh). Those which are enclosed in paper (layers of paper) are called 'spark' (or flower) tubes (hua shuang). Those which are enclosed in baskets are called 'spark (or flower) howls' (hua phw). All these are varieties of fireworks (yen huo), and a hundred of them or more may be skilfully collected together on one single framework.

Here the first sort might well be what we should call maroons, and the second clearly rockets, but the fourth is the most interesting, as we shall see (p. 473). It appears again in the remarks of Feng Ying-Ching, who says:

In Fukien there are fireworks called 'Chhin (Shih) Huang (Ty)'s hair-brand' (Chhin Huang phien). From a single bomb (hua phaen) there burst forth all sorts of sparks and flowers, ground rats (tia loo shu), 'water rats' (shui shu), etc. Hundreds of them are strung together (chhaan) inside one tube, and come out at the same time. One man holds (the fuse) and sets them all off, which is a very wonderful technique. Those

The reason why the 'earth-rat' or 'ground-rat' has such importance is that it may well have been at the origin of rocket propulsion. We assume that it was a tube of bamboo filled with gunpowder, probably occluded by a hole in the node at one end, which was allowed to rush violently about on the floor or the ground. We have a certain record of it from +1264 on account of an incident which frightened an empress at an indoor firework display; and this may be relevant, as we shall see (p. 477 below), to the beginnings of rocketry in both peace and war. The incident is reported in the Chhi Tang Yeh Yu.7,8

When Mu-Ling (another name for Emperor Li Tsung) retired, he prepared a feast in the Chih-ch'en-ten Palace Hall on the 10th day of the last month of the year in honour of (his mother), the Empress-Mother Kung Sheng. A display of fireworks (yen huo) was given in the courtyard. One of these, of the 'ground-rat' (tia loo shu) type, went straight to the steps of the thronr of the Empress-Mother, and gave her quite a fright. She stood up in anger, gathered her skirts around her, and stopped the feast. Mu-Ling, being very worried, arrested the officials who had been responsible for making the arrangements for the occasion, and awaited orders from the Empress-Mother. At dawn next day he went to apologise to her, saying that the responsible officials had been..."
careless, and took the blame upon himself. But the Empress-Mother laughed and said: 'That thing seemed to come specially to frighten me, but probably it was an unintentional mistake, and it can be forgiven.' So mother and son were reconciled and just as affectionate as before.

Having now come this far, we can turn our attention to the debatable period of Liu Chhao, Sui and Tang, which preceded the development of gunpowder in the +10th and +11th centuries. Ever since the Wu Yuan (Origins of Things), written by Lo Chhi in the +15th century, it has been customary to follow his asseveration that Sui Yang Ti (r. +605–+616) invented and used 'miscellaneous gunpowder fireworks' (chuan yao tsia kit). But he had got his history wrong, for there is no contemporary evidence to substantiate this. Poems which have been called upon do not provide it, though they indicate other things, quite interesting in themselves. For example, Sui Yang Ti himself wrote:

Wheel of the Law turns, up in the sky
Indic sounds ascend to the heavens,
Lamp-trees shine with a thousand lights
Flower flames open on the seven branches;
Moon image freezes in flowing water
Spring wind holds the night-time plums,
Banderolies move on yellow-gold ground
Bells come out from beryl estrade.

Monks chanting sutras, and girls dancing, appear at the beginning and end of the stanza, but in between is a clear reference to the 'lamp-trees' (huo shu) which were a custom of the age. Trees and their branches, whether real or of brass or bronze, were made to support thousands of 'fairy lights' (as we might say) on ceremonial occasions. Emnin found them in +689 when he visited Yangchow at festival time. But this has nothing to do with fireworks. Nor has the reply poem written by one of Sui Yang Ti’s ministers, Chuko Ying.

Light flashes as the lamp rotates,
Peach blossoms drop from falling branches,
Wreathing smoke moves round the buildings,
And the lake of the immortals reflects the floating lights.

Here the smoke may well have some relevance, but his first line probably referred to the 'pacing-horse lamp' (tsou ma t’eng), i.e. the zoetrope. And the last line recalls the Chung-Yuan festival, when little paper boats with lights in them were to be liberated on the Chinese All Souls’ Night in myriads. In any case, fireworks were not in evidence at the court of Sui Yang Ti.

Lamp-trees, of course, continued on into the Sung and later. They were probably referred to in a poem by Chang Tzu-Yeh of the mid +11th century, when, speaking of the Teng-Chi festival in the first month, he says: 'Above and below the towers and terraces the fiery lights are like stars. As one leans on the parapet, the sparks seem to be flying high up in the heavens near the constellations of Tou and Niu.' But other mentions of sparks do suggest that the practice of using fine iron filings in combustibles to give silver spangles in the smoke may go back to the Tang. There is for instance a famous poem by Su Wei-Tao (+640 to +705) which talks of shen hua, silver sparks, among the illuminations and the sparks. A thousand years later, Fang I-Chi, in his Wu Li Hsiao Shih encyclopaedia, noticed this, and concluded, in his slightly muddled-headed way, that the trees of fire, the silver sparks and the pao crackers all indicated gunpowder in Sui and Thang. But they did not.

What Sui Yang Ti undoubtedly had at his celebrations were huge bonfires (huo shan) on which inordinate quantities of incense were burnt. We get a glimpse of this from a conversation between Thang Thai Tsung and his consorts about +670, reported in the Thai-Phing Kuang Chi under the heading of 'extravagant displays' (shih chihhi). Apparently the emperor enquired about the illuminations of the halls and courtyards at the court of Sui Yang Ti, with the implication that he could possibly do better. The empress then described the bonfires which he had had all over the palace, burning hundreds of cartloads of garroo or aloes-wood and 200 tan of onycha perfume. Night was turned into day, and the aroma (yen chih) could be smelt for several dozen li. Such extravagance helped to lose the empire for him. So Thang Thai Tsung deisted. But again this had nothing to do with fireworks properly so called.

Entering now into their pre-history, we can easily find that the play of smokes, together with the actual expression yen huo, goes much further back. There is a passage in the Ching Chhu Sui Shih Chi, already quoted in connection with fire-crackers, which shows this well. It says:


*Chun Tzu-Yeh Tzu Pu I, ch. 1, p. 154, tr. auct.


*Ch. 8, p. 264, A

*Ch. 276, pp. 26, 94.


*f. 14, tr. auct.

*中元节 *張子野 *燈節 *蘇味滋 *花節

*火樹 *物理小識 *火山 *煙花

*煙火
According to Tung Hsün1 of the Wei (in the Three Kingdoms period)6 people nowadays make smoke-fires (yen huo) on Ch'eng-La7 morning (the 8th day of the 12th month) and set up figurines of peach-wood (tsa-hsien)8 in front of the doors of their houses. They also plait rush garlands to hang between the pines and cypress trees, and sacrifice a chicken and hang it on the door—all a ceremony to exorcise and get rid of the demons of epidemic disease.

Here then the smoke-fires have become fumigatory and demon-fuge. Tung Hsün was a folklorist of the +3rd century, while the text itself, as we saw before, is of c. +550.

In each of the preceding centuries something relevant and interesting occurs. For instance, according to the dynastic histories, in the year +493, a popular song circulated in Northern Wei to the effect that 'Red fire is spreading south, destroying the southern states'; and sure enough, in the same year there arrived a monk (sha-mên) at Nanking who dispersed this fire. Its colour was redder than ordinary fire and also more ethereal (se chih yu chihng hao erh wei).9 The monk performed cures of diseased persons with this 'holy fire', and the emperor of Southern Chhi tried to forbid it, but eventually the monk went away and the cult died out. Could he, one wonders, have come upon some natural ore of strontium and used it for his exhibitions of coloured flame and smoke?

Again, in the +44th century, there is a story6 about an upright man of Kuei-chi named Hsia Hsung10. His stepfather, Hsia Ching-Ning,11 engaged two sorceresses (mi ren), Chang Tan12 and Ch'en Chu13, to sacrifice to the ancestors; they chanted and danced, performing all kinds of tricks such as juggling and sword-swallowing, finally 'spat fire, and were hidden from view by a great cloud, whence streams of light flashed like lightning'. Hsia Hsung had strong Confucian objections to all this, and managed to stop the performance. But evidently it included smoke and flame, so it was yet another step on the road to fireworks. Beyond this, perhaps we need not pursue the matter, since we would enter the whole field of airén14, hygienic fumigations, liturgical incense-burning, and war-smokes containing poisons, which went back far into the -1st millennium.15 It is time to return to the end of the +2nd, with a few words on fireworks in their full development.

So let us take a brief look at fireworks in the eighteenth and nineteenth centuries, perhaps it will help us to interpret the long line of intermediate stages which led to them. And first, with respect to gunpowder-firecrackers, a preparation in which the Chinese have remained pre-eminent to this day, there are vivid accounts of the process by Berthou (1), Dyer Ball,5 Weingarten6 and Tenney Davis.7 The powder used is rather low in nitrate, with a percentage composition something like: N:66.6, S:16.6, C:16.8.8 It is filled in to little tubes of stout paper tied together into hexagonal figurate bundles, with thin paper tubes containing gunpowder as the fuse for each one successively. It is interesting to learn from Huang Shang (9) that old book paper was considered the best for making firecrackers, even during the present century, a circumstance which helps to account for the vast losses of old books sold away not for pulping but for the fireworks manufacturers.

There are many descriptions of fireworks in China (Fig. 11), from Louis Lecomte in +1696 to Dyer Ball in 1892, through John Bell (+1720), Pierre d'Incarnville (+1763), John Barrow (+1794), A. Caillot (1818), J. F. Davis (1835), the Abbé Huc (1853). They all descant on the flares, garlands, drums, rockets, Roman candles, maroons, Chinese fire and Chinese flyers, with many other works too tedious (as John Bell would have said) to rehearse. Down to the middle of the nineteenth century, Chinese fireworks were generally considered much superior to those of Europe, but one can see C. F. Ruggieri changing his mind on this between his two editions of 1801 and 1824.8 If such a turning-point ever arrived at all, it would have been rather towards the beginning of the present century. But it is more interesting to turn to the consideration of the book which seems to be the only monument of civilian pyrotechny in all Chinese literature.

The Hua Hsi Lieh (1) (Treatise on Fireworks) was written in his youth by Chao Hsüeh-Min,9 that scholar of scientific bent who was later to produce the Pen Tsiao Kuang Mu Shih (10) (Supplementary Amplifications for the 'Pandects of Natural History' by Li Shih-Chen). This was begun in +1760, first prefaced in +1765, the prolegomena added in +1780, but not printed till +1871; the last date in the text being +1803. By contrast, Yang Fu-Chi3 wrote the preface for the Hua Hsi Lieh as early as +1753, so Chao must have been studying fireworks some time before. The work was not printed till +1835.1 It shows that the state of the

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1. The remaining fragments of his Wei Li Shu preserved in T'PIL, ch. 10, are collected in YSY, ch. 26, pp. 275 ff.
3. See Skel, ch. 4, pp. 264, 2, p. de Groot (2), vol. 6, p. 951; also Hsi Chih Shu, ch. 19, p. 15.
6. Lü Ting 2 正義 3 從師 4 國人 # 出門
7. 李光 2 体 3 部 4 彈 5 女王 6 傳人 7 陳珠 8 優
8. 火器略 2 熊學部 3 上草園命名 4 製爆者
9. 30. MILITARY TECHNOLOGY
10. 30. THE GUNPOWDER EPIC
The point about Chinese Fire is that it was nothing but filings of cast iron or steel reduced to a powder more or less fine, and this, when mixed with low-nitrate gunpowder and other combustibles, would upon firing yield flame and smoke containing an infinite number of silver sparkles. A favourite Chinese name was *thieh* (iron moths), another *thick sha* (iron sand), a third *thieh hsieh* (iron granules). wrought iron will not do, so some carbon must be present. 'Cast-iron', said Cur bush, 'reduced to a powder more or less fine, is called iron-sand, because it answers to the name given to it by the Chinese. They use old iron pots, which they pulverise till the grains are no larger than a radish seed, and these they separate into sizes or numbers for particular purposes.' We have already seen that this procedure may go back to the Thang (p. 137). The simple secret was not revealed to Europe until d'Incarville (1) wrote his paper about it in +1763, but though he mentioned rusting he did not clearly say that the iron-sand grains must be coated with tung oil or glue to prevent it. The so-called 'brilliant fire' depended on powdered steel, but after 1860 the introduction of magnesium and aluminium led to enormously increased brilliancy.

So much for Chinese Fire, but what about 'Chinese Flyers'? As Robert Jones well knew in +1765, the saxon or tourbillon depended on jet propulsion; it was a single tube pivoted half-way along its length, and made to rotate in the plane of

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*b* Davis & Chao (g), p. 101.  
*See pp. 135 ff. above and pp. 473 ff. below.* Davis & Chao (g), p. 109.  
*d* Davis & Chao (g), pp. 103-4. J. F. Davis (1), vol. 2, pp. 4-5, spoke of the little boats or water-rats which the Chinese made to skim on the surface of water by rocket jet propulsion. We shall return more compendiously to the important subject of rockets below (pp. 473 ff.), but here it may be mentioned that just in Chao Hsi-ho-Min's time Chinese pyrotechnics were attracting some attention in Russia. In +1756 Larian Rosochin wrote a paper on Chinese fireworks, mostly rockets, which has been found and reproduced recently by Starikov (1).  
*e* Cur bush (g).  
*f* (5), p. 665. He also wrote a special paper on the technique (5).  
*g* True, John Bate (1) in +1653 had used 'iron scales', no doubt in an attempt to reproduce the sparks which flew from blacksmith's anvils, but this could have had no great success. Anon. (1599) is an abstract of d'Incarville in English.  
*h* See Brock (1), pp. 23, 152, 154, 189, 231, (5), p. 98. Tenney Davis (17), p. 57. D'Incarville explained that different grain-sizes would give the different effects of flowers desired. For the finest, a 'gunpowder' of 86.6% nitrate was used, for the coarsest only 60.6%. Cf. Fig. 12.  
its axis by jets of fire projected through holes pointing in opposite directions at right angles to the axis. Furthermore, when revolving fast enough it could be projected into the air by two additional holes bored in the under surface of the tube. That this should have been developed in China is quite interesting, for it was a principle parallel to the helicopter top which was so prominent there, the direct ancestor of the helicopter rotor, and the godfather of the aeroplane propeller. The energy of this was derived from rotation given by a cord previously wound round the stem, or from the pull of a bowdrill spring which travelled with it; in the Chinese flyer the energy was also self-contained, chemically provided by the gunpowder filling, but it lasted a little longer. Moreover, this was no more than a rotary application of those 'water-rats' of which J. F. Davis wrote in 1836 that 'they also make paper figures of boats to float and move upon the water by means of a stream of fire issuing from the stern'. And these in turn were simply derivatives of the rocket principle, which in its origins and warlike uses we shall study in detail presently (pp. 477 ff.). In another way, of course, the Chinese flyer was a development of the steam aeolipile of Heron of Alexandria (though people in China could not have known about that), a development most appropriate to the land of gunpowder, but besides it was in a sense the ancestor of the vertical take-off aircraft of the present day.

It is instructive to make some comparisons between the devices used in civilian pyrotechnics and those used in war. In the early stages of gunpowder weapons, as we shall see (p. 163) quantities of the mixture were probably enclosed in carton containers for use as bombs, and this persists down to the present day in maroons—cubical pasteboard boxes filled with gunpowder and exploded like extremely large crackers. The fire-lance has left many descendants. 'Fire-clubbs', cylinders of low-nitrate composition shooting forth flame, even though the range was very short, were prominent in the European seventeenth century, and known to John Bate (+1635). At the same date, John Babington spoke of 'a trunck of fire which shall cast forth divers fire-balls', so co-axitaneous projectiles were known then too (cf. p. 42). Even the word lance passed into civilian pyrotechny, though only for tubes of very small size filled with ammonium picrate or coloured fire compositions. The larger cylinders came to be called 'Roman Candles', familiar to all, formerly 'star pumps' or 'pumps with stars'; these add dextrin to the mixture, which is very low in nitrate, having a percentage composition about N 35, S 11-2, C 34-9. The candles may be up to

* See Vol. 4, p. 2, pp. 590 ff.
* These had also been mentioned by d'Incarville (1).
* Cf. Vol. 4, pp. 7, pp. 290, 207, 256. For the background see Barton (1), vol. 1, p. 208; Woodcroft (1), p. 72; Usher (1), and ed., p. 332; and Drachmann (2).
* Tenney Davis (17), p. 164.
* Davis (17), p. 54; Brock (1), pp. 111 ff. Brock (2), p. 110. This goes back to Biringuccio in +1540, if so further.
* Davis (17), p. 62; Brock (1), pp. 196, 226.
* Davis (17), p. 79; Brock (1), pp. 191 ff.
6 in. in diameter, and since they throw out individual pellets of combustible material, the co-ative principle is present, while as for size they may be compared with the eruptors (p. 263) rather than with hand-held fire-lances. Brock makes a weak attempt to derive the name, not found in England before 1 +769, from the Mardi Gras carnival of that time in Rome," but we suspect it is much more likely that the place was really al-Rûm, i.e. Byzantium, and goes back almost to the time of Marcus Graecus and Hasan al-Rammah, Mines or cannon mortars also clearly derive from the eruptor conception. As for rockets, the identity is complete, save that they are not armed, producing coloured stars instead and aimed at the zenith. 

When we review the whole history and prehistory of fireworks in China, it seems clear that the imparting of colours to smokes and flames is the backbone of the question. 'The diversity of colours indeed', wrote Barrow about 1+797, 'with which the Chinese have the secret of cloathing fire seems one of the chief merits of their pyrotechny.' Everyone noticed the same thing, Caillot, for example, in 1818: 'It is certain that the variety of colours which the Chinese have the secret of giving to flame is the greatest mystery of their fireworks.' And so also Cutbush: 'The Chinese have long been in possession of a method of rendering fire brilliant, and variegated in its colours.' But then comes the important point, not generalised, that the gunpowder formula is by no means necessary for coloured smoke and fire. It was not incumbent upon the Chinese, therefore, to wait for the +10th century before producing some of these remarkable effects.

In pursuing these we can go back to the +14th century because the Huo Lung Ching contains recipes for military signal smokes of five colours, and these are repeated word for word in the Wu Pei Chih. Four of them include low-nitrate gunpowder, but one does not. We can tabulate them as follows:

<table>
<thead>
<tr>
<th>Colour</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue-green</td>
<td>indigo (ching tai) + gunpowder.</td>
</tr>
<tr>
<td>White</td>
<td>white lead (carbonate) + gunpowder.</td>
</tr>
<tr>
<td>Red</td>
<td>red lead (tetroxide) + saltpetre, pitch and resin.</td>
</tr>
<tr>
<td>Purple</td>
<td>cinnabar (tsu fen) + gunpowder and hemp oil.</td>
</tr>
<tr>
<td>Black</td>
<td>lignite and soap-beans + gunpowder.</td>
</tr>
</tbody>
</table>

Most of these, which would have depended on the formation of some kind of aerosol of the suspended particles, would have coloured the smoke but not the flame. This kind of thing could be done with any combustible; for example the Wu Pei Huo Lung Ching has two formulae for firework-like signals, the san chang chiu (thirty-foot chrysanthemum) and the pai chang lien (hundred-foot lotus) which combine sulphur, charcoal powder and iron filings, with no saltpetre at all. This would produce the silver sparkles in the smoke.

When we come to the time of the Hsii Lüeh (+1733) we find a variety of colourations by chemical substances, and now they tint the flame as well as the smoke. For example, in all cases using low-nitrate gunpowder, the flame itself would be coloured:

- **Yellow**: arsenical sulphides.
- **Violet**: cotton fibres.
- **Green**: verdigris (copper acetate), indigo.
- **Lilac-white**: lead carbonate.
- **White**: calomel (mercurous chloride).
- **Black smoke**: pine soot and pitch.

The earliest use of a salt like copper acetate in Europe seems not to antedate Ruggieri in 1801, but in later times powerful effects such as the red of strontium and the green of barium were introduced. Chao Hsüe-b-Min, however, also mentions compositions not involving gunpowder at all. Sulphur alone gives a blue light, and with copper sulphate it is a more intense blue, saltpetre alone or with miscellaneous combustibles yields a violet light, and sodium nitrate a yellow one. It is noteworthy that the intense blue-white light of the 'Bengal Fire', so well known in England a century ago, was produced only by saltpetre and sulphur with antimony sulphide. Antimony, it seems, was first used in European pyrotechnics by Jean Appier in +1630, but since China has the largest antimony deposits in the world, it would be strange if no alchemist in those parts used one of its ores in fireworks at some time or other.

From what has now been said one can see how closely related were recreation-
al pyrotechnic coloured smokes and military signal smokes. To say much here about these latter would be to encroach too much on another sub-section in this volume, but it may just be worth while mentioning a fascinating passage on army beacon towers in the Thang Tien⁴ (Comprehensive Institutes) of +812.² The groups of five beacon-towers all along the Han times in the North-west are very familiar to those who have travelled along the Old Silk Road (cf. pt. 8n).³ Tu Yu⁴, however, recommends groups of three. Each beacon-tower (feng thai)² is provided with three raised fire-baskets (chhai lung)¹, each of which can be lit from below the battlements by a kind of incendiary fuse (liu huo sheng)⁵ running up a tube (huo thang)⁶. If all is clear, one smoke-fire is lit, if danger seems nigh, then two, and if enemy troops are in sight, all three are to give their signal. The tower is provided with a flag and a drum, it has a fire-drill and moka tinder, it is defended by a guard of six men with arrows and fire-arrows, crossbows and trebuchets, and they have adequate stores of food. Here was yet another demonstration of the characteristic Chinese skill in smoke-making.

Looking back over the whole subject, our conclusions must be that civilian pyrotechnics in the modern sense arose along with gunpowder and its warlike uses between about +850 and +1150.¹ But the colouring of smokes and flames by combining various chemicals with combustible substances, including sulphur and saltpetre, must have started a good while earlier, possibly in the Han or soon afterwards; and it would have derived from very ancient customs and processes of fumigation as such. The transition in Wu Tai and Sung times would thus have paralleled that which took place with regard to explosion itself, as the ancient decapitating bamboo gave place to fire-crackers containing gunpowder. We may end, as we began, with the doings of the Scotsman in Peking. When John Bell in +1720 went with other gentlemen of the Russia-embassy to dine at the palace of the Khang-Hsi emperor’s ninth son, they were magnificently entertained with stage-plays ‘accompanied with musick, dancing, and a kind of comedy, which lasted most part of the day’, though they could not understand any of the dialogue. Towards the end, a fight between heroes was interrupted by a spirit, who ‘descended from the clouds, in a flash of lightning, with a monstrous sword in his hand, and soon parted the combatants, by driving them all off the stage; which done, he ascended in the same manner as he came down, in a cloud of fire and smoke.’² Nothing could have been more in the Chinese tradition.

² The passage is almost verbally identical with one in T'Yu Ch' ii 5 (ch. 50), p. 244, 1, which would be some fifty years earlier. There are other examples of the same dependence.
³ Cf. Vol. 1, Fig. 15 and Vol. 4: Pt. 3, pp. 35-37.
⁴ Ch. 132 (pp. 812 2, 812 3).
⁵ Nothing to do with gunpowder at this time of course.
⁶ This term is interesting, because later on the expression applied solely to metal-barrel guns and hand-guns (cf. pp. 304, 306).
⁷ It is interesting that Brock (1), p. 230, the technician, joined with Fung Chia-Sheng (5), p. 12, the historian, in the conviction that no fireworks, properly so called, existed in the Sui and T'ang.
⁸ Bell (1), p. 143.
many references to huo chien from which we learn that oil was enclosed in a gourd (yu phaPan) and sent over attached to an arrow, presumably with some kind of fuse; this was useful for shooting upwards to attack watch-towers, or downward to burn siege equipment. Similar projectiles (hao shih) could be shot from crossbows (mu) with a range of 300 paces. And very similar arrangements are discussed in the Wei Kung Ping Fa (Military Treatise of Li Wei-Kung), a 7th-century work by Li Ching, whose fragments were recovered and published by Wang Tsung-P'ei, a couple of centuries ago.

On an earlier page (p. 85) we noted what Hsü Tung had to say about 'flying fire' (fei huo). Writing just about +1000, he remarked that it was of the nature of trebuchet 'bombs', probably incendiary, and incendiary arrows (huo chien). And it is exactly in his time that we enter a new phase of incendiary projectiles, marked by a wave of new inventions demonstrated to the emperor and his commanding generals. These, we suggest, involved the use of gunpowder as incendiary.

Almost as soon as the Sung dynasty had begun, in +969, Yo I-Fang presented a new type of fire-arrow to the emperor, and was rewarded by a gift of silk. In +970 one of the generals, Fêng Chi-Shêng, together with some other officers, presented another new model for fire-arrows; the emperor ordered it to be tested, and as it proved successful, gowns and silk were bestowed upon the inventors. In +976 the King of Wu-Yüeh State sent as a present to the Sung emperor a band of soldiers especially skilled in the shooting of incendiary arrows. Before the century was out there arose several opportunities of using the new devices in combat; for example, in +975 Thai Tshu employed fire-arrows and also incendiary bombs hurled from trebuchets against the last defenders of the Nan Thang State. Then in +994 a force of 100,000 Liao troops besieged the city of Tzu-thung, and the population was greatly alarmed, but the officer in command, Chiang Yung, ordered the trebuchets to play upon the enemy with stones while the new fire-arrows were shot off, whereupon the investing force retreated.

At the beginning of the next century the inventors were again busy. In the 3rd year of the Hsien-Phang reign-period (+1000), a naval captain, Thang Fu, presented models for an incendiary arrow (huo chien), a fire-ball (hao chhiu) and a barbed fire-ball (hao chi li), while at the same time a naval architect, Hsiang Wan, presented designs for warships. They were rewarded with numerous strings of cash. Then in +1002 a military officer, Shih Phu, reported that he knew how to make better fire-balls (huo chhiu) and fire-arrows (huo chien). Accordingly his products were tried out, by imperial order, in tests watched by ministers of State and their assistants. Thus in the preceding century the appearance of gunpowder formulae in the Wu Ching Tung Yao there were many developments of something essentially new. Otherwise why all the fuss about tests and rewards? Surely these inventions were in fact connected with the use of gunpowder low in nitrate as an incendiary more controllable and more effective than any fire-producing mixtures previously available. It would have been much less haphazard than the old fire-arrows with oil and other combustibles, and the length of fuse could have been carefully adjusted to the estimated time of travel.

The passages given in the previous paragraphs have sometimes been interpreted as signifying the first appearance of the rocket, though there is really no evidence for this, nor indication that the projectiles flew off of themselves. But the use of 'rocket-composition' as an incendiary would be exactly what one would expect for this particular time; the gunpowder mixture had not been known for very long, and the properties of high-nitrate powder were still remaining for the future to discover.

Perhaps the most enigmatic text of this time is that concerning the 'whip arrow, or javelin' and the 'gunpowder whip arrow, or javelin' (Fig. 13), which occurs in the Wu Ching Tung Yao of +1044. The passage concerning it is very difficult to interpret, and we shall have to adopt the usual course of giving two alternative translations. The first is as follows:

The whip arrow (or javelin) called pien chien.

Take a length of newly (cut) green bamboo 10 ft. long, with a diameter of 1:5 in. (as the pole, kau). The lower end is shod with iron (and fixed to the ground). A silk cord 6 ft. long is attached to the top end of it. Take also another piece of strong bamboo 6 ft. long to make the pien chien itself, and give it a pointed head (tou). Check the junction of the two poles, and fix there a bamboo guide-hoop (chu nieh).
When the moment for shooting (/fang/) comes, connect the javelin to the pole (through a loop of) the silk cord; then while one man shakes the pole and pulls it back, the other man holds the end of the javelin (aiming it), so that the pole hits against it (chü) and propels it forth (en fa chü).

The advantage of the whip arrow (or javelin) is that it can shoot (far) upwards to hit the enemy above.

Then come the mysterious words about gunpowder.

But if there are low objects or (enemy) troops, then let off (/fang/) the gunpowder whip arrow or javelin (hao yao pien chien). Make a container of the bast of birch bark, and put into it 5 oz. of gunpowder behind the javelin head. Light it and shoot it off (/fan enk fa chü).  

Thus on this interpretation the main propulsive force was provided by the elasticity of the bamboo pole bent backwards by one of the soldiers, while the other one did the aiming. Nothing is said in detail of the fuse, but the gunpowder, presumably low in nitrate, was clearly acting as an incendiary. A drawing based on this view is given in Fig. 14(a).

But there is another possibility, according to which the second pole acted more like an atlatl or throwing-stick. Let us look then at a second translation.

For whip arrows (or javelins, pien chien) one must use a new and green bamboo 10 ft. long and of diameter 1.5 in., forming a long staff. At the back end an iron chain is attached, and to the other end a silk cord 6 ft. long is fastened. Another piece of strong bamboo is sharpened to form a whipjavelin, it is also 6 ft. long, and at a specific point in the middle a hook or projection (meeb) is fitted.

[Comm. This is also called a pien tieb.]

At the time of shooting, the cord is hooked round the projection, attaching the javelin to the pole. One man wields the pole to give a force, while the other holds (and aims) the rear end of the javelin so that it can receive the impetus and fly forth. The benefit of this is the way it shoots high upwards, hitting the enemy with the accuracy of close-quarter weapons.

And the words about gunpowder follow on.

For letting off gunpowder arrows (or javelins, hao yao chien) the bast of birch bark (hsia phe) is wrapped round forming a ball with 5 oz. of gunpowder placed inside it, behind the point (the shaft of the arrow passing through the middle). Upon igniting, the arrow is shot forth.

On this version, then, one soldier gave a strong turning movement to the bamboo pole, which pulled the silk cord with it, then as the second soldier aimed

\[1\] The text says only hao yao chien, the full phrase is taken from the caption in the illustration.

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Fig. 15. The 'gunpowder whip-arrow' (hao yao pien chien), from NCTY, ch. 12, p. 60b.

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Fig. 14. Diagrams illustrating alternative reconstructions of the 'whip-javelin' and 'gunpowder whip-javelin' of the **Wu Ching Tung Yao**

The javelin, the cord, doubtless with a ring at the end, slipped off the hook and the projectile went on its way. The sketch in Fig. 14(b) attempts to explain the mechanism. It would have been a somewhat sophisticated application of the principle of the *allat*, *propulsor*, or throwing-stick, used by almost all peoples from prehistoric times onwards to increase the range of their javelins. We do not feel able to decide as between the bent pole and the throwing-stick.  

* See for instance Singer et al. (1), vol. 1, p. 57; Kroeber (1), p. 80; Montandon (1), pp. 354 ff.; Heymann (2); Pitt-Rivers (4), p. 132 and pl. 16; Underwood (1).
* Among its many obscurities the text gives no idea of the length of the iron chain, if there really was one. It seems to say that the silk cord was attached to the chain, but *hsiao* must surely indicate the top of the pole. Then the text states that the silk cord is attached to the 10 ft. pole, but the illustration (Fig. 13) shows it attached near the rear end of what seems to be the 6 ft. javelin-arrow. And on the first interpretation the purpose of the silk cord is unclear; perhaps it steadied the javelin, or held the pole back when sufficiently bent.

But of course what really matters is the function of the gunpowder. An incendiary purpose for the **huo yao pien chien** is clearly stated a few pages later on, and birch-bark containers are mentioned again, in the course of a long section entitled 'Methods for the Defence of Cities' (Shou Chêng thị Fa). But the later use of the words for designating rockets has impelled many to see in this description the earliest account of rocket propulsion. Wang Ling was inclined to this, but Feng Chi-šêng decided definitely against it. Unfortunately there is a certain ambiguity in the concluding words, and this has impelled Li Ti (4) to defend the idea that the whip-javelin was a gunpowder rocket. He uses several philological arguments, first, that the verb *fang* is used for the shooting, not *shē*, but the former was already said of fire-arrows in the Sung Shu. What he says about *fang* is more weighty; it means to boil or roast, or to cook meat offered to gods and spirits, i.e. a process rather than an action; so he would like to translate 'as it burns, it will fly forth'. He wishes to differentiate the whip-javelin from the arrow carrying a gunpowder incendiary packet shot from a bow, the device we shall study next, since he doubts that the methods of propulsion stated would have carried the javelin any significant distance if it was not a rocket. Here opinions may differ. Our view is that the javelin-arrow was a javelin-arrow, with or without its payload of incendiary gunpowder, and therefore not a rocket. If it was really self-propelled, why did it need all that auxiliary equipment worked by two men?

One hardly ever comes across a reference to the *pien chien* in any of the kinds of literature of the following centuries. But it does appear in a poem written by Chang Hsien in the middle of the 11th century. It is called Pei Feng Hsing (Affairs of the North Wind), and in it a young man driving a cart near Ch'i-yung Kuan north of Peking meets a strange and fearful horseman, who carries with him a *pien chien* in a holder. Nothing more is said of it, but this gives us at least a literary reference which suggests that the technique still remained in existence.

We do think we have a clear and concise description of exactly the kind of thing that Thang Fu and his colleagues were introducing at the turn of the millennium, but naturally it comes from some three hundred and fifty years later. In the **Huo Lung Ching** there is an illustration of the 'Fiery Pomegranate
arrow shot from a bow (kung shi hou shih-liu chien), given here in Fig. 15, and a textual explanation. It says:

Behind the arrow-head wrap up some gunpowder with two or three layers of soft paper, and bind it to the arrow shaft in a lump shaped like a pomegranate. Cover it with a piece of hemp cloth tightly tied, and sealed fast with molten pine resin. Light the fuse and then shoot it off from a bow.

The last sentence is amplified later on in the Wu Pei Chih as follows:

You can use paper pasted and oiled to make the fuse (pao hsien), which should lead into the front of the gunpowder ball. The iron arrow-head must be sharp, with backward-pointing prongs. Light the fuse to start the fire, then release the arrow from the bow, and send it off. When it reaches the target, the fire caused in the protective matting or sails cannot be extinguished with water; so the device is of great advantage.

This last remark reminds us that the difficulty of putting out a blaze caused by a mixture with its own built-in oxygen supply was another signal advantage of gunpowder as an incendiary; a similarity in a way to the old Greek Fire, though that had depended on its physical property of liquidity. Primitive incendiary combustibles would not have been so hard to put out.

What was true of bows was also true of crossbows, as is shown by another passage in the Wu Ching Tsung Yao. After explaining in detail the construction and operation of the three-spring or triple-bow arcuballista (cf. pt. 6 (f) above), it goes on to say that in the use of the San Kung Chiu-huang Tzu Nu to all these bolts one can add gunpowder, but the amount, whether heavy or light, much or little, will depend upon the strength of the catapult. This will have been another version of the incendiary projectile.

When the Sung capital, Khai-feng, fell into the hands of the Chin Tartars in + 1126 a great deal of war material was captured by them. Hsia Shao-Tseng afterwards wrote:

The palace eunuch Liang Phing-Wang showed (the invaders) round the imperial palace, and told them of the toys and precious things contained therein, while Tung Shu presented a complete list of queens, concubines, young princes, concubines and the like. A certain Li handed over 20,000 fire-arrows (hao chien), a (standard) model of the trebuchet for hurling projectiles filled with molten metal, and four-bow arcuballista— all of which had been prepared by (Sung) Ts'ai Tsung for the conquest of (Nan) Thang. In peacetime these officials had lived off the fat of the land, yet now what heartlessness to the country did they show!

This probably explains the arrow-like objects seen in the illustration: there is only one in WPC, drawn more clearly.

Thus here again we have the incendiary arrows, at this time almost certainly containing gunpowder, or with arrangements to do so.

During the whole of the remainder of the Sung dynasty these weapons found much employment. In +1130, four years after the fall of the capital at Khai-feng, the Chin Tartars used them with much effect against Han Shih-Chung, comb-
manding the fleet of the Southern Sung. But the Sung responded in kind the following year, when a brigade, besieged at Tang-thu, using petrel flamethrowers and five-pole trebuchets as well as gunpowder fire-arrows, succeeded in burning all the enemy’s scaling-ladders and wooden siege-works, so that the investment was raised. Then in +1206, when the Sung army was defending Hsiang-yang, Chao Wan-Nien’s account of the siege uses, perhaps for the first time, the expression huo yao chien, ‘gunpowder arrows;’ this may conceivably indicate the first appearance of the rocket, a point which we shall consider presently, but more probably it still referred to the function of gunpowder as an incendiary. The works of the Chin Tartar force were certainly destroyed on this occasion. After that the terminology reverts to the usual ambiguous ‘fire-arrows,’ as in the account of the Southern Sung army fighting the Mongols in +1275, where we read of huo shih. At this time (+1274, +1279) Bayan was invading the south, opposed by Liu Wên-Huan as Sung commander-in-chief, and many sources tell of their use of huo phao, trebuchets casting incendiary bombs, probably of low-nitrate gunpowder.

We can probably trace back the incendiary arrows using gunpowder to an event of +1083. One of the commanders, Chao Hsi-hsia, asked for further munitions, whereupon he was given 1000 strong bows (shen pi kung), 100,000 arrows and 250,000 yao chien, which might be more arrows, but were more probably gunpowder-carrying ones. Then Li Hsin, in his Khuo Ao Chi, described a combat against the Chin Tartars in +1090 during which fire-bombs (huo phao) were used. These incendiary projectiles saw much service during the ensuing thirty years, culminating in the fall of Kaifeng. They also figured largely during the celebrated defence of T‘an-an in +1127 by Chhen Kuei, used too by the Chin Tartars attacking the city. Soon afterwards Lin Chih-Ping urged the equipment of all the Sung warships with gunpowder fire-trebuchets and gunpowder incendiary arrows. By +1160 we have an account of an important naval engagement between the Sung and the Jurchen Chin forces, Li Pao in command of the Sung squadron, and Chêng Chia the admiral of Chin. The Chin Shih says:

Chêng Chia did not know the sea routes (among the islands) well, nor much about the management of ships, and he did not believe (that the enemy, the Sung, was near). But all of a sudden they appeared, and finding us quite unready to hurl the incendiary gunpowder projectiles on to our ships. So seeing all his ships going up in flames, and having no means of escape, Chêng Chia jumped into the sea and was drowned.

Four years later, under attack at Haichow by the Chin army, a Sung officer, Wei Shêng, invented new forms of mobile trebuchet like field artillery which could hurl both stones and gunpowder incendiaries some 200 paces. It was about this time, in +1176, that the fall of a meteorite was compared with the letting off of a gunpowder projectile trebuchet, ju fa huo phao, as Chhou Mi afterwards put it, using contemporary records. This was a felicitous description, as the main effect would have been an alarming whoosh sound, like the noise of a heavy vehicle passing at an unpleasantly near distance. No doubt the line between the incendiary and the explosive was never clearly fixed; some of the huo chien and huo phao projectiles may have been made with gunpowder containing a higher nitrate content about +1200, but it is hardly possible to settle the question. The transition was as likely not so very slow, with many local diversities. In +1206 and +1207, while Chao Wan-Nien was defending Hsiangyang against the Chin Tartars, Wang Yin-Chhü was conducting a similarly successful defence of Té-an (like Chhen Kuei eighty years before). In reading through his son’s book, the Khi-Hsi T‘e-An Shou Chheng Lu, one is struck by the great predominance of incendiary weapons, to which there are at least fifteen references, though huo phao and huo chien were freely used. To gunpowder as such there is only one, where it is said to have been packed with rice straw and used-matting fragments into teak-sacks, then launched against the enemy—clearly an incendiary device.

In the foregoing pages it will have been noticed that some of the inventors such as Thang Fu and Shih Phu also initiated gunpowder-containing incendiary warballs which were to be shot off from trebuchets. Among devices of this kind described in the Wu Chhing Tsyang Yao (+1244) we find the ‘iron-beaked fire kite’ (t’ieh tsui huo yao) and the ‘bamboo fire kite’ (chu huo yao). The text for

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* HWHTK, ch. 121 (p. 3953-3); HSCH/TCTC, ch. 2, p. 12.
* Tain Lu Shih Chou, ch. 1, pp. 11 a, 130.
* T‘a hsi Hsiang-Yang Shou Chheng Lu, p. 79.
* E.g. Sung Shih, ch. 490, pp. 48 b, Tain Shih, ch. 150, p. 194; Kuei Chhing Wu Lei, ch. 41, pp. 15 a, 204.
* Sung Shih, ch. 157, p. 85. The same expression, yao chien, comes again in Kui Hsin Tsha Chhieh (P’ieh Chi), ch. 2, p. 59 a in connection with the Hsiangyang siege just mentioned.
* Ch. 30, p. 86.
* Fêng Chia-Shih (1), pp. 56-7.
* Shou Chheng Lu, ch. 5, p. 6 d, ch. 4, p. 6 a.
* Sung Hsi Yao Kou, ch. 186, P‘ing Secr. ch. 2, p. 32 a. These were the specifications which included the sung têh or sighting-tube, for taking altitudes on shipboard, cf. Vol. 4 pt. 3, pp. 575-6.
* 當攻 * 姚萬年 * 火强箭 * 火炎 * 孟臣
* 畫火 * 火筒 * 火筒
* 胡掠箭 * 火掠箭
* 呼掠箭
* 野火 * 火箭 * 火箭
* 火箭
* 火箭
* 火炎 * 林之平
* 章斗 * 俞浩

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* HWHTK, ch. 121 (p. 3956-3); Sung Chi-Sun Chheng Yang Chhao, ch. 5, p. 32 a.
* E.g. Sung Shih, ch. 490, pp. 48 b, Tain Shih, ch. 150, p. 194; Kuei Chhing Wu Lei, ch. 41, pp. 15 a, 204.
* Sung Shih, ch. 157, p. 85. The same expression, yao chien, comes again in Kui Hsin Tsha Chhieh (P’ieh Chi), ch. 2, p. 59 a in connection with the Hsiangyang siege just mentioned.

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* HWHTK, ch. 121 (p. 3956-3); Sung Chi-Sun Chheng Yang Chhao, ch. 5, p. 32 a.
* T‘a hsi Hsiang-Yang Shou Chheng Lu, p. 79.
* E.g. Sung Shih, ch. 490, pp. 48 b, Tain Shih, ch. 150, p. 194; Kuei Chhing Wu Lei, ch. 41, pp. 15 a, 204.
* Sung Shih, ch. 157, p. 85. The same expression, yao chien, comes again in Kui Hsin Tsha Chhieh (P’ieh Chi), ch. 2, p. 59 a in connection with the Hsiangyang siege just mentioned.

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* Ch. 30, p. 86.
* Fêng Chia-Shih (1), pp. 56-7.
* Shou Chheng Lu, ch. 5, p. 6 d, ch. 4, p. 6 a.
* Sung Hsi Yao Kou, ch. 186, P‘ing Secr. ch. 2, p. 32 a. These were the specifications which included the sung têh or sighting-tube, for taking altitudes on shipboard, cf. Vol. 4 pt. 3, pp. 575-6.
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* 火火箭 * 林之平
* 章斗 * 俞浩

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30. MILITARY TECHNOLOGY

30. THE GUNPOWDER EPIC
the illustration given in Fig. 16 says:

The 'iron-beaked fire kite' has a wooden body, an iron beak, and a bundle of straw as a tail. Gunpowder is enclosed in (front of) the tail.6

The 'bamboo fire kite' is made of a coarse bamboo basket framework, large in the belly and narrow at the mouth, with a rather elongated shape. Several layers of paper are pasted over the framework, and brushed (with oil) until the cover becomes yellow. 1 lb. of gunpowder is put inside, and some round stones are added to increase the weight. Then a bundle of straw weighing 3 to 5 lb. is tied on to form the tail.

These two things are (used) in the same way as the 'barbed fire-ball'. When the enemy comes to attack one's city wall, they are both launched from trebuchets (p'ho5). They will set fire to the equipment collected by the enemy, and strike terror into his troop formations.

In spite of the word 'kite', which could equally well be translated 'kestrel' or 'sparrow-hawk', these two projectiles were evidently meant to be thrown over like bombs, and the paper kite (which was certainly a Chinese invention) is not involved.5

This brings us to the subject of fire-balls, bombs and grenades in general, our discourse next in order. The distinction between the incendiary and the explosive is difficult to draw, since we need to know what we are never told, namely the proportion of saltpetre in the mixture. But as we shall see, certain items of terminology may inform us of the moment when the borderline was crossed.

Before going further, however, let us dispose of a projectile which was certainly not explosive, even though containing gunpowder. 'Fire-balls' (hao chhi5) were made to be hurled from trebuchets towards the enemy. We have already described (p. 75) the 'igniter' or 'range-finding' fire-ball (yin hao chhi5) used for ascertaining distances. But there was also a 'barbed' or hooked fire-ball (ch'i li hao chhi5), intended for attaching itself to objects or structures (Fig. 17). The Wu Ching Tsung Yao says:7

The barbed, or calthrop, fire-ball has three sharp-edged six-pointed iron spikes, and is rolled up with gunpowder inside it. It has a hempen rope 2 ft. long (with a ring on the

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6. The point of the iron beak was presumably to direct the flames in a particular direction.
7. This was discussed in Vol. 4, pt. 2, pp. 577 ff., whence we may recall the leafer raid of 4122 (pp. 577 ff.) and the man-lifting kites of the 13th century (p. 589), which could have been used for sporting. It is true that a board of some kind is shown suspended over a city from a sort of flying windmill in Walter de Milamere's famous MS (cf. p. 287); James 1544, 154–5, fol. 373, 78a. This representation would be evidence for 1327 in Europe, but the design is so fanciful and impractical that it must have been imaginary. There is a good deal more to be said about windmill arrangements or hot-air balloon dragon-standards than we were able to put in Vol. 4, pt. 2, pp. 597–8, but it is not really relevant here.
8. WCTTY, ch. 15, pp. 64a, 65a, 65b. tr. acct. Of Arima (1), pp. 31–2. The SKCS edition writes pa5 fu5 instead of hao fu5, but this is an obvious misprint because all other texts say the latter, e.g. Wu Ching Tsung Yao, ch. 12, pp. 60, 8a; Ho Ling Ching, pt. 1, ch. 3, pp. 5a, 5a, b; Huang yang-fu ed. pp. 470, 498a; Wu Po Ch'ih, ch. 150, pp. 4a, 5a, 6a.
end) threaded through it.² On the outside it is enveloped in paper, to which is applied various chemical substances.³ It also has eight iron calthrops, each of which is provided with hooks (ni kia⁴). When you want to let it go you set light to it by piercing it with a (red-hot) iron poker, so that smoke begins to come out.

The text continues by giving the gunpowder formula for use with this weapon; it is the second of those which we examined above (p. 122), and its nitrate-content did not exceed 50%.

A fire-ball with barbs, spikes or hooks (cf. p. 120) makes one naturally think of those clusters of radiating spikes, known as calthrops, which were scattered on a road or any piece of ground to deter the onset of cavalry. This principle was of course a very ancient one, going back to the –4th century with the Mo Tzu book.⁵ But that was not quite what was at issue here—the barbed or hooked fire-ball was intended to attach itself to wooden buildings or to the sails of ships, and so set them on fire. It is interesting that exactly the same device was used later on in Europe, whether derivatively or independently, incendiary shot with hooks designed to catch on to rigging and sails, with destructive consequences.⁶

It was natural that incendiary bombs and grenades containing low-nitrate gunpowder should persist into the +17th century and later. Thus the Ping Lu of +1606 mentions some of these. For example, the ‘flying fire-pestle’ (fei huo chhui⁷) was simply a bottle-shaped wooden grenade, eight inches long and with sharp spikes or hooks protruding from its surface (Fig. 18). When thrown on to an enemy ship it would attach itself by these to sails, rigging or woodwork, and then the flames of the explosion or deflagration, even though strong enough only to break the casing, would set the craft on fire.⁸ A rather simpler version was the ‘flying swallow’ (fei yen⁹), nothing but a tube of bamboo or carton containing gunpowder of 68-5% saltpetre,¹ yet also provided with hooks for attachment to the sails and structures of the enemy.¹ Such devices were the direct ancestors of the incendiary bombs of the present day.

(10) Bombs and Grenades

We are now at the frontier between incendiary gunpowder and explosive gunpowder. The probability is that the huo chhia¹⁰ and huo phao¹¹ of the +10th and +11th centuries involved only low-nitrate mixtures, nevertheless very effective in

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¹ Perhaps this acted in the same way as the sling in which the projectile rested at the end of the long arm of the trebuchet.
² This may well mean more gunpowder.
³ Ch. 54, p. 153. Then all the ancient military works, such as the Liu Tsao, speak of it. Cf. Chang Hung-Chiao (17), p. 425.
⁵ PL, ch. 12, pp. 598, 602.
⁶ The composition is in this case actually given: in percentages, N 68-5; S 12-5; C 192.
⁷ PL, ch. 12, p. 612.
⁸ huo chhia ¹ huo phao ² huo chhia ³ fire-bomb ¹ fire-bomb ²
setting fire to siege machines and towers on land or 'wooden walls' at sea. But now a new term, phi li phao, seems to mark the appearance of a new thing, the 'thunderclap bomb', for the first time truly explosive. It would have been something like a maroon, consisting of higher-nitrate gunpowder, enclosed in a weak case of bamboo, carton and the like; with the property of giving a loud bang when exploded, and therefore more suitable (unless combined with other things) for causing fright rather than serious injury to the enemy's horses and men. As we shall see, this weapon was characteristic of the conflicts of the +12th century. Following upon this, there was a further step to the chien thien lei or 'heaven-shaking thunder-crash bomb', also identifiable as the thien huo phao or 'iron bomb', and also projected from trebuchets. Here for the first time brisant high-nitrate gunpowder was used, enclosed in a strong casing of metal, and thus calculated to cause serious injury to the enemy's troops upon detonation, a word we can now at last make use of. Broadly speaking, this development was characteristic of the +13th century. Its development had taken some two and a half centuries, since the first use of the term huo phao seems to have occurred in +1004, when Hsi Tung mentioned it in one of his discussions of attack by fire in the Hu Chhien Ching.6

There was one great advantage about the use of explosive projectiles, whether thin-walled or stout-walled, but so simple that it has not often been mentioned. When both sides were equipped with trebuchets, the stones hurled by the enemy could with relative ease be collected and used as ammunition to hurl back against them. But Li Shao-I (7) has pointed out, maroons and bombs disintegrated, doing as much damage as possible in the process, and the fragments were not available for re-use in the opposite direction.

It is a matter of great interest that the 'thunderclap fire-ball, or bomb' already appears in the Wu Ching Tung Yao, a fact which must surely mean that some of the Sung artisans of the first half of the +11th century already knew what would happen if one increased the percentage of saltpetre in the gunpowder mixture. The point was vital, since now for the first time a true explosion could be brought about. Here is the description (cf. Fig. 19):b

The thunderclap bomb (phi li huo chiu) contains a length of two or three internodes of dry bamboo with a diameter of 1.5 in. There must be no cracks, and the scepta are to be retained to avoid any leakage. Thirty pieces of thin broken porcelain the size of iron coins are mixed with 3 or 4 lb. of gunpowder, and packed around the bamboo tube. The tube is wrapped within the ball, but with about an inch or so protruding at each end. A (gun)powder mixture is then applied all over the outer surface of the ball.

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5 Ch. 6, p. 46, though even then in the author's commentary only.
6 WCTC/CC, ch. 12, pp. 67a, 68a, 69a, tr. sect. There are parallel descriptions in HLC, ch. 3, p. 74, 5, and HPC, ch. 102, p. 62a, 4, both abridged, otherwise essentially the same. HLC says 50 lb. of gunpowder, which would have been a much bigger bomb, but perhaps it was a misprint for 3 or 4. Cf. Okada Nohoto (1).

第18图：‘飞火’（ji bi huo chu）from Ping Lu, p. 56a.
Fig. 19. The 'thunderclap bomb' (phi li phao, or phi li huo chia), type of the bomb with weak casing. From WCTF, ch. 12, pp. 673 ff. The other two objects illustrated are the red-hot iron brands used for igniting the projectile before it was hurled from the trebuchet.

[Comm. The gunpowder mixture for application around the outside is given under the fire-ball section.]

If the enemy digs a tunnel to attack the city, then a sap must be excavated so as to connect with it. A (long) red-hot iron brand is used to set off the thunderclap bomb, which produces a noise indeed like thunder. Bamboo fans are used to drive the smoke and flame down the tunnel, so as to stifle and burn the enemy's sappers.

[Comm. The soldier setting off the bomb should suck some liquiorice (kan thao) as a protection.]

Here several interesting points arise. Presumably the point of the unbroken bamboo was to act like a fire-cracker and add to the fearsomeness of the explosion. Secondly, the nature of the covering is not stated, but as other descriptions will show, it was of carton or thick layers like a paper parcel. Thirdly, the sort of gunpowder applied round the outside is explicitly stated to have been of the fire-ball incendiary type, therefore low in nitrate, and it must have been mixed with some kind of gum to hold it in place. It would be extremely interesting to reconstruct and test the whole device.

So far we have not found the thunderclap bomb referred to in battle descriptions before the end of the 11th century, but after that time they come thick and fast—perhaps a shortage of saltpetre delayed the general use of the weapon. One of the earliest concerns the valiant but unsuccessful defence of Khaiêng (Piênching), the Sung capital, against the hosts of the Chin Tartars. One of the Sung commanders, Li Kang, left us an eye-witness account of the use of the thunderclap bomb. He wrote:

First Tshai Mou gave orders to all the officers and soldiers that (even) when the Chin troops came near the city, the trebuchets and arcuballistae were not to be used, and anyone who did so would be beaten; whereas our men were very angry. I myself then took over the command, and ordered them to shoot off any such artillery as they should see fit, and those who attained their targets best were well rewarded. At night the thunderclap bombs were used, hitting the lines of the enemy well, and throwing them into great confusion. Many fled, howling with fright.

The thunderclap bomb was sometimes combined with the blinding lachrymatory smoke caused by finely powdered lime. Here the classical instance is the Battle of Tshai-shih, where in 1161 the Sung admiral Yü Yün-Wên won a
great victory over the Jurchen Chin forces which were trying to cross the Yangtze and invade the south. In his Hai Chhi Fu¹ (Rhapsodic Ode on the Sea-eel Paddle-wheel Warships), Yang Wan-Li² wrote as follows:³

In the kuan-ku year of the Shao-Hsing reign-period, the rebels of (Wanyen) Liang⁴ came to the north (bank) of the River in force, intending to capture the people's boats, and hoisted flags indicating that they wished to cross over. But our fleet was hidden behind Chhi-pao Shan (island), with orders to come out when a flag signal was given. So a horseman was sent up to the top of the mountain with a hidden flag, and then when the enemy were in mid-stream suddenly the flag appeared; whereupon our ships rushed forward, and burned the enemy on both sides. The men on board them paddled fast on the treadmills, and the ships glided forwards as though they were flying, yet no one was visible on board. The enemy thought that they were made of paper. Then all of a sudden a thunderclap bomb was let off. It was made with paper (carton) and filled with lime and sulphur. (Launched from trebuchets) these thunderclap bombs came dropping down from the air, and upon meeting the water exploded with a noise like thunder, the sulphur bursting into flames.⁵ The carton case rebounded and broke, scattering the lime to form a smoky fog which blinded the eyes of men and horses so that they could see nothing. Our ships then went forward to attack theirs, and their men and horses were all drowned, so that they were utterly defeated.⁶

It would be interesting to know what the arrangements were which which induced the Chinese to use this new invention, but in fact this was needless, since we know now that the thunderclap bomb contained explosive gunpowder. Probably the noise

was as important here as the toxic smoke, and that required this higher-nitrate mixture.

Actually, the blinding effect of clouds of finely powdered lime was an old military technique in China; we have two accounts of it already in the same century. For example, in +1134, when a Sung garrison was shut up in Haochow by the Chin Tartars.⁷

Orders were given to the townspeople to transport (to the walls) jars of lime (hui phang'). As before, the Chin soldiers erected (wooden) towers at the river mouth in order to attack the city, but from its ramparts projectiles of molten iron were sent over, together with the jars of lime, and stones (all from trebuchets) as well as arrows (from crossbows and arrowballistae).

Thus battered, the enemy raised the siege. Then, in the following year, when the Sung general Yo Fei⁸ was campaigning against the bandit chief Yang Yao', we hear that the army also made 'lime-bombs' (hui phao). Very thin and brittle earthenware containers were filled with poisonous chemicals, powdered lime, and iron calthrops. In combat they were used to assault the enemy's ships. The lime formed clouds of fog in the air, so that the rebel soldiers could not open their eyes. They wished to make the same kinds of things themselves, but their potters were not able to produce them, so they suffered great defeats.

Hence we get a little light on the nature of the vessels used to contain the lime when it was discharged in projectile form; an echo thus of the fragile bottles used in Arabian warfare for hurling over napthha or distilled petroleum (p. 44 above). We can even trace the poison-gas effect a thousand years earlier, when in the Han period, about +178, the governor of Ling-ling, Yang Hsuan', was fighting a peasant revolt near Kueiyang. The Hou Han Shu says:⁹

The bandits were numerous, and Yang's forces very weak, so his men were filled with alarm and despondency. But he organized several dozen horse-drawn vehicles carrying bellows (phi naou') to blow powdered lime (shih hui') strongly forth, he caused incendiary rags to be tied to the tails of several horses, and he prepared other vehicles full of bowmen and crossbowmen. The lime chariots went forward first, and as the bellows were piled the smoke was blown forwards according to the wind (shen feng ku hui'), then the rags were kindled and the frightened horses rushed forwards throwing the enemy lines into confusion, after which the bowmen and crossbowmen opened fire, the drums and gongs were sounded, and the terrified enemy was utterly destroyed and dispersed. Many were killed and wounded, and their commander beheaded.

¹ See Chao Po-Ming Hui Fu, ch. 165, p. 28, tr. autct.
² We met him before, in Vol. 4, pt. 2, p. 422; in connection with his remarkable 25-wheeler paddle-wheel warships.
³ Lu Hsing An Pi Chü, ch. 1, p. 34, tr. autct. The text dates from about +1190.
⁴ Cf. p. 199 above.
⁶ 画着／佛著／山著／镜镇／镜镇
⁷ 画着／佛著／山著／镜镇／镜镇
⁸ 画着／佛著／山著／镜镇／镜镇
⁹ 画着／佛著／山著／镜镇／镜镇
From about +1187 there comes a curious story, recorded by a scholar of the Jurchen Chin dynasty, Yuan Hao-Wên, some fifty years later. What he said was this:4

Towards the end of the Ta-Ting reign-period there lived north of Thayuan a certain hunter named Thieh Li. One evening he found a great number of foxes in a certain place. So knowing the path that they followed, he set a trap, and at the second watch of the night he climbed up into a tree carrying at his waist a vessel of gunpowder (hua yao kuan tsu). The coven of foxes duly came under the tree, whereupon he lit the fuse and threw the vessel down; it burst with a great report, and scared all the foxes. They were so confused that with one accord they rushed into the net which he had prepared for them. Then he climbed down the tree and killed them all (for their fur).

Here the bomb was in all probability a narrow-mouthed pottery vase or amphora; in any case it takes its place in the array of weak-walled containers. It is interesting that such bombs could be used for hunting as well as for warfare.

But we must return to the thunderclap bombs. When Chao Shun1 was conducting his successful defence of Hsiang-yang against the Chin Tartars in +1207² he found them a very useful weapon. Afterwards Chao Wan-Nien3 wrote:4

In the evening he (Chao Shun) sent out a commando party of more than a thousand brave soldiers, and at midnight they went forward from Ho-thou to attack the enemy. The archers held up their torches and shouted, while the soldiers on the city walls also shouted and beat drums while the thunderclap bombs were shot off. The (Chin) wretches were terrified and quite lost their senses, men and horses running away as fast as they could.

On the 5th day at 10 o'clock in the morning, the enemy collected themselves together, and again attacked the city. Thereupon the (Sung) commander gave orders that the soldiers on the city walls should beat drums and raise their shouts, while at the same time more thunderclap bombs were hurled forth. The enemy cavalry were again frightened, and retreated.

On the evening of the 25th day, taking advantage of the rain and overcast sky, the commander urgently sent the officers Chang Fu6 and Hao Yen7 to prepare boats large and small, more than thirty in number, enough to carry 1000 crossbowmen, 500 trident spearmen, and 100 drummers, together with thunderclap bombs (phi li phao) and gunpowder arrows (hua yao chien). They took cover by the river bank below the enemy’s encampment. Then at the stroke of a drum the crossbowmen let fly a volley, and immediately following this all the drums sounded and all the crossbows were fired. Simultaneously the thunderclap bombs and the fire-arrows were sent into the enemy’s
camp. How many were killed and wounded in this attack could not be known, but men and horses were thrown into confusion and trampled upon each other. By the fifth night they were flying away in all directions. The (Sung) commander then ordered his men to retire, not even one being wounded…

On the 26th day, one of them, by name Fan Chhi1, who had been captured, walked back and regained the lines, saying that the whole Chin force had been asleep when the attack took place, so that they had no time to mount their horses or to collect their baggage. Such was the confusion that the barbarian army lost two or three thousand dead or wounded, and more than eight hundred horses.

This vivid account suggests that the explosive character of the thunderclap bombs took its toll, even though their casings were quite weak, just as the crossbow bolts, fire-arrows and close-quarter weapons certainly did. With this, then, we may proceed to gunpowder bombs with stronger casings.

On the way we may pause to notice that in the +13th century there are several references to ‘signal bombs’ (hsin phao). For example, in +1276, when A-Chu3 was attacking Yangchow, these were fired as messages to troop detachments; and there are other instances, including one of +1293, when the order was given to collect all those still in the stores in Chekiang. Although they are called ‘heaven-shaking’ (chen thien), they never seem to cause the slightest damage, so they were most probably carton bombs or maroons timed to explode in mid-air, and therefore belonging more to the phi li phao than the chen thien category.

From here onwards we have to adopt a method rather different from that used for the explosive projectiles with weak casings; for in the Wu Ching Tsung Yao of +1044 there is no mention of bombs or grenades with strong ones. We must therefore take a look at the battle accounts and other descriptions which deal with these cast-iron missiles. Then having considered these, we may say something of the literature from +1350 onwards, which has a good many specifications for explosive projectiles of both kinds, with casings strong as well as weak. By that time, of course, we were well beyond the time of arrival of gunpowder weapons in Europe, so we shall return to the much earlier development of the fire-lance, the rocket, and the metal-barrel cannon in China.

The story begins with the successful siege of Chihi-chou4 by the Jurchen Chin forces in +1221. That dynasty was by now almost at the end of its tether, the rising Mongolian power in the north having taken their capital of Peking in +1215, since when they had set up at Khalfeng. Though menaced in their rear they continued to struggle with the Sung. On this occasion, as we can see from

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3. This date these well could have been rockets, but we must postpone till p. 472ff. our examination of the time of their first appearance.
6. Kuo Chih Ch’uan, ch. 41, p. 616.
7. Kuo Chih Ch’uan, ch. 41, p. 616.
The account of the siege, Heih-siu Chi Chih Lu, written by Chao Yu-Jung, who had himself been an eye-witness and participant, the Sung division holding the fortified city seems to have had nearly everything—the 7,000 incendiary gunpowder arrows for use with crossbows (huo huo yao chien), and 10,000 to be shot from bows (sung huo yao chien), 3,000 barred fire-balls (chi li huo phao), and 20,000 large leather projectiles (phi ta phao), presumably low-nitrate gunpowder in bags. To these the somewhat later book Hsing Chien Hsi Chih adds, besides unspecified incendiary bombards (hsun phao) which could pass right over high obstructions, as also grenades (shou phao), now—for the first time—true metal-barrel guns, or proto-guns (hau thang), literally 'fire-tubes', a point to which we shall of course return. The Sung soldiers had matting and wet clay as protection against the petrol flame-throwers and incendiary bombs and arrows of the Chin Tartars, who also used expendable birds (hwo chih) to set the roofs of the houses within the city on fire. Although the Sung artillers would use more than 3,000 incendiary bombs in a single day, there is no mention of explosive thunderclap bombs. But now, again for the first time, comes something else new; the Ch'in army was provided with explosive bombs of cast iron (theh huo phao), and these they used to attack the defenders, which must amount to a detonating (phao cho) high-nitrate gunpowder mixture that had been reached at last, nothing less would have burst the iron casing. Their shape was like that of a bottle-gourd (phao), says Chao Yu-Jung, with a small opening, and they were made from cast iron, about 2 in. thick. Feng Chi-Shang suspected that the Sung troops were also equipped with these, but we do not know exactly what they were like. In any case, it seems sure that we have to do here with an early appearance of the thunder-crash bomb or grenade (chen zien le), surpassing the thunderclap bomb (phi li phao) because of the much greater strength of its casing, and the much greater damage that it would do when it burst. And indeed Chao Yu-Jung does say that the sound was like thunder (thong ta ju phi li), and the effectiveness very great, shaking the walls of houses, and killing and wounding many people.

The first appearance of chen zien le (thunder-crash bomb) as a technical term seems to occur just ten years later, in +1231, when the Chin Tartars were themselves in turn besieged in a city in Shansi by Mongol forces. A Chin general, Wanyen E-Kho, was in command at Ho-chung, when his defenses were over-run by the Mongolian army. So he escaped in ships with three thousand of his men (down the Yellow River). The Mongols pursued them along the northern bank with clamour and uproar of drums, while arrows and stones fell like rain. Now several li away a Mongolian fleet came out and intercepted them, so that they could not get through. But the Chin ships had on board a supply of those fire-bombs called 'thunder-crash' missiles, and they hurled these at the enemy. The flashes and flames could distinctly be seen. The Northerners had not many troops on their barges, so eventually the Chin fleet broke through, and safely reached Tung-kuan.

Thus the cast-iron explosive bombs were here used in a naval battle between the Chin and the Yuan.

Among the weapons of the defenders there was the heaven-shaking thunder-crash bomb (chen zien le). It consisted of gunpowder put into an iron container (thieh kuan), then when the fuse was lit (and the projectile shot off) there was a great explosion, the noise whereof was like thunder, audible for more than a hundred li, and the vegetation was scorched and blasted by the heat over an area of more than half a mou. When hit, even armour was quite pierced through. Therefore the Mongol soldiers made cowhide sheets to cover their approach trenches (hau phu tung) and men beneath the walls, and dug as it were niches (kuan) each large enough to contain a man, hoping that in this way the (Chin) troops above would not be able to do anything about it. But someone (up there) suggested the technique of lowering the thunder-crash bombs on iron chains. When these reached the trenches where the Mongols were making their dug-outs, the bombs were set off, with the result that the cowhide and the attacking soldiers were all blown to bits, not even a trace being left behind.

Moreover, the defensors had at their disposal flying-fire spears (fai huo ching). These were filled with gunpowder, and when ignited, the flames shot forwards for a distance of more than ten paces, so that no one durst come near. These thunder-crash bombs and flying-fire spears were the only two weapons that the Mongol soldiern were really afraid of.

According to Feng Chi-Shang (1), p. 39, his biography is in Sung Shih, ch. 449, p. 226. He had been a judge in Chihchow.

Feng Chi-Shang (1), p. 39.

Chen Chih Lu, Ch. 4, p. 156, 1. 174. The fact (p. 174) that the Sung defensors had at their disposal such a large number of incendiary devices was probably exaggerated for the sake of greater effect.

The Sung soldiers did not use the various forms of incendiary device invented by the Sung dynasty, generally a little after the Sung-Chin war; the Sung inventions were few in number and less radical in shape. The Sung Chih Lu, which has been mentioned, says that they used the gunpowder bombs in a little way, and the Sung defensors used them to cause a great uproar of clanging and clamour.

Chen Chih Lu, Ch. 4, p. 156, 1. 174. The defensors had at their disposal many kinds of incendiary devices, and the Sung Chih Lu, which has been mentioned, says that they used the gunpowder bombs in a little way, and the Sung defensors used them to cause a great uproar of clanging and clamour.

Chen Chih Lu, Ch. 4, p. 156, 1. 174. The defensors had at their disposal many kinds of incendiary devices, and the Sung Chih Lu, which has been mentioned, says that they used the gunpowder bombs in a little way, and the Sung defensors used them to cause a great uproar of clanging and clamour.

Chen Chih Lu, Ch. 4, p. 156, 1. 174. The defensors had at their disposal many kinds of incendiary devices, and the Sung Chih Lu, which has been mentioned, says that they used the gunpowder bombs in a little way, and the Sung defensors used them to cause a great uproar of clanging and clamour.
Thus in this graphic passage we can see the Chin Tartars using both explosive cast-iron bombs and incendiary gunpowder flame-throwers or fire-lances, this last an important development to which we shall shortly return (p. 220). It did not save them from the fall of the city and the virtual collapse of their dynasty. Destruction was due anyway for many other reasons, but we need not visualise the bombs as being so effective and reliable as modern weapons of the same kind; probably they often failed to go off, or even exploded prematurely. All the same, it was a famous defence, and worthy of note in any world military history.

This passage has been the property of Western historians for nearly two and a half centuries. It would hardly be expected that eighteenth-century writers would have been very clear about the nature of the weapons used, but in 1849 St Julien (6) gave a full translation of the passage. He appreciated in principle the explosive character of the bombs, but supposed the fire-lances to have been rockets. Commenting on this, Reinaud & Favé (in whose long paper it was first published), concluded that the bombs were essentially incendiary, though they did not rule out altogether a true explosive petard, the iron casing of which would shatter. As for the fire-lance, they accepted St Julien's interpretation of it as a rocket. Later on, Schlegel (12) understood the passage up to a point, but for a reason which will appear in a moment (p. 179), thought wrongly that the weapons were cannons, a mistake in which he was joined afterwards by Lu Mou-Tê, though fully rectified by Pelliot (49, 59). Although Reinaud & Favé had been quite right in denying that the Khai-fêng weapons were cannons, their assertion that the propellant power of gunpowder was then quite unknown, is today more dubious, for we have already found huo thang (metal-barrel guns or proto-guns) among the stores of Chhichow in +1221.1 Perhaps the first person to state almost correctly the nature of both the Khai-fêng weapons was Makers in 1870, who gave quite a good translation.2 Such are the vicissitudes of the history of technology.

Another eye-witness account comes from the pen of Liu Chi3, a scholar of the

Jurchen Chin realm. In his book of reminiscences, the Kui Chhien Chih4, he afterwards wrote:

The army of the Northerners (the Mongols) then attacked the city (of Khai-fêng) with their trebuchets.... The assault became more and more fierce, so that the trebuchet stones flew through the air like rain. People said that they were like half-millstones or half-sledgehammers. The Chin defenders could not face them. But in the city there were the kind of fire-missiles called 'heaven-shaking thunder-crash bombs', and these were at last used in reply, so that the Northern troops suffered many casualties, and when not wounded by the explosions were burnt to death by the fires that they caused....

All the people in the city were conscripted into a Home Guard called the Fang Chhêng Ting Chuang. An order was issued to the effect that any man who remained at home would be summarily executed. Even the scholars and students in the Academy were drafted as soldiers. The students petitioned to have a University Guard formed, to be called Thai Haíêch Ting Chuang.5 But a discussion at court decided that the bookish gentlemen were too weak for the hard work involved in being bomb-throwing artillerists (phao fu). So they appealed to the emperor himself, but his decision was that they should all be given desk jobs in the Ministry of the Interior (Hu Pu), and thus in the end they were spared the painful labour of the artillerists....

This suggests that the Chin Tartar State could command a certain patriotism before it was overwhelmed by the Mongolian power.

A few years later, when the Chin State was at its last gasp a commander named Kuo Pin5 found himself in +1236 defending a city called Hui-chou6. He commanded all the metals that could be found, including gold and silver, copper and bronze, as well as iron, for making the explosive bomb-shells, but it was all to no avail, and eventually the last pockets of resistance surrendered to the all-conquering Mongols.

Next in line, of course was the Southern Sung, and next we have to look at the warfare between them and the Mongols. In +1257, before the campaigns began, a meritorious official, Li Tsêng-Pô7, was gravely disturbed at the lack of preparedness in the arsenals of Ching8 and Huai9, near the border with the Mongols in the north. In his Kho Chai Tsu Kao, Hui Kao Hou10 he recorded his complaints, and they concern us because of the fire-weapons he enumerated. He began by saying that the armour was rusty and the munitions decayed, and that repeated requests to the court brought no results. For every ten items we ask for, the Arsenals Administration12 sends only one or two.
This was certainly Chang Kuei, who commanded the vanguard of ships. But what is important for the historian is that both sides were now using iron bombshells. Mr Liu might have been burnt by a fireball, but would hardly have been seriously wounded, as by an iron bomb-fragment; while incendiary gunpowder might have set the Sung ships on fire, but would not have done so much damage to their men. Let us continue in the words of the Sung dynastic history. Early in the siege there were swimmers who left the cities to get salt and firewood, but many of these were captured, after which the siege was tightened, and a price put on the heads of dead Sung soldiers—then came the relief convoy of the two Chungs in +1272. The Sung Shih says:*

Since the Han River was the only way of deliverance (for the garrison), one hundred (paddle-boat) ships were assembled at a point below Thuan-shan, and after a couple of days they entered Kao-thou-kang harbour. Then (after loading) they took up a rectangular formation, every ship being equipped with fire-lances (huo chih-chan), trebuchets and bombs (huo phao), burning charcoal (chih chih-than), large axes and heavy crossbows. When the night had worn on three quarters of an hour by the water-clock, the fleet hoisted anchor and sailed out into the river using red lamps as signals. (Chang) Kuei led the van, and (Chang) Shun commanded the rearguard; so with a following wind they breasted the waves, making straight for the enemy ahead. When they got above Mu-hung-than, there were the ships of the northerners (the Mongols) stationed right across the river, with no gap where they could get through. So taking advantage of their armament, they cut right through the iron cables (bichh hisan) and tore out several hundred stakes (tsaa-saan), and sailing on they fought an energetic rearguard action for 120 li until dawn, when they reached the waters beside Hsiang-yang.

Here the historian will be interested in the bombs and the fire-lances, but one can see how Chang Kuei and his ship came to be captured. This was, of course, the siege in which the Mongols employed the counterweighted, or 'Muslim' trebuchets for the first time (cf. pt. 6 (f) 5 above).

At the risk of a surfeit of battle accounts, just one more must be given before we return to technological description. In +1277 the Mongols mounted a great campaign against the remaining Sung resistance in Kuangsi; their army was led by a Uighur Muslim artillery general in the Mongol service named A-Li-Hai-Ya, while Ma Chi, the Sung general, attempted to oppose him. But he was outflanked and had to fall back upon the provincial capital Kweilin. After a siege of more than three months, the main Sung garrison gave in, but Ma and a
brigadier of the name of Lou Chhien-Hsia\(^1\) continued to defend one of the demi-

lunes with some 250 men. Finally:\(^8\)

Lou, coming to the top of the wall, shouted out 'Our soldiers are so hungry that we have
not (the strength to) come out and surrender; but if you will give us food we will listen to
your commands'. So several oxen and a number of bushels of rice were given to them.
One of the officers opened the gate, and taking in the food shut it again. (Some of) the
enemy then got up on to the city walls, and saw the (Sung) soldiers dividing the rice and
slicing up the meat. Before the cooking was finished they ate it all. Then the sound of
horn and drum was heard, so that the (Mongol) commanders, thinking that fighting was
going to begin again, put on their armour and made ready. But (suddenly) Lou ordered
his men to set off an (enormous) bomb (huo phao)\(^5\). The noise was thunderous, accompa-
nied by something like an earthquake; the city wall split in twain, and the smoke and
dust filled the heavens. The foreign (Mongol) soldiers were terrified, and many of them
were killed. When people came near to look, after the fires had died down, there was
nothing left but ashes.

This was evidently no grenade,\(^3\) but rather something approaching a land-mine,
able to destroy so many people. Consequently it leads naturally to the next
sub-section, on land- and sea-mines, reasonable here because we have detailed
descriptions from only a century later. But first we must look at the only illustration
of a +13th-century bomb-shell which has come down to us, and also tell
the story of a man who found some of the shells still remaining in +1522. Then,
after viewing the bomb descriptions of the Ming, land-mines will be on the
agenda.

Fig. 20 shows the only surviving picture of a +13th-century bursting bomb-
shell that has come down to us, assuredly the thunder-crash bomb or chen thien
lei\(^6\) of earlier China. It is taken from a horizontal scroll or makimono of paintings
and text, entitled Mûko Shûrai Ektoba\(^4\) (Illustrated Narrative of the Mongol In-
vasions of Japan), done by some unknown master in +1293 to illustrate the
adventures of a nobleman named Takezaki Suenaga.\(^5\) It shows Takezaki him-
self on the right, with his badly wounded horse falling under him,\(^\ast\) while on
the left stands a Mongol archer missed by Japanese arrows.\(^6\) Between them
there is a bursting bomb-shell the comet-like tail of which suggests that it
had come from the right, i.e. the Japanese side, yet since it was the Mongolian
army alone which used these thie thao phao\(^7\) it must have come from the
left, and happens to be throwing the flame of its burst forwards. Since the

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\(^1\) Sung Shih, ch. 451, p. 6a, h, tr. auct.
\(^2\) As was thought by Chavannes (22), who gave otherwise a good account of the incident of suicide rather
than surrender. Cf. Mu de Chih, ch. 21, p. 172.
\(^3\) A caption says that this part of the painting was done by Takezaki himself.
\(^4\) Ch. 1, pp. 119, 25a.
\(^5\) 蕨軒軒  '火砲'
\(^6\) 里天雷  '蒙古仰射炮'
\(^7\) 竹崎季長  '鐵火砲'

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Fig. 30. The only surviving picture of a +13th-century bursting bomb-shell, from the Mûko Shûrai Ektoba, ch. 1, pp. 25a, 26a, a nearly
contemporary account of the Mongolian invasion of Japan, in +1294.
event occurred so short a time before, in +1274, the drawing has a considerable authenticity. 4

Neither caption nor narrative has anything to say about the ietshub! b but there are texts which do, notably the Hachiman Gudoki 2 (Tales of the God of War told to the Simple), an anonymous work of the +14th century, which nevertheless agrees closely with the account of the battle in the scroll. Here we can read the following account of the incident: 3

The commanding general kept his position on high ground, and directed the various detachments as need be with signals from hand-drums. But whenever the (Mongol) soldiers took to flight, they sent iron bomb-shells (ietshub) flying against us, which made our side dizzy and confused. Our soldiers were frightened out of their wits by the thundering explosions; their eyes were blinded, their ears deafened, so that they could hardly distinguish east from west. According to our manner of fighting, we must first call out by name someone from the enemy ranks, and then attack in single combat. But they (the Mongols) took no notice at all of such conventions; they rushed forward all together in a mass, grappling with any individuals they could catch and killing them. 3

This was the expedition led by the Mongol general Hu-Tun 7 which landed at Hakata in Kyushu. 4 There is independent evidence from the Chinese side that iron bomb-shells were used in these engagements.5 The Mongols did so again in the second invasion, in +1281, at Sekiura, under the command of the Chinese admiral Fan Wên-Hu 6, who had apparently asked Khubilai Khan for the services of Uighur or Muslim counterweighted trebuchet engineers, and been refused, the emperor seeing no use for them in naval warfare. 6 We need no more than refer to the often-quoted parallel between these Mongol expeditions and the Spanish armada three hundred years later, both broken up by storm and gale not without energetic resistance by the island nations in question. At all events, the picture in Takezaki's scroll is a precious heritage for historians of technology.

Lastly, there are the words of a scholar who actually saw iron bomb-shells dating a couple of centuries back, dumped on the walls of a great city. This was

in +1322, Ho Mêng-Chhûn 1 afterwards wrote as follows: 2

In the spring I was sent to Shensi, and there at Sian 9 on the city wall I saw some old cast-iron bomb-shells, of the kind that were known in former times as heaven-shaking thunder-crash' bombs. In shape they were like two bowls that could be joined together (de cahn) to make a ball, and at the top there was a small hole the size of a finger. These things are not used by the army now, but I am sure that it was one of the weapons used by the Jurchen China people when defending Khaîling (against the Mongols).

This was a satisfying observation, though one wishes that a few had been saved from the scrap-iron merchants for the benefit of military museums today. Curiously, it was this passage which gave rise to a classic misunderstanding. Ho Mêng-Chhûn's words were supposedly quoted in Thang Shun-Chih 5's Paï Pien 7 encyclopedia of +1581, whence they found their way into the Ko Chih Cheng Yuan of +1735, 6 and so to Schlegel (12) in 1902. Somewhere along the line the double bowls were corrupted to 'double rollers' (ho tha 1) and this led to Schlegel's 'closed rollers', which dominated the literature for some time, since he was determined to prove that the heaven-shaking thunder-crash weapons were in fact cannon. It took Pelliot (49, 59), as so often, to put the matter right. The deceptiveness of the situation lay in the fact that just during the heyday of cast-iron bomb-shells, metal-barrel guns and cannon were in fact arising, as we see elsewhere (pp. 23, 170 above, pp. 304 below). But it takes many years to unravel these tangled skeins of history which the centuries have confused.

As for the inevitable comparison with Europe, we have now seen that it is possible to trace back the use of cast-iron bomb-shells and grenades in China to +1221, and that must have been coming into regular employment about the beginning of that century. 5 But the first date for hollow iron bomb-shells in Europe appears to be +1467, when they were used by the Burgundians in their wars. 7 Thus alike all the other gunpowder weapons there is a lag of a couple of centuries at least between their first appearance in China and the earliest dates for them in the West. Judging from Romocki's account of the Beliffrits of Conrad Kyeser, written about +1410, the Europeans repeated the Chinese experience in having casings of different strengths for their bombs 6

It now remains only to take a look at the descriptions of bombs in the +14th century and later, seeing how the weak-casing devices (phi li phi) and the strong-casing ones (yen thee nei) had developed by those times. The best source is the Hau Lung Ching (Fire-Drake Manual) which refers to the techniques in use

Notes

1. This translation is based on the work of Dr Nakaoa Tetsuro, his interest and help with the translation. This note is taken from the English edition of the book. 2. The translation by Dr Nakaoa Tetsuro, his interest and help with the translation. 3. The translation by Dr Nakaoa Tetsuro, his interest and help with the translation. 4. The translation by Dr Nakaoa Tetsuro, his interest and help with the translation. 5. The translation by Dr Nakaoa Tetsuro, his interest and help with the translation. 6. The translation by Dr Nakaoa Tetsuro, his interest and help with the translation. 7. The translation by Dr Nakaoa Tetsuro, his interest and help with the translation. 8. The translation by Dr Nakaoa Tetsuro, his interest and help with the translation. 9. The translation by Dr Nakaoa Tetsuro, his interest and help with the translation.
about +1350, when the Ming were about to take over from the Yuan, but the descriptions and illustrations continue to be repeated, with the wording often copied verbatim, in later compendia such as the *Ping Lu* of +1606 and the *Wu Pei Chih* of +1621, by which time some of them must have become rather archaic weapons. Let us begin with the strong-casing bombs and grenades, then proceed to the weak-casing maroon-like devices, giving a couple of translations for each.

Thus first we encounter the 'bone-burning and bruising fire-oil magic bomb' (*tsan ku hou yu shen phao*). The caption (see Fig. 21) says:

For this bomb you take tung oil, urine (*yin hsiu*), sal ammoniac, faeces (*chin chih*), scallion juice, and heat them so as to coat a lot of iron pellets (*thih shao*) and bits of broken porcelain. Then fill in (with a gunpowder core) to a casing of cast iron making a fragmentation bomb (*sheng thi chu hsiou tsan phao*). When it bursts it breaks into pieces which wound the skin and break the bones (of enemy soldiers) and blind their eyes. Even birds flying in the air cannot escape the effects of the explosion.

Here, as we shall see in other cases, the object was to mix poisonous and other deleterious materials with the gunpowder, so that the explosion would produce effects other than mechanical; but how far the organic materials would survive the heat of the detonation and produce the desired effects when dissipated in the smoke could only be tested by experiment. Another specification was for the 'magic-fire meteoric bomb that goes against the wind' (*tsuan feng shen hao liu hsing phao*). The instructions (see Fig. 22) say:

One uses cast iron to make a round ball, and one packs into it 'poison gunpowder' (*ts an hou*), 'flying gunpowder' (*fei hou*), 'blinding gunpowder' (*ju hou*), and 'bruising and burning gunpowder' (*tsan hou*). Then you use hard wood to make a core (ma). On each side of it there are two holes for fuses, four altogether, which lead in from the outside, and another which is wound round and round inside. All are wrapped in alum-saturated paper (to keep them dry). This bomb can be made so large that it takes draught animals to carry it about, or so small that it can be thrown by hand.

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*Especially when one remembers that the metal-barrel gun and cannon using the propellant force of gunpowder was developing through the +13th century, and complete before its end.  
'This elegant designation of 'silver rust' was probably derived from the yellow film of sulphide characteristic of unpolished silver.  
'Lit. 'golden juice'.  
'HLC, pt. 1, ch. 2, pp. 70, 72, Hsiangyang ed., *Hou Chih Tu* ch. 12, tr. auct.  
'Composition given in pt. 1, ch. 1, pp. 65, 67, 70; it contains arsenicals, vegetable poisons (aconite, croton) and animal poisons (cannibalism, toad venom), etc.  
'Composition given in pt. 1, ch. 1, p. 76; it contains powdered soap-bean and ginkgo leaves.  
'Composition in pt. 1, ch. 1, pp. 75, 76; it contains powdered soap-bean and ginkgo leaves. It is interesting that soap-bean was used for many centuries, cf. p. 104 above.  
'Composition in pt. 1, ch. 1, pp. 75, 76; it contains powdered soap-bean and ginkgo leaves. It is interesting that soap-bean was used for many centuries, cf. p. 104 above.  
'Composition in pt. 1, ch. 1, p. 89; iron pellets or filings, sal ammoniac, tung oil, and tiger-hunting poison.  
On this last see the indispensable paper of Blasier (1). All these compositions need further investigation.  
'Or perhaps rather 'to carry it in action'; cf. p. 213 below.
Here the purpose of the core is not obvious, unless it was to act as a spout for the flames of the low-nitrate gunpowder pending the explosion of the high-nitrate mixture. But the same principle is involved, that of mixing poisonous materials together with the saltpetre, sulphur and charcoal. Lastly, we may mention the ‘dropping-from-heaven bomb’ (thien chui phao), seen in Fig. 23. It is described as about the size of a bushel measure, and intended to be hurled up very high into the air, presumably by a trebuchet or an arbalista, whence it should land on the enemy camp, preferably during a dark night. The enemy soldiers then fall to killing each other in their alarm. The sound of the explosion is like thunder; so a metal casing is to be supposed, and the bomb contains dozens of incendiary packets (huo kuan) which are scattered in all directions.

Turning now to the weak-casing bombs deriving from the phi li phao, there is first the ‘bee-swarm bomb’ (chen feng phao). The description (see Fig. 24) says:

Bamboo strips are woven into the shape of a ball and pasted round with forty or fifty layers of thick paper, then dried in the sun. Afterwards it is wrapped up further in fifteen layers of oiled paper. Make an opening in it and fill it with 2 lb. of gunpowder, and half a pound of iron calthrops, putting in also several dozen flying-swallow poison-fire gunpowder (ji yen tu hau) fire-crackers made of paper. This bomb has a very strong power, for not only can it hit the enemy personnel (with the objects), but also when the flying-swallow fire comes forth it can stick to their persons and still burn. It can also set fire to the sails of enemy ships and burn fiercely; but it can be extinguished with water.

This then was a projectile of fairly primitive type, primarily incendiary rather than bursting a metal case into fragments. Our second example comes from a different source, the Thien Kung Khan Wu of +1637 (Fig. 25). It is the well-known

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1. The quantities are not always given in the composition formulae, only the constituents.
4. The composition of this does not appear to be given in HLC, but it was probably similar to the others.
5. A very similar type of bomb, the ‘great bee-hive’ (chhi-feng shao) is described in Chou Chih-tung-Ya's Hai Hai Kuan Chi (Second Collection of Documents about West Lake at Hanghau and its Neighbourhood), ch. 17 (p. 335). This occurs in a piece of much interest, one of the few which describe gunpowder weapons (with illustrations) apart from the military compendium. It is entitled Liu Po-Wen Chiu Hai Phao Chi Chiang, "On the Pacification of Central Chekiang Province by the Able Officers recommended by Liu Po-Wen", and it refers to that remarkable military commander and scholar of scientific and technological interests, Liu Chi, whose work we have already several times encountered (cf. pp. 45). He was of great assistance to Chu Yuan-Chang in conquering the empire for the Ming. Liu's campaigns in Chekiang were conducted between +1540 and +1543 against both the inland rebels under Hai Shou-Hai and the coastal pirates under Fang Kuo-Chen, who continued to rule the province, aiding sometimes with the Yuan and sometimes with the Ming, until +1578. Liu was therefore acting at the time as a Yuan official. But the design for bombs, fire-lances and rockets must certainly go back to +1540, so we should be grateful to Chou for preserving the document about +1637. For our knowledge of this interesting survival we are indebted to Dr Liu Yu-Tchang in 1954.
6. The projectile was evidently meant to be hurled like a grenade by means of a loop of rope used as a handle.
Fig. 23. The 'dropping-from-heaven bomb' (tiên chũ pháo), from HLC, pt. 1, ch. 2, p. 124 and HCT, p. 152.

Fig. 24. The 'bee-swarm bomb' (chồn fìng pháo), from HLC, pt. 1, ch. 7, p. 94, b and HCT, p. 156. One of the class of weak-casing bombs.
passage on the bomb called ‘match for ten thousand enemies’ (shen jen ti), Sung Ying-Hsing says:

(When attacks are made upon) the walls of small cities in remote prefectures; if the available guns (phao) are too weak to repulse the enemy, then bombs (huo phao) should be suspended (i.e. dropped) from the battlements; if the situation continues to worsen, then the ‘match for ten thousand’ bomb should be employed. This recently developed weapon can be used according to the circumstances, and unlike the previous one, it can be thrown in any direction. The saltpetre and sulphur in the bomb, on being ignited (explode), and blow many men and horses to pieces in an instant.

The method is to use a dried empty clay ball with a small hole for filling, and in it are put the gunpowder, including sulphur and saltpetre, together with ‘poison gunpowder’ (tu hao) and ‘magic gunpowder’ (shen hao). The relative proportion of the three gunpowders can be varied at will. After the fuse (jin hui) has been fitted, the bomb is enclosed in a wooden frame. Alternatively a wooden tub, coated on the inside with the sort of clay used for image-making, can be used. It is absolutely necessary to use the wooden framework or the tub in order to prevent any premature breakage as the missile falls (until the gunpowder explodes). When a city is under attack by an enemy the defenders on the walls light the fuse and throw the bomb down. The force of the explosion spins the bomb round in all directions, but the city walls protect one’s own men from its effects on that side, while the enemy’s men and horses are not so fortunate. This is the best of weapons for the defence of cities. It is important that those who have charge of such affairs should realize that the understanding of gunpowder and the knowledge of the construction of fire-weapons come from human ingenuity, so that those concerned may have to take as much as ten years to master it all.

Sung Ying-Hsing was no army man, one feels, otherwise he would hardly have described such an archaic weapon with so much enthusiasm. But in the backblocks it may well have been used still at the end of the Ming. A rather similar device described in the Hsiao Lung Ching two or three centuries earlier was the ‘flying-sand magic bomb releasing ten thousand fires’ (shen hao fei chu shen phao) seen in Fig. 26. Here a tube of gunpowder was put into an earthenware pot containing quicklime, resin and alcoholic extracts of poisonous plants, all to be released by the explosion; this was thrown down from city-walls, recalling the lime bombs of Yi Yin-Wen’s naval victory (p. 165 above).

*Another of the...
same kind was the ‘wind-and-dust-bomb’ (fēng chén pāo) of Fig. 27. Many more could be discussed, but this should be sufficient to show that the parallel traditions of weak-casing pēi li pāo and strong-casing chēn tiēn leǐ continued down to the latter part of the 16th century and the beginning of the Chhing.\(^8\)

One gets an interesting sidelight on this from the book of Juan Mendoza, written in +1585 and translated into English by Robert Parke three years later. Speaking of the Chinese soldiers, he says:\(^9\)

> These footmen be marvellous full of policie, and ingenious in warlike or martiall afferes: and although they have some valor for to assalt and beside the enemy, yet doo they profite themselves of policies, devises and instruments of fire, and of fire worke. Thus do they use as we by land in their wars as by sea, many boomes of fire, full of old iron, and arrowes made with powder and fire worke, with the which they doo much harme and destroy their enimes.....

Here no doubt are references to fire-lances with co-viative projectiles, possibly also to rockets, as well as to the ‘bombe’ with casings weak or strong. In due course we shall discuss them all (pp. 220 and 472 below).

In fact their longevity was even greater than this. During the war of 1856–8, when the ‘red-haired barbarians’ (i.e. the British Navy) were attacking the Bogue Forts and the city of Canton,\(^4\) Admiral Sir William Kennedy was a midshipman, and his subsequent account of the proceedings, written fifty years later, can be read in his rather jingoistic autobiography, full of period flavour. What he says is of considerable technological interest:\(^7\)

The Chinese were fully prepared for us; the junks lay broadside on, with their guns run out on one side, springs on their cables to keep their broadside bearing, and ‘stink-pots’ at the mast-heads. These offensive weapons are worthy of description. The stink-pot is an earthenware vessel filled with (gun)powder, sulphur, etc. Each junk had cages at the mast-head, which in action were occupied by one or more men, whose duty it was to throw down these stink-pots on to the decks of the enemy, or into boats attempting to

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\(^{a}\) HLC, pt. 1, ch. 3, p. 114, b, Hsiangyang ed. p. 148. The vase shape of the container is worth noticing here, for it may have been this which gave to the earliest cannon-founders the idea of making guns in this form, thickening the walls round the explosion-chamber.

\(^{b}\) There is an interesting illustration of bombs in the Thai Tzu Shih Lu\(^2\), a work which we shall study more carefully later on (p. 396 below) because of the rich information it gives concerning the Chinese field artillery about +1600. The book recounts the exploits of Nurhachi (d. +1666), the Manchu prince afterwards regarded as the principal ancestor of the Chhing dynastic house. In Fig. 28 we see the siege of Ningyuan\(^2\) in +1666, with Ming bombs bursting on the roofs of each of the Manchu assault ladders. Although they do not look as if they were doing much damage, this siege was in fact one of Nurhachi’s few failures, and the city was held for the Ming by its gallant commanding general Yuan Chhing-Hu\(^4\). Note that by now the Manchu themselves are firing muskets from behind mobile ramparts.

\(^{c}\) This was the ‘Arrow’ war, so named from the praise loraes which precipitated it; the Anglo-French incursion which led to the treaty system. On the general background see Fairbank (4), pp. 243ff.; Wakeman (4).

\(^{d}\) Kennedy (1), p. 43. Later in his book he gives a translation of a proclamation by the Governor of Liang-Kuang which includes detailed instructions about the management and use of the stink-pots (pp. 65ff., 67).
Fig. 27. The 'wind-and-dust bomb' (fēng ān pào), from 

Fig. 28. Bombs at the siege of Ningyuan by the Manchu prince Nurhachi in +1626. Although they do not seem to be very effective against the roofs of the Manchu assault ladders, they must have been by this time 'thunder-crash bombs' (chen thien lei), i.e. bombs with strong iron casings. The picture is taken from the 
Thi Tìu Shô Lu, a work which would not be expected to do much justice to Ming military technology, but in fact the siege had to be raised after a spirited defence by Yuan Chhung-Huan.
would certainly have to jump overboard or be stifled.

From this description it is clear that the military technicians of the +11th century, or Yu Yuan-Wen's men in the +12th, would have been quite at home with the poison-smoke weak-casing projectiles still used by Chinese forces in the middle of the nineteenth century. And from what we have seen on the composition of such bombs (pp. 123, 144, 167 above) we can fairly well imagine it too. Was not all this a chapter in the pre-history of tear-gas grenades? But we have no records that the medieval Chinese used it on civilian populations.

(11) Land and Sea Mines

We have now followed the fortunes of gunpowder with its continually rising nitrate content from its first uses as slow match and incendiary through the explosive weak-casing maroon to the strong-casing cast-iron bombs and grenades which gave true detonations. By +1277 the case of the 'enormous bomb' of Lou Chhien-Hsia (p. 176 above) makes it clear that something more of the nature of a land-mine was then available, and it is to these greater masses of explosive that we must now briefly turn our attention. It also seems probable that the thunder-crash bombs which were let down on chains to the Mongol sap trenches in the siege of +1292 were also larger than the customary iron bombshells lobbed over from trebuchets, in which case it would be more reasonable to speak of mines in that affray also. In any case, it looks as if the size of the infernal machines was growing steadily all through the +13th century. By the time that we get to the middle of the +14th we can find specific descriptions of mines in the Huo Lung Ching.

In early times the terms phao and huo phao evidently covered mines, though the name later adopted was 'ground thunder' (ti lei). Several types of mine are described in the various versions of the 'Fire-Drake Manual' as well as in the Wu Pei Chih. For example, the 'invincible ground-thunder mine', wa ti ti lei phao is clearly intended to be buried in places where the enemy is likely to pass. The Huo Lung Ching says:

The mine, made of cast iron, is perfectly spherical in shape. It holds one peck or five pints of (black) powder, depending on its size. The 'magic gunpowder' (then huo), 'poison gunpowder' (ja huo) and 'blinding and burning gunpowder' (fa huo) compositions are all suitable for use (in this device). Hard wood is used for making the wad (fa ma), which carries three different fuses in case of defective connection, and they join at the 'touch hole' (hao chiih). The mines are buried in places where the enemy is expected to come. When the enemy is induced to enter (the minefield) the mines are exploded at a given signal, emitting flames (and fragments) and a tremendous noise.

What exactly the triggering mechanism was we are not told, so one has to suppose that a long fuse was ignited by hand from an ambush or some sort of concealment just at the right time. The speed of transmission along the fuse would have had to be nicely calculated.

Another form of land-mine, but one using a firing device touched off by the enemy, is represented by the 'ground-thunder explosive camp' (ti lei cha ying), one of the 'self-trespassing' (tsue fan) type. It presumably derived its name from the fact that it was laid in the ground in large numbers in strategic positions, like the tents of an army encampment. The Huo Lung Ching says:

These mines are mostly installed at frontier gates and passes. Pieces of bamboo are sawn into sections nine feet in length, all septa in the bamboo being removed, save only the last; and it is then bandaged round with fresh cow-hide tape. Boiling oil is next poured into (the tube) and left there for some time before being removed. The fuse starts from the bottom of the tube, and (black powder) is compressed into it to form an explosive mine (cha phao). The gunpowder fills up eight-tenths of the tube, while dead or iron pellets take up the rest of the space; then the open end is sealed with wax. A trench five feet in depth is dug (for the mines to be concealed). The fuse is connected to a firing device which ignites them when disturbed.

Although the text does not say so, the eight bamboo 'guns' are held together by two discoidal boards pierced by holes of just the right size, as can clearly be seen in the illustration (Fig. 29). From the specification they must have been buried at a slanting angle, probably pointing up the path, and as the picture says, the whole contraption is to be concealed by earth and grass. As for the boiling oil, its purpose was presumably to harden the interior of the bamboo for its once-only function.

The 'self-tripped trespass mine' (tsue fan phao) operated in the same way (Fig. 30). Again the Huo Lung Ching says:

It is made of iron or rock, or even porcelain or earthenware, with a cavity inside, very like the explosive mine mentioned above. Outside, the fuse runs through a series of

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2. HLC, pt. 1, ch. 3, p. 193 above.
3. See also Wu Pei Chih ch. 234, pp. 48, 52.
4. This is reminiscent of the automatic crossbowmen in the tomb of Chhin Shih Huang Ti (pt. 6, (c) 32 above).
5. Dr. Clayton Bredt suggests, from recent experiments, that its purpose was rather to waterproof the bamboo and to kill boring insects. Freshly cut bamboo is immensely strong but very susceptible to insect attack, and the labyrinth of holes under 1 mm in diameter is soon broken up by moisture, moulds and bacteria, especially if the tube is exposed to soil. Under such conditions it would soon be useless for firing anything. The bamboo borers are beetle larvae such as Lecit brunneus and Cyrtotrogus lepticera (R 55; Tu Ya-Chh‘an et al. (1), p. 173 f).
6. HLC, pt. 1, ch. 3, p. 262, b; tr. auct. Also in the Hsiangyang-fu edition, Huo Chi Chih, p. 351, and Wu Pei Chih, ch. 3, p. 261, b; tr. auct. Also in Wu Pei Chih ch. 234, pp. 53, 61.
Fig. 29. The 'ground-thunder explosive camp land-mine' (in the jug). The eight bamboo 'guns' are held together by two discoidal boards pierced by holes of suitable size. From HLC (HKPP), ch. 3, p. 254.

Fig. 30. The 'self-erupted trench land-mine' (see fig. plan). From HLC (HKPP), ch. 9, p. 264.
'fire-ducts' (huo tsiao), which connect several of these devices installed at strategic points. When the enemy ventures on to ground containing one of these mines, all the others are set to explode (quickly) one after the other.

Another rock-cut infernal machine was the 'stone-cut explosive land-mine' (shih cha phao). Again the Hwu Lung Ching says:

This is a piece of rock carved into a spherical shape, and it can be of various sizes. Inside it is hollow, and contains explosive (black) gunpowder, which is packed in tight with a pestle to fill up nine-tenths of the space. A small section of bamboo is inserted for the fuse. The gunpowder is covered over with a piece of paper, above which is placed some dried earth, and a pound of clay above that in which the fuse is coiled round. For the defence of cities the land-mine is buried and hidden underground (at appropriate places), and this is what can be used for ground-thunder.

It says much for the labour-force available to the old Chinese military engineers, who were able to keep an army of stone-masons chipping away at such land-mines. But even where suitable lumps of rock were available, they would not be easily replaced once one had shot one's bolt, as it were.

Yet another apparatus, the 'Supreme Pole combination mine' (Thai Chi tsang phao), mounted a battery of little guns pointing in eight directions (pa kua chihung), which were set off by an automatic trigger mechanism. The case for them could be of wrought iron or hard wood, with ports for the missiles, and it could be installed in unguarded camps or mounted passes, where a returning or advancing enemy would be likely to trip it (Fig. 31). This idea is old, probably of the early 14th century, because it occurs in the first stratum of the Hwu Lung Ching, but its specification persists in many later books.

Nothing is given in the text to elucidate the firing device used to set off these mines. But for the 'explosive mine' (cha phao), the text of the Fire-Drake Manual mentions at least the type of ignition arrangement, though not describing it fully. The Hwu Lung Ching explains the matter thus:

The explosive mine is made of cast iron about the size of a rice-bowl, hollow inside with (black) powder rammed into it. A small bamboo tube is inserted and through this passes the fuse, while outside (the mine) a long fuse is led through fire-ducts. Pick a place where

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2 HLC, pt. 1, ch. 3, p. 28a, b tr. act. See also the Hsiyang-yu edition, Hwu Chhi Thu, p. 352, and Hwu Kung Fei tao, ch. 3, p. 28a. b. Also in Wu Po Chih ch. 234, pp. 7b, 8a. The illustration and description in ch. 122, p. 27a (wei tsang phao) are also striking. A photograph of actual specimens is in Lo Ch‘ü-Wén (1).
3 For the significance of this name see Vol. 2, pp. 400 ff.
5 HLC, pt. 1, ch. 3, p. 30a, b. HKP, ibid.; Hsiyang ed. HLT, p. 40a.
6 WPC, ch. 134, pp. 9b, 9b, PL, ch. 12, p. 66a, 7. Lai Hien-Chou (12) has devoted a special paper to the exploration of the firing and timing devices, which include, as we shall see, the joss-stick, the long-glowing composition, and the suddenly released flint-and-steel mechanism.
7 HLC, pt. 1, ch. 3, p. 37a, b. tr. act. See also the Hsiyang-yu edition, Hwu Chhi Thu, p. 38a and Hwu Kung Fei tao ed. ch. 3, p. 37a. b. Also in Wu Po Chih, ch. 234, pp. 5b, 7a.
8 HLC, pt. 1, ch. 3, p. 37a, b. tr. act. See also the Hsiyang-yu edition, Hwu Chhi Thu, p. 38a and Hwu Kung Fei tao ed.
the enemy will have to pass through, dig pits and bury several dozen such mines in the ground. All the mines are connected by fuses through the gunpowder fire-ducts, and all originate from a steel wheel (kang lun). This must be well concealed from the enemy. On triggering the firing device the mines will explode, sending pieces of iron flying in all directions and shooting up flames towards the sky.

Thus from this it is clear that there was some arrangement of flint and steel, set in motion by the injudicious enemy, which directed sparks on to tinder and set light to the train of fuses. From the illustration (Fig. 32) it is clear that there could be at least two steel wheel systems either of which would activate the whole mechanism.

How exactly the arrangement worked was not revealed in a printed book until early in the +17th century. It consisted of a couple of the steel wheels, presumably serrated, fixed on a single axle and so placed as to rest on flints. A cord wound round a drum on the axle was attached to a weight at one end, and the mechanism kept in position by a pin. When the pin was removed by an unwary enemy stepping on a piece of board or plank attached to it, the pin released the weight, with the result that the wheels produced sparks by rubbing against the flints, thus lighting the fuses and setting off the mines. The earliest description of this steel-wheel firing device is in the Ping Lu, and the same account is repeated in the Wu Pei Chih. The illustration in the former (Fig. 33) shows the assembly rather diagrammatically, including the two wheels with their flints and weight-drive, the ‘doorstep boards’ (hsan pan) and the retaining pins (chi chen) released by them. The picture in the latter is considerably more informative, and shows all the components both separately and assembled (Fig. 34).

There is more than meets the eye in this set-up, especially when we remember that it goes back to the middle of the +14th century, certainly not later than +1360. Its two essential components, the flint-and-steel igniter and the weight-drive, both invite some thought, since they call to mind parallel devices in Europe, either of later date or not likely to have been known in China at the time. First, sparks struck off by steel on flint were a very ancient item in all civilisations, going back almost to the beginning of the iron age, but their use in connection with gunpowder came in Europe much later than +1360. The wheel-lock musket, which ignited its priming powder by a spark struck from a piece of iron pyrites and a steel wheel, does not go back further than the sketch by Leonardo da Vinci about +1500, and the first firm date for the actual thing is +1526. The flintlock musket, fired by the descent of a piece of flint and its impact on the steel pan-cover of the priming, was first mentioned only in
Fig. 33. A more elaborate pictorial description of the steel and flint firing mechanism (fa huo shih), from PL, ch. 12, p. 62a. Two steel wheels were suddenly rotated by a falling weight, the cord of which was wound round their axle, when the enemy stepped upon one or other of the two boards (huan pan) and released the retaining pins (chi chen). The fuses were thus lit by the sparks from the flints igniting the tinder, and the device exploded. This, the earliest illustration, is of +1606.

Fig. 34. An even more explicit illustration of the firing mechanism (flint and steel worked by a falling weight) suitable for an infernal machine or a firework display; from WPC, ch. 134, p. 15b.
+1547." It has not so far been suggested that these were inspired by a previous Chinese practice, and perhaps the idea behind them was obvious enough, but it does remain true that one of those "transmission clusters" in which techniques passed from China to Europe, did occupy the second half of the +14th century. Secondly, the weight-drive is a rather curious device to find in China in the middle of the +14th century, for although it had successfully powered the first mechanical clocks of medieval Europe soon after +1300, it hardly could have passed East so quickly; and the indigenous hydro-mechanical linkwork-escapement clocks of China worked on a different principle, that of an inhibited vertically mounted driving-wheel using water or mercury from a constant-level tank. On the other hand, there is evidence that the Hellenistic anaphoric clock was known and used by the medieval Chinese as well as the Arabs, so the weight-drive could have originated fairly easily from the anaphoric float, and it might have done so in both West and East independently. One generally thinks of the weight-drive having come into China only with the mechanical clocks introduced by the Jesuits in the +17th century, but the present evidence suggests that it had been there for a long time already. Perhaps the secret, or 'restricted', nature of its use helped to keep it dark. But the paradox remains that a flint-and-steel device was used in China for gunpowder ignition a century and a half or so before it found the same use in Europe; while on the other hand the weight-drive appeared in China for gunpowder ignition rather secretly half a century after it had begun to power European mechanical clocks, yet two and a half centuries before these came into China as the gifts of the Jesuit missionaries.

As for explosive mines in Europe, there is not much evidence of them before the middle of the +15th century. The first clearly recorded case of a plan for such an infernal machine seems to occur in +1409 in a war between Pisa and Florence, but whether it was actually practised is not quite clear. The first design for anything similar to the firing device of the Fire-Drake Manual did not come, apparently, until +1573, when Samuel Zimmermann of Augsburg invented a contrivance for igniting fireworks or a mine at a distance by the use of

1 Before this period, the priming powder or the charge itself was always ignited by a piece of slow-match, just as in the flame-thrower of +916 (cf. p. 81 above).
2 Needham (64), pp. 61--2, 201. Among the great inventions coming at this time were the blast furnace for cast iron, block-printing, and segmental arch bridges.
4 Vol. 4, pt. 2, pp. 293, 406 ff., 532, 541. Liu Hsien-Chou (12) suggests that the so-called "device" (cf. Vol. 4, pt. 2, p. 355) was the prototype. It must have been a very old observation that an empty bucket, let alone a full one, was liable to run away down the well if not checked at the well-head.
5 All through the +16th century in China improvements were being made in land and sea mines, as for instance by Tsung Hsiao (after +1530). He was the military official who urged the recovery of the Ordes region from the Mongols, but was executed as the instance of opponents of his policy, see Wang Pao-Wu (?), p. 55; Liu Hsien-Chou (12).

*30. THE GUNPOWDER EPIC*

The weight-drive flint-and-steel mechanism was not the only one used in China for setting off infernal machines. Recipes existed for mixtures which would glow for long periods given an adequate supply of air, ready to ignite a fuse when brought mechanically into contact with it. For example, the Wu P'ei Chi describes a device of this kind for use with a booby-trap (Fig. 35). In the 'underground sky-soaring thunder' ('fu ti ch'ung ti yen le') the mines are placed three feet underground with the fuses leading to a point below a bowl containing a slow-burning incandescent material ('hao chung'). Lances or pikes with long handles are set up vertically above the bowl; then when the lighted enemy comes to appropriate the weapons the bowl is upset and the mine fuses ignited. The Wu Pei Hsiao Lung Ching contains a formula for making the slow-burning incandescent material, which it claims will burn continuously from 26 days to a month without going out. It is made of 1 lb. of white sandalwood powder ('hui mau'), 3 oz. of iron rust ('hao long') or 'thick iron', 5 oz. of 'white' charcoal powder ('pai tan ma'), 2 oz. of yellow charcoal powder, 6 oz. of the dried powdered flesh of 'red' dates ('hung tsao') and 3 oz. of bran. White charcoal was simply charcoal whitened with quicklime. In a similar recipe given in the earlier Ping Fa P'ei Ch'uan Ching (c. +1590) it is simply given as 'charcoal powder'. In principle the stuff was not unlike the glowing incense-powders used in temples, but without most of the fragrant constituents, and the time was doubled added to keep the mixture dry.

Still other ignition and timing methods were used in sea-mines for naval warfare—one was the burning down of a joss-stick. The Hsiao Lung Ching has an interesting specification for such a sea-mine. It reads as follows:

The sea-mine called the 'submarine dragon-king' ('shiu ti hung lung phat') is made of wrought iron, and carried on a 'submerged' wooden board ('su phat'), [apparently weight-driven with stones; see Fig. 37]. The (mine) is encased in an ox-bladder ('mou phat'). Its subtlety lies in the fact that a thin incense-stick ('dih phat') is arranged (to float) above the mine in a container. The (burning) of this joss-stick determines the time at which the fuse is ignited, but without air its glowing would of course go out, so the container is

flint-and-steel, springs and string. To this clockwork was in time added, bringing about the time-bomb, once again by the use of the weight-drive.

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30. MILITARY TECHNOLOGY

Fig. 35. A booby-trap called the 'underground sky-soaring thunder' (Ju ti chhing-ien ti). A stand of arms is set up with a land-mine underneath, and this is set off by the enemy whose step uppers a bowl of slow-burning incandescent material when he comes to take possession of the halberds, pikes and lances. From WPC, ch. 134, p. 145.

The illustration for this in all the editions (Fig. 30) is diagrammatic in the extreme, with no indicative lettering, so it is necessary to look also at the picture in the Thien Kung Khat Wu of +1637, three centuries later, which does give a few identifications though still very badly (Fig. 37). The only difference is that the lacquered leather bag replaces the ox-bladder, while a cord pulled from the shore releases a flint-and-steel firing mechanism. The Chhing edition adds only artistic detail to the Ming picture, though it provides a graphic drawing of an underwater explosion. Also the name of the sea-mine has now changed, to the 'chaos-producing river-dragon' (hun chiang lung).

So far we have been elucidating Chinese practice of the +14th century. Apparently Europeans had not advanced so far at that time (if it is an advance to be able to blow up ships), for the first plan for sea-mines was presented to Queen Elizabeth by Ralph Rabbards in +1574. When it came to the nineteenth century, the Chinese naturally improved their sea-mines by borrowing from Western practice. In 1842, at the time of the Opium Wars, Phan Shih-Chhêng, the wealthy merchant-shipbuilder and technologist at Canton, engaged an American naval officer J. D. Reynolds (Jen Lei-Sau) to conduct experiments with sea-mines as part of the modernisation of China's coastal defences, and Phan himself participated in the trials. Later he contributed a piece on them for the 1852 edition of the Hai Kao Thu Chih (Illustrated Memoir on the Occidental Maritime Nations) of Wei Yuan & Lin Tsê-Hsî; and this was the

connected with the mine by a (long) piece of goat's intestine (through which passes the fuse).

[Comm. The saltpetre-saturated (fuse) can also come from a roughly made iron fish (as the floating container).] 3

At the upper end the (joss-stick in the container) is kept floating by (an arrangement of) goose and wild-duck feathers, so that it moves up and down with the ripples of the water. On a dark (night) the mine is sent downstream (towards the enemy's ships), and when the joss-stick has burnt down to the fuse, there is a great explosion.

The following references are those made in the previous note. 3

4. Here again there is an echo of another Chinese medieval technique, namely the floating magnetic compass, where a shallow hollow iron fish took the place of the needle. Cf. Vol. 4, pt. 1, pp. 253-5. This one would have to have been rather deeper so as to take the joss-stick. On combustion clocks in general in Chinese culture see Vol. 3, pp. 309 ff.

5. The same applies to the description in WPC, ch. 133, p. 49.


7. In the text but not in the illustration; which shows a derivation from HLC.


9. The background to this will be found in the paper of Bauermeister (1), though it deals with designs only from +1787 onwards, and mentions no Chinese antecedents.

10. Phan was known to beil as Poon See-Sing, and to Roodor as Poon See-Ching. His common name among foreigners was Tingqua (derived from the office he held), and he was a descendant of the founder of the famous merchant Co-Hung in the city.

Fig. 36. A sea-mine, the 'submarine dragon-king' (shai li lang ming phao), from the mid-14th century, in HLC (HCT), p. 354. For explanation, see text. The firing mechanism consists of a floated incense-stick which lights the fuse when it burns down, this last being contained in a length of goat's intestine, and connecting with the explosive charge which is floated at a certain depth submerged below.

Fig. 37. The more explicit diagram of the same device in TRK, ch. 3 (Excellent Weapons sect.), p. 269. In the current facsimile Ming edition it is ch. 3 (ch. 15), p. 386. The derivation from the HLC drawing is very evident, but the text says that the ox-bladder containing the explosive is replaced by a lacquered leather bag, and that the incense stick gives way to a cord pulled from the shore to release a flint and wire firing mechanism.
source of the interesting paper of Beal (4) seven years later.2 Twenty of these sea-mines were made at the Canton arsenal in 1843.3

The mine consisted of a hexagonal wooden waterproof brass-bound chest (hsu4) submerged in the water by means of adjustable iron weights (tien chiai5) and suspended by two chains or ropes (hsian sheng6) from a buoy (jou chih6). Two openings in the cover enabled the charge of some 160 lb. of gunpowder to be inserted (ju yao kung6) and a third allowed water to enter a tube (shai kuan khang8) at the proper time. All three openings were sealed, two by ‘charge covers’ (yao kai7) and the third by a protective cover (hsa kai7) for the water-tube, which incorporated a filter to avoid any danger of blockage. When the time came the mine was towed on the end of a rope (yin sheng6) from a boat silently approaching the enemy ship, or even by a swimmer or a diver, and then fastened to its anchor-cable. Upon the removal of the protective cover, the water, passing down the narrow tube, gradually filled a cylinder with accordion-pleated sides and raised its upper end; this eventually activated a lever which released three spring-hammers to fall upon as many percussion-caps and so set off the charge.

The mine thus had a latent period of between thirty and thirty-five minutes, allowing for the escape of the mining party.6

Admiral Kennedy, whom we have met before (p. 189), had a considerable respect for the sea-mines used by the Chinese Navy during the fighting on the Canton River in 1856. He afterwards wrote as follows:4

To guard against fire-fails and torpedoes we made a boom across the River with spars and chains, connecting it with the shore on both sides. Some old junks were moored in mid-stream above and below the shipping; these junks were also connected with the shore, leaving a passage for a friendly vessel, and this space was also closed by chains which could be removed at pleasure. All this was most necessary, as the Chinese were very cunning in the use of torpedoes and infernal machines, for which the Canton River was well adapted. Almost every night we received some kind attention in the shape of a junk loaded with combustibles, floated down with the stream and set on fire when close to us. Another clever apparatus consisted of one or more iron tanks filled with powder, and sunk to the level of the water, having on the outside wire springs connected with a trigger, so as to explode on touching a ship’s side. These were more dangerous than the junks or fire-ships, being so low in the water as to require the utmost vigilance to detect them. Our business was to sink or explode them before they got near enough to do us any harm, but this was not always possible; at times we managed to destroy some, and others drifted wide of the mark, but on one occasion they very nearly succeeded....

Chiao Yü and his plus-century military and naval technologists would probably have been quite pleased if they had known that no less than five hundred years later their sea-mines, suitably improved, would have given so much bother to the heirs of modern science and the industrial revolution.

Now that we have become accustomed to the detonation of large masses of high-nitrate gunpowder, the moment has perhaps come to look again at accounts of arsenal explosions, of which several have come down to us from late Sung and Yuan times. For example, in Chou Mi's (Chu Hsi Tsa Chih)7 we find note of the following incident:8

Chao Nan-Chung, when prime minister (chheng hsiang3) ... reared four tigers at his private house in Li-yang, and kept them within a palisade near the gunpowder arsenal. On a certain day, while the gunpowder was being dried, a fire broke out and a terrible explosion followed. The noise was like the crash of thunder, the ground trembled, and many houses collapsed. The four tigers were killed instantly. This news spread from mouth to mouth among the people, and the incident was considered a frightening marvelling.

Since Chao Khuei9 (Chao Nan-Chung) died in +1266, the calamity would have occurred about +1260, just the time when the Southern Sung were defending their dynasty against the Mongols, a few years after Li Tseng-Po had been complaining about the arsenal administration (p. 173 above) and a few years before the siege of Hsiang-yang (p. 168 above).

The Kuei Hsi Tsa Chih, written in +1295, goes on to report an even more alarming occurrence; the discovery of an arsenal in +1280, just after the Mongols had taken over.

The disaster of the trebuchet bomb arsenal at Wei-yang6 was still more terrible. Formerly the artisan positions were all held by southerners (i.e. the Chinese). But they engaged in peculation, so they had to be dismissed, and all their jobs were given to northerners (probably Mongols, or Chinese who had served them). Unfortunately, these men understood nothing of the handling of chemical substances. Suddenly, one day, while sulphur was being ground fine, it burst into flame, then the (stored) fire-lances caught fire, and flashed hither and thither like frightened snakes. (At first) the workers thought it was funny, laughing and joking, but after a short time the fire got into the bomb store, and then there was a noise like a volcanic eruption and the howling of a storm at sea.

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1. Chien Chi, p. 139, 140, tr. auct.
2. Ibid., p. 140, b, tr. auct.
3. Under the Yuan dynasty there were three classes of citizens. First came the Mongols (Meng-ku or pei jen), secondly the Arabs, Persians or Europeans hired to serve the Great Khan, people with coloured pupils in their eyes (si mao jen), and finally in the third class the Chinese (southerners, nan jen).
4. 蒙古
5. 明代
6. 吴辛盟
7. 钦南仲
8. 杨益
9. 之
10. 蒙古
11. 北人
12. 七
13. 人
14. 人
The whole city was terrified, thinking that an army was approaching, and panic soon spread among the people, who could not tell whether it was near or far away. Even at a distance of a hundred li tiles shook and houses trembled. People gave alarms of fire, but the troops were held strictly to discipline. The disturbance lasted a whole day and night. After order had been restored an inspection was made, and it was found that a hundred men of the guards had been blown to bits, beams and pillars had been left asunder or carried away by the force of the explosion to a distance of over ten li. The smooth ground was scooped into craters and trenches more than ten feet deep. Above two hundred families living in the neighbourhood were victims of this unexpected disaster. This was indeed an unusual occurrence.

This graphic description bears witness to what the principle of the 'sorcerer's apprentice' could do where explosives were concerned. It is interesting to reflect that it could not have happened in the Europe of that time, for Roger Bacon's first notice of gunpowder was then only a dozen years old, while nearly half a century had yet to pass before the first practical use of gunpowder in Western warfare. 

Similar stories continue down in Chinese literature until modern times. For example, it is recorded that in +1363 a certain augur named Chang Chung predicted a great disaster, but assured Chu Yuan-Chang, the future Ming emperor, that no harm would come to him personally. Sure enough, a month later the Chung-Chhin Pavilion caught fire, and a thunderous explosion followed when the bombs and powder stored there were touched off.

(12) BIZARRE DELIVERY SYSTEMS

We now approach the tubular fire-lance, ancestor of all metal-barrel guns and cannon, but before we can discuss it we must pause to take note of various peculiar methods for the delivery of incendiaries and explosives devised by the Chinese in medieval times. Although at first sight a modern reader may be inclined to dismiss them as fanciful, they are in fact of quite considerable interest because one can trace in several of the devices a clear progress in sophistication as time went by. One can also find the whole succession from incendiary to high-nitrate gunpowder plainly exposed in them. Most began with the use of expendable animals, a method which must be almost as old as warfare itself. We

have already noted an example from ancient Hebrew history, Samson tying firebrands to the tails of foxes and driving them towards the enemy's cornfields. Now in what follows we shall trace the development of such systems from the beginning of the +8th century onwards. First there were the 'fire-birds' (hao chhin'), partridge-like creatures sent off to sit upon the enemy's thatched roofs and set them alight (Fig. 38); they carried a walnut receptacle filled with burning moxa tinder, pierced with two holes, and tied round their necks. The illustration comes from Wu Ch'ing Tung Yao (+1044), but the text about them is verbally identical with a predecessor in the Hu Chhin Chih, and that takes us back as far as +692. The picture and description is then repeated in practically all the subsequent military compendia.

Another sort of fire-bird was represented by the 'apricot-stone fire-isparrows' (chia hou fung'). They were smaller birds, and the burning moxa tinder was enclosed in a split apricot-stone attached to their legs; several hundred were to be let loose at one time to fly to the enemy's camps and granaries and set them on fire. The Hau Lung Ching also has this, but it is an interesting surprise, for on the very next page this work of about +1350 has something very different, no less than a winged rocket, i.e. an artificial bird propelled by four rocket-tubes attached to feathered rods. This is the 'magic-fire flying crow' (tien huo fei jaj), with its accompanying text and illustration repeated in later works. Here we must do no more than mention it, reserving its description for the subsection on rockets, but it does show the continuity between the ancient techniques and the far more ingenious ones of later times.

The expendable animals continue with the 'fire-beasts' (hao shou), deer, boars or other wild animals sent towards the enemy carrying on their heads burning moxa tinder in a gourd (phiao) with four holes. One of the earliest appearances of this text must be in the Hu Chhin Ching (begun in +1062 and finished by +1094), and there is a good illustration in the Wu Ch'ing Tung Yao. This particular play seems not to have led to anything further, but it is possible that the birds were induced to leave by pricking their tails, while the animals were despatched towards the enemy by tying oil-soaked reeds to their tails and setting them alight.

\[\text{\footnotesize Notes:}\]

2. WCTYCC, ch. 11, p. 212, 8.
3. HCC, ch. 4 (ch. 324) p. 123. Since the account was written only a decade or so later, there is every reason to accept the reality of the arsenical explosion.
4. Even the most archaic of them survived in military books into the +17th century and later, but to what extent they were any use by then or whether anyone attempted to use them, is not so sure. Such was Chinese conservatism, however, that their description and illustration certainly persisted long after the introduction of relatively modern types of guns and cannon. But Ch'ing K'han is said to have used the fire-bird technique when besieging Jin cities, Chung (12), Eng. tr. p. 50, Franke (34) pp. 190, 734.
Next came the 'fire-ox' (huo niu), which moved, as we shall see, with the times. He is not in the Hu Chhien Ching, but in +1040 the Wu Ching Tsung Yao shows him (Fig. 39) pounding away towards the enemy lines at a very un-cattle-like pace, but that is because a large tub of incendiary material is attached to his rump and burning. Although the animal is provided with a couple of spears tied on, it cannot have caused much damage if the fire was put out, and the generals must have felt it undesirable to give the enemy such free supplies of beef. Very different was the situation after it became possible to attach a large bomb of high-nitrate gunpowder to the back of the animal, as we see (Fig. 40) in the later works. It now had some real point, though it was still an expendable animal; this was the situation by the end of the +13th century, though our illustration comes from the Wu Pei Huo Lung Ching of about +1400. And it had changed its name, for it was now called the 'rolling thunder-bomb fire-ox' (huo niu lung lei phao).

Another striking change which came over an ancient plan or tactic as time went by appears in the matter of the 'fire-soldier' (huo ping). In the Hu Chhien Ching and the Wu Ching Tsung Yao he is a real person, a rider on a gagged horse who gallops round the enemy camp lighting and throwing in combustible materials (Fig. 41), then, if confusion results, an attack is made. But by the +14th century he is replaced by a wooden human figure, also mounted on a horse, but stuffed behind his paper face and bamboo accoutrements with incendiary substances and carrying a large bomb timed to explode when it reaches the enemy lines (Fig. 42). Here of course the animal had to be despatched by the age-old method of tying firebrands to its tail. The arrangement is now called the 'heaven-shaking' thunder-bomb carried by the wooden man on the fire-horse (mu jen hau ma thien lei phao), or in the more succinct phrase of the Wu Pei Chih the 'wooden man on the live horse' (mu jen hou ma).

A variant of this, rather less convincing in character, was the 'flying-carriage fire-dragon pushed along the ground' (huo lung chhian ti fei chieh). Here a bomb or land-mine was concealed within the body of a wooden figure of a winged dragon or similar animal mounted on a two-wheeled cart and pushed forward by two

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* His traditional originator was Thiem Tan7, a general of Chhi, in the campaigns of 729 against Yen State. But there was no incendiary element about Thiem's stampeding cattle, with sharp blades attached to their horns, except the bundles of oiled rushes tied to their tails, by which, when lit, they were set in motion.

+ HCT, ch. 11, p. 21a, b. Also in HLC, pt. 1, ch. 3, pp. 21a, b; HKPP, ibid.; HCT, p. 336; WPC, ch. 131, pp. 174, 178.

++ WP1, ch. 2, pp. 23a-3b; HLC, pt. 3, pp. 176, b; HKPP, ch. 3, p. 21a, b; HCT, p. 336; WPC, ch. 131, pp. 178, 196, b, 204. One of the two pictures in this last work shows a camouflaging cover over the animal and its burden.

+++ HCC, ch. 6 (ch. 54), p. 54; WCTYCC, ch. 11, p. 23a, b. Also in TPC, ch. 4, p. 8a.

++ We illustrate from WP1, ch. 2, pp. 21a-24. But there is a particularly long specification in WPC, ch. 131, pp. 153-172. Attack is to be made as soon as the explosion occurs.

++++ HLC, pt. 2, ch. 3, pp. 18a, 19a; WP1, ch. 3, pp. 21a-24; WPC, ch. 132, pp. 20, 5a.
Fig. 39. The 'fire-on', another expendable animal, from WCTT, ch. 11, p. 254.

Fig. 40. The bomb-carrying fire-on, from WPHC, ch. 2, p. 28.
Fig. 41. A 'fire-soldier' rider (huo ping), from WCTF, ch. 11 p. 234. He gallops round the enemy camp, throwing in combustible incendiary materials.

Fig. 42. Bomb-containing robot rider, intended to explode when carried into the enemy camp; WPHLC, ch. 3, p. 22.
soldiers. The wings had eye-holes through which they could look, and acted as a shield for them, but it is hard to believe that the device could ever have been effective. The body contained several of the different kinds of gunpowder (cf. p. 117 above), and in some versions spears projecting at the front were tipped with tiger-poison. The Wu Pei Chih also figures and describes wooden animals with a wheel at each foot, containing smoke materials or bombs with metal fragments, each to be pushed forward by a single soldier. These were called ‘wooden fire-beasts’ (mu huo shou).

Very special conditions would have to have prevailed before anything of this kind could have been useful, and the same conclusion might well apply to another device described in the old books, namely the ‘wind-and-thunder fire-rollers’ (feng lei huo kun). These were simply cylindrical rollers of bamboo and paper about a foot in diameter and three feet long, which were filled with poison-fire gunpowder, iron fragments, and five cast-iron bombshells in each, then rolled down from above into the enemy camp (Fig. 43). No doubt defenders occupying higher positions on slopes had from time immemorial hurled down loose rocks and logs upon their enemies, but for the fire-rollers to have been effective it would have been desirable to induce the foe to encamp at the head of a valley, for example, surrounded by grassy declivities on nearly all sides, and that might well have been difficult. However, this peculiar firearm is worth recording.

Expendable animals carrying incendiaries go far back in the history of most civilisations. They are mentioned in the Arthasastra, which implies the early centuries of the present era; and birds in particular appear in Hasan al-Rammāh’s books, c. +1280, which is natural enough since his connections with China were so close. As for frightening figures of dragons and the like, we have to contend with a vast ancient literature on automata. Firdawsi, for example, about +1020, took from the legends of Alexander the Great a story about iron horses and riders on wheels that he had had made, and sent against elephants, which they destroyed by means of the naphtha within them. As late as +1463 Roberto Valturio figured a machina arabica, a great dragon figure, which shot forth arrows from guns in its mouth. But all this need not be pursued further here.

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4. The texts do not always say that the cylinders have to be rolled down from a higher position, but it is fairly self-evident.
10. 近火器
11. 道雷克

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Fig. 43  Wind-and-thunder fire rollers (feng lu huo kun), from HLC (HCT), p. 906.
We find ourselves now at a true focal point in the evolution of the gun and cannon. At some moment after the first invention of the deflagrative, ultimately explosive and detonative, mixture of saltpetre, sulphur and charcoal, it occurred to someone to enclose the low-nitrate powder in a tube, and make it play upon the enemy. From this derived in the course of time all barrels whatsoever, ranging through bamboo (no doubt the first most obviously to hand) through carton-paper and leather to copper, bronze, wrought iron and cast iron. Exactly when this crucial step was taken we may shortly see, for the first time to do is to study the most important statements about the use of fire-lances in the dynastic histories and similar texts. Essentially the fire-lance or fire-pike constituted a five-minute flame-thrower, as it were a rocket held on the end of a pole, with its open end directed towards the adversary; and if sufficient supplies were available, one can have little difficulty in imagining that the weapon would have discouraged enemy troops from climbing up and invading one’s city wall. Secondly, we may go on to have a look at some of the many types of fire-lances described and illustrated in the military compendia; culminating in the larger ‘eruptor’ (as we call it), no longer hand-held, but mounted on various kinds of stand or carriage. Many other questions will then present themselves, for instance the relation of the fire-lance barrel to the blow-gun, its persistence in warfare, its passage to the West by way of the Arab world and its adoption there, with finally some comments on how effective it was in combat.

Now to begin with we can trace a parallelism between the fire-lance and the bombs already discussed, for as Fig. 234 (p. 580) shows, we can divide them into weak-casing types and strong-casing types. In each of these we can find, as time goes by, a slow birth of the projectile, for it was not long before men found that the flames of the low-nitrate gunpowder would carry out with them, at a considerable velocity and with no little force, solid objects of many kinds. These we term ‘co-viative projectiles’ (again coining a word) because the gunpowder was not fully propellant, and the object or objects did not occlude the whole bore of the tube. Two distinguishable developments have to be portrayed in Fig. 234, the progressive strengthening of the tube, and the incorporation of projectiles in the powder. Thus first dividing the prototypic fire-lance into two sorts, those with relatively perishable tubes and those with metal tubes, we can further divide the former into simple types, those with two or more barrels, and those in which the bamboo tube was contained within a winding of iron wire. Then comes the missile series. It starts with sand particles, designed to blind and confuse the enemy, goes on to lead pellets and miscellaneous bits of broken metal and pottery, preferably with sharp edges, and reaches its climax with the despatch of actual arrows. Exactly the same sequence is repeated in the case of the metal-barrel fire-lances, except that the books figure no example of the simple barrel or the sand—in fact one gets the strong impression that the reason for the introduction of the metal barrel was the need to emphasise the element of co-viative projectiles.

In surveying Fig. 234 we begin to realise how closely the fire-lance eventually approximated to the hand-gun and the bombard, and how clearly it is possible to trace the stages step by step from the pure flame-thrower through the co-viative projectiles to the occlusive ball or arrow; and doubtless the proportion of nitrate in the mixture was rising all the time. One form (Fig. 61) fired a stone ball, another (Fig. 58) was a mixed type, with a lead bullet issued from the central barrel, flames from the surrounding ones, and a pipe- or lance-point for final use if the enemy got too close.

Furthermore the terminology changed gradually; starting with literal exactness as huo chhiang (fire-spear), it became in due course huo thang (fire-tube) and eventually chhungh (the later specific name for a gun of any kind). This word had anciently meant any kind of socket, as in an axe or halberd, hollowed out to receive the wooden handle, so its adoption for the later use is very understandable. But here its interest for us is that it was applied, as we shall see, to some of the forms before the end of the fire-lance sequence. Also it is interesting to note that when Li Tseng-Po was complaining in +1230 about the inadequacies of the Sung arsenals administration he used the phrase huo chhiang i pai wu thang, i.e. ‘105 tubes of fire-lances’, using the word thang as one of those classifiers or collective particles characteristic of Chinese grammar. Of course it was perfectly natural to enumerate fire-tubes as tubes, but in order to know when such tubes had a projectile fully fitting the bore, and high-nitrate gunpowder at last behind it, we need to know a lot more detail than is usually given in the descriptions. The first appearance of the phrase huo thang (fire-pipe) is, as we have already seen (p. 21), ancient; it originally meant a component of a signal-beacon tower, either a fuse running up to light the smoke-fire on the platform above, or a tube like a tuyère connected with a bellows to keep the fire going. All this had nothing to do with gunpowder. But the first appearance of the term huo thang in our sense seems to be the reference in the Hsing Chiu Chu Khi (What an Army Commander in the Field ought to Know) about +1230, where it accompanies huo phao (bombs), shou phao (grenades) and ming hao yu.

* Elsewhere (Vol. 4, pt. 2, pp. 61-5) we expatiated upon the importance of this naturally-occurring material for so many aspects of Chinese technology, a wonderful ready-made tubing useful for an infinity of purposes. Bredt (1) makes the same point.
(petrol for flame-throwers)." What exactly it referred to at that time remains uncertain, perhaps a fire-lance with co-viative projectiles, perhaps a true barrel-gun; after all, these last are now attested by archaeological evidence for c. +1290 (cf. p. 293 below), so the fully developed form was already 'in the air'. The general upshot is that the passage from the fire-lance to the hand-gun and the bombard was one of slow stages with many shades of meaning and distinction, no sharp break occurring at any time.

Let us now review the passages in Chinese literature which mention the use of fire-lances in warfare. For many years past the loci classicus has been the T'ie-An Shou Chhing Lu, the account of the famous siege of Té-an by the Chhn Tartars in +1132, when Chhen Kuei成功fully held it for the Sung. The text says:

We also used bomb gunpowder (lit. fire bomb powder, huo phao yao) and long poles of bamboo to make more than twenty fire-lances (hou chhian). Also striking lances (chhuang chhian) and swords with hooks at the ends (hsu lien), many of each. It took two men to handle each one. These things were got ready to use from the ramparts whenever the assault towers with their flying bridges (hsien chian) approached the city.

And a further reference occurs in Chhen Kuei’s biography in the dynastic history, which tells how

(Chhen) Kuei, with sixty men, carrying fire-lances (hou chhian), made a sally from the West Gate, and using a fire-ox (hou nia) to assist them, burnt the flying bridges, so that in a short time all were completely destroyed. So (Li) Heng3 pulled up his stockades and went away.

Here the nuance seems to be that the fire-lances were used not so much to oppose invading soldiers who got on to the city wall as to set light to the woodwork of the enemy’s siege equipment. Still, they could well have been used in close-quarter combat too.

But did these events, occurring in the early years of the +12th century, really constitute the first appearance of the fire-lance upon the stage of warfare? It has been customary to think so. But in 1978 an unusually important discovery was made by Clayton Bredt in the Musée Guimet in Paris.4 There he found a painted silk banner from Tunhuang, doublets of Paul Pelliot’s acquisitions, which dates from the middle of the +1oth century,5 and which may well contain, as he himself said,6 'the earliest representation of a Chinese pyrotechnic weapon'. The painting7 portrays the assault of the demon Mara8 and his cohorts on the meditating Buddha, seeking to distract him from his attainment of understanding of the nature and mechanism of the universe, and to prevent his enlightenment (Fig. 44). Although the figures in the painting are all supernatural beings a number of them are dressed in military armour and bear weapons—reflex bows, and straight double-edged swords, in particular—which are reasonably accurate depictions of late Thang arms. The weapon which is important for us here, however, is a fire-lance, namely a long pole with a cylinder at its end from which issue flames that shoot forward. They do not go upward like a torch, as if there were no pressure behind them, but rather blaze forwards as if from a flamethrower containing rocket composition—which was exactly what the fire-lance was. The figure holding this is a devil with a head-dress of three serpents (Fig. 45), and he is pointing it to the left about the level of the upper part of the Buddha’s halo. Just below him to the left there is another devil with a serpent entangled in his eyes and mouth, who seems to be about to throw a small bomb or grenade from which flames are already coming out. Many other features of great interest occur in the painting, but we cannot discuss them here.8

If the dating is right, and there is no reason for doubting it, the implication can only be that the fire-lance originated about +950 in the Wu Tai period not long before the Sung, i.e. some thirty years after the time when we concluded (p. 89 above) that the gunpowder mixture was first used in war, namely to make a kind of slow-match for a petrol flame-thrower (+919). The transition to a low-nitrate gunpowder flame-thrower would thus have been extremely natural, but it remains remarkable that (so far as we can see) there is neither mention nor illustration of a fire-lance in +11th-century books such as the Hu Chhien Chhing or the Wu Chhing Tsung Yoo. For the next picture of the device we have to await +1350 or so, the time of the Hua Lheng Chhing, though then and thereafter there are dozens of varieties, which lasted well into the musket era. Perhaps the fire-lance was kept extremely secret throughout the rest of the +1oth century and all through the +11th;9 perhaps gunpowder could not then be produced in quantity, and other uses therefore had the preference. But the iconographic evidence of the Buddhist banner seems incontrovertible.

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3. According to the archaeological expertise of Dr Robert Jea-Benard and his colleagues of the Museum staff
4. In what follows we have kept as far as possible to the wording of Dr Bredt’s own letter.
5. MG +563; no. 6 in the Vander—Nicolas Catalogue. It was no. 315 in the 1935 Exhibition on the Old Silk Road.
6. Dr Bredt makes the point that the Chinese Buddhist frescoes and paintings have hitherto been quite insufficiently concerned for technological details, which is indeed undeniable.
7. Examples of the scenery there was in those times have already been given on p. 94 above.
8. Kindly
Returning now to the texts, the majority of the evidence comes from the +13th century, that very one which (on all present indications) saw the birth of the true barrel-gun and cannon. We have already encountered (p. 171 above) a key text from +1232, when Chhihchan Ho-Hsi was commanding the Jurchen Chin troops in the defence of Khaifeng.⁴

They also used 'flying-fire spears' ('fei huo chiang') filled with gunpowder, in order to discharge flame. Upon ignition, the flames suddenly shot forward more than ten paces, and no one dared to go near them. The Mongol soldiers feared only these two things, i.e. the cast-iron thunder-crash bombs and the fire-lance flame-throwers. This is the passage which caused so much confusion in the later literature since St. Julien in 1849 translated the technical term as 'flying fire-arrows' and interpreted it as meaning rockets.⁵ This was a grave mistake.⁶

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⁴ Chin Shi, ch. 113, p. 194, tr. auct.
⁵ Here is a classic case of the 'uncertain hyphen', for it was 'flying-fire lances', not 'flying-fire arrows'. St. Julien took the text from TCKM, pt. 3, ch. 13, pp. 49 f. His translation (8) appeared in Reinaud & Favé (2), p. 289. Cf. Reinaud & Favé (1), p. 196; Wang Ling (1), p. 172; Féng Chin-Shăng (6, p. 68; Davis & Ware (1), p. 342. Haseenstain (5), got it right; but Lu Mou-Té (1), p. 32 thought that iron cannon were meant.
⁶ But it runs through the whole of the literature, from Grosier (1), vol. 7, pp. 126 f. to Jacob (4), pp. 154–5. And it is still perpetuated, as by H. Franke (24), p. 171, and Sun Fang To (1), pp. 1, 3, 16.
In the following year fire-lances figured largely again in an engagement on the canals surrounding the city of Kuei-Tê¹ in Honan, where the Chin troops defeated a large force of Mongols. In +1233 a detachment of the Chung hsiao Chin² (Loyal and Filial Army) prepared to evacuate Kuei-Tê in the knowledge that the Mongols were coming, and intended to retreat to Tshai. But the commander, Phuchha Kuan-Nu³, drew up a plan of attack on the positions which he guessed that the Mongols would occupy. The text continues:⁴

On the fifth day of the fifth month they sacrificed to Heaven, secretly prepared fire-lances, and embarked 500 (Chin) soldiers outside the south gate, whence they sailed first east and then north. During the night they killed the (enemy) guards outside the dykes, and reached the Wang family temple. Then they got to the north gate and waited, but the Mongols, fearing a defeat, retired in part to Hsiuchow. However, at the fourth watch there came an attack, in which at first the Chin troops gave way; but (Phuchha) Kuan-Nu divided his small craft into squadrons of five, seven and ten boats, which came out from behind the defences and caught (the Mongols) both from front and rear, using the fire-spouting lances (kuan-chiang thu jia⁵). The northern army could not stand up to this and fled, losing more than 3500 men drowned. Finally their stockades were burnt, and our force returned.

Here the five-minute flame-throwers seem clearly to have been used as close-combat weapons, as well perhaps as incendiaries for wooden defence works. The same account gives details of how they were made in Phuchha Kuan-Nu’s time, but we postpone it for a moment in order to dwell first on other battle relations.

By +1257 we have the complaints of Li Ta-ťung about the ineffectiveness of the Sung arsenal administration (already translated p. 174 above), in which he mentions fire-lances. Then two years later there comes an important statement about inventions made in the arsenal at Shou-chhun-fu⁶, which suggests that the ‘boys in the back room’ were more active than the clerks in the issuing office.⁷

Researches of the latter raised an interesting point; however, it may just be that the flying-fire lances of +1252 shot out arrows as well as flames. Sun noticed that the texts of two modern authors who tried to improve the dynastic history of the Mongols used a slightly different phrase—lene thu chung tung⁸, i.e. tubes which spouted arrows as well as fire. That fix an early date for the appearance of arrows as co-operative projectiles (cf. p. 250 above). The two books concerned were the Ming Wu-Eh Shih Ch’ü⁹ (History of the Mongols) by Chu Chou (1912), ch. 29, p. 134, and the Hsin Yuan Shih¹⁰ (New History of the Yuan Dynasty) by Kho Shao-Ming¹¹ (1922) ch. 122, pp. 35-42. But neither of these works has authority as high as the Chien Shih and the Yuan Shih themselves, so until their authors had access to still records not generally available, their military nomenclature is not very sure. One point that makes us suspicious is that we have not found the word pluh⁰ in any of the contemporary texts, though it does frequently occur in the latter military compendia from the Hua Lung Chang towards. So the name must remain in doubt. But whatever the weapons were, they were not rockets.

The American National Aeronautics and Space Administration (NASA) Museum at Langley, in a very laudable effort to do justice to Chinese priority, displays a painting showing the ‘rockets’ of +1252 being let off by soldiers from basket launchers (cf. p. 498 and Fig. 190). So once again the mistake is perpetrated.

¹ Chien Shih, ch. 156, p. 124, 8 tr. exact.
² Sung Shih, ch. 157, p. 151, 8 tr. exact.
³ Ching Shih, ch. 156, p. 124, 8 tr. exact.
⁴ Phuchha Kuan-Nu.
⁵ Sung Shih, ch. 157, p. 158, 8 tr. exact.
⁶ The term ‘boys in the back room’ (to) is always a very general one, and it is not clear here whether they were men who had access to the administrative records or clerks in the issuing office.
⁷ This has been discussed already in Vol. 5, pt. 2, Sect. 39 (12), it above.
⁸ I.e., some 250 yards.
⁹ Brock (1), p. 185, describes a Roman candle mortar throwing out discrete balls of half-combusted rocket mixture, and elsewhere (pp. 456 f.) describes ‘flame-lances’ containing a ‘fuel charge’ and shot-off on impact by a ‘lifting charge’. But we agree with Patterson (5), pp. 246-7, that such Chinese projectiles were solid objects, as in the many later cases where the expression kuan-hsiang occurs.
⁰ The fire-lance was so unlike anything used in modern times that Lo Mou-Tê (1), p. 36, may well be excused for supposing that the Shou-chhun arsenals was making guns with truly propellet gunpowder. Von Lippmann (22), in (3), vol. 1, p. 189, understood it better, but he believed that the projectiles were only Brand-skulltöpfe i.e., balls of combustible and incendiary material); we doubt whether the text will bear this interpretation. Where he went for wrong, however, was in his view that Chinese firearms never got independent beyond this stage.
"30. The Gunpowder Epic® The first of these was the ‘box-and-tube crossbow’ (lan thung mu wu), i.e. the magazine crossbow which was very convenient and steady (for loading and firing), and could also be used at night (because the projectiles fell into place automatically). The other was the ‘flame-spouting lance’ (chu huo chih-iang). A bamboo tube of large diameter was used as the barrel (chung), and inside it they put a bundle of projectiles (lit. a nest of eggs, 120 kle). After ignition, and when the blazing stream of flame was ending, the bundle was shot forth as if it were a trebuchet projectile (mao), with a noise that could be heard more than 150 paces away.

Presumably the bundle disintegrated as it flew, sending the objects, whether fragments of metal or pottery, pellets or bullets, in all directions. In any case this is one of the earliest references we have to co-operative projectiles; but we doubt whether the invention was really new in +1257.

The epic story of the relief of Hsiangyang by Chang Shun and Chang Kuei has already been given (p. 174-5 above), and it will be remembered that all the ships of their fleet were provided with fire-lances to repel boarders. That was in +1272. Four years later we have an account of a battle of the Sung against the Mongols which emphasises the lance aspect of the fire-lance. Bay go (Po Yen) when invading the Sung territory, ordered one of his officers, Shih Pi⁷, to attack Yangchow; the garrison commander, Chiang Tshai⁸, led a sortie to surround the Yang-tzu bridge, but suffered a great defeat. Then Chiang Tshai returned with his men by night, but thirsh Shih Pi was victorious. At daybreak Chiang Tahai, seeing that Shih Pi’s troops were few, pressed an attack, but Shih Pi resisted fiercely. Two (Sung) cavalrymen rushed at him to pour fire on him with fire-lances, but he so defended himself with his sabre that to left and right every man fell; and he himself personally killed more than a hundred…

This shows that the lance or pipe to which the barrel of the weapon was attached was a very real arm in itself, and could be used when the flames and projectiles of the latter were all spent. It may be of significance that the word chih-iang here is once again (cf. p. 222) written with the metal rather than the wood
radical, but it would be quite dangerous to deduce from this that there were no metal tubes in use before +1276.

Lastly we return to the precious description of the making of fire-lances about +1290, written a century or so later, at a time when they were certainly still in use. The Chin Shih says:

The method of making (fire-)lances was to take (thick) 'imperial yellow' paper and to make it into a tube (with walls composed of) sixteen layers, about two feet long. It was then filled (with a mixture of) willow charcoal, iron in the form of powder, porcelain fragments, sulphur, arsenious oxide (phi shuang), and other things. It was then bound with cords to the end of the lance. Each soldier carried with him, hanging down (from his belt) a small iron fire-box (of glowing tinder). At the appropriate time during combat he lit (the fuse), and the flames shot forth from the lance head more than a dozen feet. After the composition had burnt out the tube was not damaged. When Pien-ching (i.e. Khaifeng) was being besieged (in +1126) these (fire-lances) were used a great deal, and they still are today.

Here the omission of the essential constituent, saltpetre, may or may not have been deliberate, but we can be quite sure that it was present. The enemy was probably blinded and confused by the sparkling of the 'Chinese iron' (cf. p. 141 above). The tubes seem rather short, but that was perhaps the best length that paper would stand; and the use of paper is doubtless surprising in itself for those who do not know that in suitable conditions a paper like carton can be made, strong and hard enough even to be used for protective combat armour. Perhaps in the northern part of the country there was not enough bamboo available for tubes of the necessary calibre. At all events, this passage forms a good transition to the types of fire-lances which we are now in a position to examine. And as we proceed to do this, it may be well to recall that the fire-lance became the possession of the Arabs by about +1280 (as the book of Hasan al-Rammah, p. 42 above, shows). With three centuries of Chinese experience behind it, this can hardly be conceived as anything but derivative.

It is possible also to find references to the fire-lance in poetry. For example, Chang Hsien (fl. +1341) wrote a number of poems on military subjects, and one of them is entitled Fu Yang Hsing (On Soldierly Proceeding) at Fu-yang.

It goes as follows:

1. In his Fe Su Ch'i (Jade Box Collection), ch. 3, p. 274 (p. 765-7). Fu-yang was in Shantung province. The poem was first noted by Wang Long (1), p. 172, but he interpreted it as referring to bombards, which the context shows can hardly be right.

2. 扶桑
3. 孟士澄
4. 梁行
5. 張澄
6. 江南
7. 伏龍
8. 陸炎
9. 高少真
10. 賴衍德

The general mounted his horse, and flourished his gold-painted whip, On the mountain-top the white flags were like birds flying. Westwards came cavalry in thousands, crowding like bees, And the sound of the drums echoed from all four quarters.

The Tartar town was defended around by a palisade And the Chin people lurked behind great wooden stakes Boasting that five hundred fierce commanders guarded it within. When the iron gate (of the entrance) did not open Fire-barrels (huo thang) were used to attack and burn it.

Soon the strength of the Tartars (huo yao) ebbed, and their soldiers fled, From north to south of the town there were puddles of blood, And the clouds were red for the space of ten li afar. As the flames set by the flying fire-crows (fei hua pei) enveloped the town. Our brave general drinks a cup, and forbares from chasing the enemy, Letting his men just pillage the homes and household goods Of the three hundred contumacious barbarian families.

Here the focal point is evidently flame-throwers rather than metal-barrel guns. But if the reference is indeed to the wars between the Chin Tartars and the Mongols, as it seems to be, the poem must refer to some episode before +1234, the date of extinction of the Jurchen Chin dynasty. Chang Hsien need not have been given an eye-witness account, but rather depicting an assault of the previous century which was part of the heritage of Yuan tradition.

The prototypic fire-lance is the weapon named in the books li hua chtiang (pear-flower spear), and consisted simply of the tube of low-nitrate gunpowder attached to the business end of a lance or pike. According to the descriptions:

A pear-flower tube is bound tightly to the end of a long spear, and ignited when face to face with the enemy. As it burns the (flames) shoot forth as far as several dozen feet. Anyone that gets in the way [of its chemical force] is inevitably burnt to death; and after the fire has ended, you can still use the spear-point to pierce the enemy through. It is the best of all fire-weapons. [In the Sung, Li Chhian always used it in his heroic exploits in Shantung, where there was a saying that with twenty (loyal) pear-flower spearmen no enemy would be left in the world.] This technique was for some time lost, but Hsi

1. Ch. 116, p. 124, tr. avet.
2. Lit. 'sah', as often in these texts.
3. A noteworthy expression.
5. Of course the writers may have been thinking more of +1292.
7. In his Fe Su Ch'i (Jade Box Collection), ch. 3, p. 274 (p. 765-7). Fu-yang was in Shantung province. The poem was first noted by Wang Long (1), p. 172, but he interpreted it as referring to bombards, which the context shows can hardly be right.
8. This comes from Sung Shih, ch. 477, p. 168 (copied in Pa Pien Li Tsuan and other places); but what Li Chhian's wife Yang Miao-Chen (herself a military commander at times) said to one of his officers Cheng Yen-T'ii was slightly different: 'After using the pear-flower fire-lance for twenty years past, there is no enemy left in the land.' But now times had changed, and new alliances had to be sought, etc.
Kuo, a Repayment Clerk in the Administrative Commission office, re-discovered it and successfully tested it, so that it was again brought into standard use.\(^a\)

None of the sources says what the material of the tube was, but bamboo is the most likely, rather than paper or leather (Fig. 46).

Li Chhían (b.c. +1180) was an intriguing and enigmatic figure, a military adventurer who rose to the command of very substantial forces, part brigands, part rebel guerrillas, and for some twenty years played off the Sung, the Chin Tartars and the Mongols against one another. His army was known as the Red Jackets (Hung Ao). In +1213 he joined forces with a similar character, Yang An-Kuo\(^b\), and became his brother-in-law. Shantung province was at this time debatable land, and first Li Chhían won and held it as a kind of Lord of the Marches for the Sung, then later went over to the Mongol side and died besieging Yangchow on their behalf in +1231. He was closely associated with the use of the fire-lance in combat.

The ‘pear-flower spear’ appears again in the section on spear play in Chhi Chhí-Kuang\(^c\)'s Chi Hsiao Hsin Shih\(^d\) (New Treatise on Military and Naval Efficiency) of +1560.\(^e\) He says that the best school of practice with the long spear comes from the Yang tradition (presumably referring to Yang An-Kuo, d. +1215); it surpasses the Sha\(^f\) school of short-spearmanship and the Ma\(^g\) school of pike-manship. Chhi does not positively say that all pear-flower spears have flame-thrower tubes attached to them, nor do his illustrations show this, but he does refer to earthquake and thunder in connection with them, so he may have been wrapping something up. On the other hand it may be more likely that the later simple spear acquired that name from the fact that it had once been a fire-lance, before these were abandoned in favour of hand-guns and muskets. Otherwise one could hardly explain the nomenclature.

Parallel to the fire-lance was that other Sung device called the ‘fire-tube’ (hao thang\(^h\)). One account of it, in the Hsing Chhín Hsi Chhí\(^i\) of about +1230, describes it as a short section of large-diameter bamboo, so it was most probably also essentially a flame-thrower, differing from the fire-lance mainly in that it was held directly in the hand, often being provided with a wooden handle or ‘tiller’ (cf. Figs. 48, 50, 51) not attached to the head of a spear. Co-axiative projectiles were already in the fire-lance by that same date, the time of Phuchha Kuan-Nu, as we have just seen (pp. 221, 226 above), and the ‘flame-spurting lances’ (chhu tiao

\(^a\) This seems somewhat garbled. Hsi Kuo was in fact a scholar-official sent north by the Sung government in +1225 as Commissioner (in succession to Chu Shih) to hold together the quasi-bandit irregulars under Li Chhían in Shantung, and keep them loyal to the Sung against the Chin Tartars. After his assassination in +1229 it was not long before Li had to give in to the Mongols and enter their service with his troops. What the story probably means, therefore, is that Hsi Kuo transmitted various forms of knowledge regarding fire-lances from Li's military engineers to those of the Sung in the south.

\(^b\) Ch. 10, p. 16.

\(^c\) Ch. 30.

\(^d\) CH, pt. 2, ch. 2, p. 240.

\(^e\) CH, pt. 2, ch. 2, p. 240.
chhiang) of +1259 only confirm it. The projectiles had almost certainly not been present in +1132 (p. 222 above) or earlier. Exactly when the fire-tube followed suit remains uncertain because we cannot tie down the date at which that itself appeared.

In the early +14th century, when the material of the Hua Lung Ching was being collected, fire-lances and fire-tubes came in many versions and had many different names. One case where we can be sure that the tube was of bamboo is that of the 'sky-filling spurt-tube' (man thien phen thung). The description (Fig. 47) says:

A tube is cut from average-size bamboo, taking two internodes for length, and wrapped round with layers of cloth and glue, like the hoops made for barrels by cooperers. For the gunpowder a mixture of saltpetre, sulphur, (charcoal) and arsenious oxide is used. The tubes are then fastened to the heads of long lances, and let off when defending city-walls.

Other accounts all say that fragments of broken porcelain were also included.

That five-minute flame-throwers of this kind were very common in the first part of the +14th century appears from the memoir entitled Liu Po-Wên Chien Hsien Pheng Chi Ch'ung (The Pacification of Central Chekiang (Province) by the Able Officers recommended by Liu Po-Wên), in the Hsi Hu Erh Chi already mentioned (p. 183). Liu Chi, one of the putative authors of part of the Hua Lung Ching itself (p. 25 above), campaigned in Chekiang as a Yuan general between +1340 and +1350 against both inland rebels and coastal Sino-Japanese pirates. The memoir depicts two fire-lances or fire-tubes, a man thien yen phen thung (sky-filling smoke-spurt-tube), and a fet thien phen thung (heaven-flying spurt-tube). The first shot out bits of broken porcelain and generated a lachrymatory smoke, the second produced balls of arsenical poison amidst the flames. These are clearly similar to the device just described, but also to several others in the military encyclopaedia. This gives us independent confirmatory evidence for the practical and large-scale use of these low-nitrate gunpowder flame-throwers in several decades of the first half of the +14th century.

Devices of this kind continued to proliferate far into the +17th century, long

after the development of the true gun and cannon—more than four centuries, indeed, after the first of these. One can see in them a veritable series of steps which would lead in the end to high-nitrate gunpowder exerting its propellant effect upon a projectile that filled a whole bore of the tube. Among the weapons of fire-lance type mentioned in the Wu Pri Chih (+1621) is the 'poison-dragon
magically efficient fire-sprouting tube' (in long phén huo shen thuang).
It consists of a bamboo tube emitting poisonous flames, and was recommended, as usual, for defending city-walls. Then come the co-ative projectiles again, in their most highly divided small-particle form. The 'empyrean-soaring sand-tube' (fei huang sha thuang) sends out flame and sand from a bamboo tube, with the intention of causing blindness when it gets into the eyes of the enemy. Another similar weapon described also in the Fire-Drake Manual is the 'orifices-penetrating flying-sand magic-mist tube' (tsuan hsueh fei shen wu thuang), which spouts out flame, sand, poisons, sal ammoniac and many other chemicals (Fig. 47). With a favourable wind, it is said, the mixture will exert its effects several li away, and if soporic drugs are added the enemy will not awaken so that they can easily be attacked. However that may be, the use of fire-lances primarily for generating smoke-screens or poison-smokes must go back rather a long way, for the Wu Lin Chia Shih (written in +1270 concerning events around +1170), speaks of imperial army drill demonstrations in which smoke lances (yeh chuang) were used.

It will have been noticed from the preceding paragraphs that arsenical compounds were often ejected with the flames of fire-lance flame-throwers, and that was only one aspect of a tendency to mix poisonous substances with gunpowder which runs through all the formulae in Chinese texts from the +11th century onwards (cf. pp. 118, 129, 125). An almost contemporary experience of this can be found in the book of Mildred Cable and Francesca French, two British missionaries who lived and worked in Sinkiang during the days of the warlords Ma Pu-Fang and Ma Chung-Ying. In 1930 they were called upon to treat some soldiers whose wounds had been caused by 'fire-arrows' (more probably fire-lances) discovered in the old disused arsenal at Hami. 'These wounds were septic, and the flesh was charred as though burned by some chemical.' The suggestion of Cable and French that it was due to phosphorus is highly improbable, but mercury, often as the sulphide or one of the chlorides, was commonly used in such compositions in addition to arsenic, and that could well have led to the effects described.

And now we come to another great turning-point, the first appearance of the metal barrel. It is of cardinal importance that this occurred in connection with a flame-thrower and co-ative projectiles, not with high-nitrate gunpowder and an occlusive shot. The date is very difficult to fix, but the fact that the following description occurs in the first part of the Hao Lung Ching puts it in the earliest stratum of the weaponry there assembled, so that it must be before about +1350, and was probably as old as +1200, if we take into account all the other historical data we have. The name of the device was the 'bandit-striking pene-
The barrel is made of iron, 3 ft long, with a stock or handle 2 ft long, and the weapon is used by foot-soldiers. It has a range of 300 paces. The enemy can be shot with pellets (at a distance) or struck with the gun itself (at close quarters), and the device is very useful because of this dual function.

We shall soon see other examples of metal-barrel flame-throwers.

Next we may consider a bottle-shaped flame-thrower called the 'phalanx-charging fire-gourd' (chhung chen huo hu-lu). The Huo Lung Ching (Fig. 50) says:

Its shape is like a bottle-gourd, and the interior forms the (ignition) chamber of the gun (chhung) holding lead pellets and 1 sheng of 'poison gunpowder' (tu huo). The stock, made of hard wood, is 6 ft long. In action it is wielded by one brave soldier, in between men holding 'fire shields', right in the front line. When enemy positions are charged with a detachment of such weapons, they cause panic among both men and horses. It is an efficient weapon for cavalrymen as well as foot-soldiers.

None of the sources tells us what the gourd itself was made of, but rather than being carved out of wood it is perhaps more likely that it was fashioned from metal. In this case we should very much like to know whether its bore was uniform inside or whether it followed the outer shape. This raises the question of the vase-shaped or 'ampulliform' bombards, which we shall have to discuss later on (p. 289); a significant common trait between China and the West.

Besides flame, poison, sand, porcelain fragments and metal pellets, the flame-throwers were also used to discharge arrows. This was another step on the way to the true gun or cannon, and it has the special interest that the earliest depiction of bombards in Europe (+1327, see Figs. 82, 83) shows them firing off arrows. But the Chinese illustrations usually draw the tubes with parallel or divergent straight sides rather than the bulbous vase-shaped forms of Walter de Milamete, though these were certainly known and used in China too, as we shall duly see (p. 329 below). Since nothing is ever said (in so many words) about the occlusion of the bore by a plug at the rear end of the arrow, one supposes that it

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30. THE GUNPOWDER EPIC

Fig. 49. The first of all metal barrels, not for high-nitrate gunpowder and a bore-filling projectile, but for a low-nitrate flame-throwing fire-lance and small co-vicative missiles. The 'hand-striking penetrating gun' (chi tsei pien chhung), in HLC (HCT), p. 18a.
Fig. 30. An amphiiform fire-lance with lead pellets as co-operative projectiles, the 'phalanx-charging fire-gourd' (zheng fang hu bu ku), in H.E.C. (HCT), p. 324.

Fig. 31. Arrows as co-operative projectiles, the 'single-flight magic-fire arrow' (yi fen feng hou dou), from H.E.C., pt. 1, ch. 3, p. 250. One can see here what may have been an attempt to depict a plug or wad filling the bore at the base of the arrow; it seems the device may have approximated to a true gun (a 'proto-gun', cf. p. 257), but there is no evidence that the gunpowder was filled in only behind it.
was just shot out by the force and rush of the rocket-composition burning in the enclosed space (cf. p. 480). One can see this situation, for instance, in the 'single-flight magic-fire arrow' (tan fei shen huo chien'). The Huo Lung Ching says (Figs. 51, 52).

Use a barrel 3 ft long cast from high-grade bronze and designed to take only a single arrow. Put 0.3 oz. of 'blinding gunpowder' (ja yao)? as charge into the barrel before firing, whereupon the arrow is sent flying like a fiery serpent, with a range of between 200 and 300 paces. It can pierce the heart or the belly when it strikes a man or a horse, and can even transfix several persons at once.

In the Huo Kung Pei Yao edition of the Fire-Drake Manual the caption indicates that the arrow-head should be tipped with bear or tiger poison.

Then the 'magical (fire-)lance arrow' (shen chihang chien) described in the Huo Lung Ching, the Ping Lu and the Wu Pei Chih, discharged amidst the flames not only an arrow but lead pellets as well. These were contained in some kind of wooden tube or holder (mu sung izz) which conceivably acted as a plug or wad. The weapon is said to have been acquired or developed when the Ming sent an expeditionary force to Annam; this would refer to the campaigns of +1406 and +1410 under the able generals Chang Fu and Chiben Chhi'ai. The special point about the device was that it was made of the very hard and heavy iron-wood (thien-li-mu), probably the barrel as well as the tiller. Again, the arrow is said to have a range of about 300 paces.

The 'awe-inspiring fierce-fire yaksha gun' (shen wei lieh huo ye-chha chhung) of the Fire-Drake Manual (Fig. 53) discharged multiple arrows together with strong poisoned flames. Its barrel was bound with rough cloth and many turns of iron wire, and its arrows came from a cradle ejected at the same time. This again may well imply a plug or wad filling up the bore.

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a On the other hand the ranges given, up to 300 paces (500 yards), suggest (if they are not optimistic exaggerations) a primitive gun with fully occluded bore rather than co-axial projectiles sent out with the flames of a fire-lance. With that one would expect at most only a tenth of such a distance. Evidently we are here trembling on the verge of the true gun.

b HLC, pt. 1, ch. 2, p. 25 b; Huo Chii Tha ed. p. 21 b; tr. auct. Cf. WPC, ch. 176, pp. 15 a, 16 a. Davis & Ware (1), p. 525.

c Cf. p. 180 above.

d Again this may be an exaggeration.

e Huo Kung Pei Yao, ch. 3, p. 251, b

f HLC, pt. 1, ch. 2, p. 254, b; Huo Chii Tha ed. p. 20 b; Huo Kung Pei Yao, ch. 3, p. 251, b; ch. 11, pp. 57 a–58 b; and WPC, ch. 126, pp. 98, 100.

g Cf. p. 311 below.

h We have come across this before, in Vol. 4, pt. 3, p. 416, in connection with shipbuilding. It may have come from palm-trees of Kiangtung and Annam such as Sigis sambhii or Arenga esculenta; or it may have been the Meda forma of Kiangtung, or the hemlock-spruce Tsuga integri.

i This name was derived from the ogres of Buddhism (and India) called jatas, supposed to devour human beings at night.

j HLC, pt. 1, ch. 2, pp. 154, k; Huo Chii Tha ed. p. 188.

k The text says: jung chien mu chhi we-fim; use a block of hard wood to make a common cradle.

**Fig. 52.** The picture of the same device (Fig. 51) from HCT, p. 21 b; there is no sign of any wad. But the description of the penetrating power of the arrow suggests propellance rather than co-axial discharge. On the other hand, some versions indicate that the arrow-head was tipped with tiger-poison, so that its speed of flight need not have been great for it to do much damage.
The 'lotus-bunch' (Fig. 54) emitted flame and many small arrows, but its chief interest lies in the fact that it was the only other one of the whole series of arrow-firing flame-throwers which had a bamboo barrel (Fig. 55). This was 2 ft 5 in. long, with all the septa removed except the end one (which was protected by clay), and a metal ring at the mouth. Outside it had to be bound with many layers of hempen cord, and cloth soaked in a saturated solution of alum to protect against the fire. Here there is no sign of a plug or wad.

The fire-tube or spurting-tube naturally took some considerable time to be reloaded after firing (when it was feasible to do this at all), so for dealing with enemy soldiers at close quarters the fire-lance remained the weapon of preference—just as in the West bayonets were fixed to muskets four hundred years later, from about +1650 onwards. The prototypic 'pear-flower lance' (lihua chhiang) described above (pp. 229 ff.) was soon elaborated in various ways. For instance, the number of barrels could be increased, and indeed the fire-lance (hao chhiang) as such, of the military compendia, had twin flame-thrower tubes (Fig. 55). When one of these was burnt out, a fuse automatically ignited the second, thus prolonging the flames, and after that the halberd-like blade, knives and hooks of the lance-head came into play.

We can also illustrate these fire-lances from a little-known source, the Chhie Chhung Thu (Illustrated Account of Muskets, Field Artillery and Mobile Shields), written by Chao Shih-Chên as an appendix to other military treatises in +1585. As Fig. 56 shows, he depicts six 'ten types of weapons for use by soldiers accompanying field-guns'. Two of these fire-lances have three barrels each, and are called 'the three-eyed lance of the beginning of the dynasty' (kao chha san yen chhiang), and 'the miraculous triple resister' (san shen tang) respectively. The double-tube one is also said to derive from the same time. That would take the prototype back to +1468, just the period of the Hua Lung Ching. The inscription says that in the king-tzu year (+1360) a Taoist of the Kung-te Su temple, more than a hundred years old at the time, first made the designs for these weapons, and transmitted them to posterity—a statement which links up in an interesting way with the Taoist connections described in Chiao Yu's preface (p. 28 above).

Of course various types of fire-lances also discharged co-axiative projectiles. Even with bamboo tubes this was possible, as in the case of the 'winged-tiger gun' (li hu chhiang), a fire-lance sending forth lead pellets (chhien tan) as well as

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The text is a natural representation of the given page. No additional facts or entities are to be inferred from the text.
Fig. 54. A bamboo-tube fire-lance emitting many arrows along with the flames; the 'lotus-bunch' (i pa lian) from HLC, pt. 2, ch. 2, p. 28a. No sign of any wad or cradle.

Fig. 55. Fire-lance with two tubes, the second of which ignited automatically when the first one had almost burnt out. HLC, pt. 2, ch. 2, p. 23a.
flames from three large barrels just behind the spear-point. The 'wasp's-nest of lead pellets' (chhiyen tan i wo feng) however, a fire-tube rather than a fire-lance, was carried on a bandolier, and shot out several hundred lead pellets at one firing from a metal tube. This would have been a rather later stage of development.

Sometimes fire-lances approximated very closely to guns, with parallel-sided tubular barrels. For example, the 'horse-felling fire-serpent magically efficient cudgel' (tao ma hao shen kan) in the Fire-Drake Manual and the Wu Pei Chih, is described as follows:

It is made of wrought iron in the form of a hollow tube, which holds lead pellets and magic-fire gunpowder [mixed with poison-gunpowder]. It is 3 ft long and is fixed to a wooden stock 4 ft long. In practice it is held by a soldier to bring down horses in the front line of an attack. (Another way is to have two parallel tubes of iron, one like a musket for the lead balls, the other for the fire-lance flames; this is very useful in combat.)

The word kan (cudgel) may remind us of the names 'fire-stick' and 'thunder-stick' used outside China and Europe to denote light Western fire-arms. Curiously, there was also a weapon looking very like a sword, and called the 'thunder-fire whip' (lu hao jieh). This name must have been derived from a sword-like object described and illustrated in the Wu Ching Tung Yan. The 'iron whip' (thuck jieh) seemed articulated, and presumably used for bashing the enemy about. But the 'thunder-fire whip' was not like this, it was essentially a rigid fire-tube in the shape of a sword, made of bronze or iron and tapering to a small muzzle. It was 3 ft 2 in. long, with a gunpowder charge of 5 in., a small hole through the barrel 'blade' for the fuse, and a wooden hilt 4 in. long. Only a particularly strong man could wield it, and it discharged three lead balls as big as coins in diameter. This is a striking instance of a skeuomorph. In the history of technology there has always been a tendency for the shapes of objects in a new material to imitate the shapes which they had in older ones; so here, where the artisans were dealing with a proto-gun, they felt impelled to make it take the shape of that familiar weapon, the sword.

Somewhat analogous to this was the 'vast-as-heaven enemy-extirminating

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Fig. 36: Fire-lances from the Chih Ching Thu by Chao Shih-Chên (+1385). Double and triple tubes went back to the beginning of the dynasty, but the time of the first version of the Huo Lung Ching.

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4. Known as the 'horse-felling fire-serpent magical cudgel' (tao ma hao shen kan) in the Wu Pei Huo Lung Ching.
5. HLC, pt. 1, ch. 2, p. 299. & C. Davis & Ware (1), p. 236.
7. But when the word 'stick' occurs in early European literature, it usually means the handle or tiller on which the hand-gun was mounted, as in Langenfleiter; cf. Purdenius (4), p. 147.
8. HLC, pt. 1, ch. 8, p. 311. & C. Davis & Ware (2), p. 376.
9. WCTYCC, ch. 13, p. 144. & C. Davis & Ware (2), p. 376.
10. Articulation is not distinctly stated, but the drawing stands next to that of a war-sail. Cf. Vol. 4, pt. 2, p. 601 and Fig. 376.
Yin-Yang shovel' (tang thien mieng khou Yin Yang chhan¹), which had a broad crescent-shaped blade at the end, and emitted poison as well as flames and lead pellets.◊ More honestly responding to the new technology was the 'mattock gun' (kuo chhung²), a sort of fire-lance fixed at right angles to a long pole, which was used as an extension arm to point the weapon at enemy troops from a high position such as a city wall. If they were in fact climbing up 'cloud-ladders' (pt. 6 g (2), viii above) to attack you, it would have been just the thing. Besides the flames it produced six or seven lead shot at a time from a metal barrel (Fig. 57), according to the description in the Wu Pei Chih.◊

With the introduction of the metal barrel and lead shot the fire-lance and the spurting-tube had almost completed their evolution into hand-guns. One can see this from the terminology, where chhiang³, thung⁴ and chhung⁵ tend to be used rather indiscriminately.◊ Indeed there are a number of fire-lances in which a single ball was used instead of multiple pellets. Whether this single projectile still remained co-viative, i.e. whether it failed to fill the bore of the tube completely, and whether the gunpowder was still too low in nitrate to exert its full propellant power, are questions hard to resolve on the evidence available. But whenever only one projectile is mentioned, we may well be justified in believing that we see at last the true gun at work. Moreover, there are some particularly interesting cases where this was combined with separate flame-thrower tubes.

For example, the Huo Kang Pei Yao version of the Fire-Drake Manual describes a 'sky-soaring poison-dragon magically efficient fire-lance' (fei thien tu lung shen huo chhiang⁶), saying:◊

The lance-head itself measures 1.5 ft. in length, and is made either of cast bronze or wrought iron; (the central tube) is hollow inside and holds one lead ball. The casting also includes two barrels (thung⁴) containing poison-gunpowder each set 2.5 in. from the top of the spear, and fastened securely to its shaft. (It is also provided with a sharp crescentic blade and a stock like an ordinary lance.)

When encountering the enemy, at a distance the lead ball can be shot off to hit him, at closer range poisonous flames can be projected to burn him, and then in hand-to-hand combat the weapon can be used as a (bident) spear to pierce him.◊ Thus one weapon has three uses, and nothing can surpass its versatility.

◊ HLC, pt. 1, ch. 5, p. 308; b, Huo Chi Thu ed. p. 244; WPC, ch. 128, pp. 128, 138.
◊ WPC, ch. 128, pp. 126, 163.
◊ The first of these words was eventually transferred to the rifle in China, but the third (read jhi) is more common for that arm in Japan. Similarly this last was widely used interchangeably with pho⁷ for any piece of artillery.
◊ HLC, pt. 1, ch. 5, p. 274; b, Huo Chi Thu ed. p. 228. WPC, ch. 128, pp. 48, 54, changes the order of the words in the name.
◊ WPC adds other constituents, such as sal ammoniac and tung oil.
◊ WPC adds, 'smear with tiger poison.'
◊ WPC adds that the wound made by the bullet will be exacerbated by the poison and burnt by the flames, finally being infected by the tiger poison on the blade, so that the enemy will assuredly die. This supposes that one individual would be sufficiently obliging as to approach steadily and suffer all the effects. Finally the text says that the lance is so heavy that it takes three soldiers to manage it.

This remarkable device is shown in Fig. 58. The fact that only one shot was fired from the central barrel, which had two flame-thrower tubes alongside it, does suggest that in the former the ball did fill the bore and that the effect was truly propellant; if so, the device was a remarkable intermediate stage between the fire-lance and the gun, combining both. A similar synthetic assembly is to be
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Fig. 59. A bamboo gun or cannon wrapped with raw-hide and rattan [preserved from China in British Museum (Museum of Mankind) no. 9572]. It is said to show signs of considerable use, but is still in good condition (photo Clayson Bredt, t).
Here there can be little doubt that we have left the realm of co-viative projectiles (in spite of the name used), but the nitrate can hardly have reached full explosive strength or the barrel would have burst—as perhaps it sometimes did. It would also be somewhat questionable how often the proto-gun could be used with fresh charges.

In medieval China the fire-lances were sometimes mounted in batteries on mobile racks, giving the effect of what can only be described as a 'proto-tank'. Although the descriptions do not belong to the oldest stratum of the Fire-Drake Manual, the system probably originated as early as the +14th century if not some time before. The Hsiao Lung Ching and the Wu Pei Chih call it the 'ingenious mobile ever-victorious poison-fire rack' (shen sheng shen shen shen huo phing feng chih\(^2\)); for Ping Lu it is the 'magic-fire iron-enveloped perfect camp-protector' (shen huo wan chhiian chhi wej yei ying\(^3\)). The latter text begins by saying that fortified encampments are most useful for protecting armies and generals, but if one is encircled by the enemy one can quickly leave it and bring the mobile racks into action to cover one's retreat. The texts then go on (Fig. 60):

A rack is made from hard wood, almost as high as a city-gate [like a box with four layers], and mounted on eight wheels so that it can be turned and pushed (in any direction). It is covered with raw oxhide, and within there are 12 fire-weapons [16 in each layer]. At long range one fires off the appropriate weapons, i.e. guns large and small, with bullets and arrows; at close range others are more effective, such as crossbow fire-arrows, fire-lances and fire-pikes. 10 [5] soldiers are needed to work it.

When the enemy approaches the gate, all the weapons are fired at a single moment, giving a noise like a great peal of thunder, so that his men and horses are all blown to pieces. You can then open the city-gate, and relaxing, talk and laugh (as if nothing had happened); this is the very best device for the guarding of cities.

[... Crenellated battlements (nii chhiang\(^4\)) in the defences (of encampments and city walls) are convenient for keeping watch; and there should be (mobile) racks to store the fire-weapons in four layers. Underneath they have double wheels, so that they can be pushed around. There are also shields (shen phay\(^5\)) at the eight entrances (of the camp) for protecting (the soldiers and the racks). If the enemy starts an assault, the fire-weapons are let off simultaneously, so that they are all destroyed. This (mobile rack) is the most precious arm for saving the lives of the generals and the army, so it ought to be fully appreciated.]

This conjures up a vision of a city gate suddenly opening, and the mobile rack trundling forward, with soldiers protected by shields on each side, then 'delivering a broadside, with all guns blazing', as one might say. No doubt there were plenty of co-viative projectiles in the fire-lances and spurtng-tubes which it carried. But there is a suggestion, in the last part of the passage, that such mobile racks as these were also used as stores which could be run back and forth along...
the battlements providing fresh fire-lances for the defenders. When one remembers that each of these would probably burn out in five minutes or so, it would obviously have been very desirable to organise constant supplies, and mobile racks like these would have been very useful.

The use of the fire-lance continued to be recommended throughout the 16th century; as an example one could take the *Shen Chhi Pha Huo Win* (Miscellaneous Questions and Answers arising out of the Treatise on Guns) written by Chao Shih-Chen in +1599.8 Once again the *li hua chhian* makes its appearance, but now alongside all kinds of more modern things, such as mobile armoured shields for field-guns, bullet-moulds and muskets, and even a kind of primitive machine-gun.9 The fire-lance was not yet quite dead. Indeed, the forms of it which projected arrows had been quite prominent in the successful operations of Chhi Chi-Kuang's 'new model army' against the Sino-Japanese pirates on the south-eastern coasts in the fifties and sixties of the century.10

There was still a place for the spurting-tube (thihng) as late as +1643, in the *Hao Kung Chihsia Yao* of Chiao Hsiu11 and Adam Schall von Bell. The illustration shows it as a fire-barrel, with a handle 4 ft long; it was certainly of bamboo bound with wire and string, and it emitted an arrow or lead shot as well as flames.12 From the gunpowder formula given for it, which was rather high in nitrate,13 one may guess that the projectile was no longer co-rotative, but the weapon may have burst quite often and could hardly have been used more than a few times. By a striking coincidence, this date is the same as that for the last recorded use of fire-lances in the West, at the siege of Bristol, in the English Civil War.14 Another bamboo-barrel proto-gun was the 'invincible bamboo general' (wu ti chu chhian-chhian) described by Ho Ju-Pin in the *P'ing Lu* of +1606.15 The barrel was fortified by a winding of iron wire, and the weapon fired a single stone ball: from the illustration (Fig. 61) it is hard to tell whether this completely filled

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*Fig. 56 is taken from his *Chihsia T'u, some dozen years earlier in date.

* The same is true of Wang Ming-Hao's *Hao Kung Win* 7, written a year or two earlier (c. +1598) and preserved in the *Huang Ming Chhih Shih Fang* (Shih Fang of Fung Ying-Chhiang) (+1602), ch. 16, p. 516 (pp. 1287-1318). Wang includes much on fire-lances, along with accounts of bombs, mines and sea-mines, breech-loading culverins and cast-iron small and large, muskets, rockets and rocket-launchers. Elvin (2), p. 94, was the first to draw attention to this piece, but we cannot associate ourselves with his estimate of Ming gunpowder technology. Wang Ming-Hao was also the author of important military books such as the *Ying Thau Pi Chau*.

* See Huang Jen-Yu (3), pp. 198, 173, 180, with references.

* Ch. 1 (Thau), p. 198 (p. 32).

* Ch. 1, p. 284, 4.

* Ch. 2, p. 104, 4. The percentage composition was N, S, C: 74.1:18:2.

* Parlington (5), p. 5.


* 1 槍芯(槍頭) "gun's head"
  2 冠 (冠) "head"
  3 率 (率) "rate"
  4 各 (各) "each"
  5 匠 (匠) "craftsmen"
  6 糖 (糖) "sugar"
  7 糖 (糖) "sugar"
  8 糖 (糖) "sugar"
  9 糖 (糖) "sugar"
  10 糖 (糖) "sugar"
  11 糖 (糖) "sugar"
  12 木 (木) "wood"
  13 木 (木) "wood"

* Fig. 61. A hand-held bamboo-barrel proto-gun, the 'invincible bamboo general' (wu ti chu chhian-chhian), from PL, ch. 12, p. 333. It fired a single stone ball. The wooden barrel-cap prevented the powder from getting wet.
the bore, but it probably did. The shape of the whole is sophisticated enough, but one would rather have been somewhere else when it was being let off.

However, it remains true that the majority of fire-lances and fire-tubes that discharged projectiles, whether co-axial or not, described in the Huo Lung Ching and later books such as Ping Lu and Wu Pei Chih, had metal barrels. How closely they could approach to the true gun, arquebus or musket, can be seen from our final example, the 'one-eyed magically efficient gun' (tu yen shen chhung), a kind of gingall,\textsuperscript{3} fired with the help of a rest or support. The Huo Lung Ching says:\textsuperscript{4}

This is made of wrought iron by a skilled smith. It can be as short as two or three feet, or else four feet or more. A hole is drilled underneath (i.e. at the back of) the gun, so that a wooden tiller can be attached to it. In front the gun is supported by an iron ring, which also serves the purpose of taking a better aim at the target.

The illustration (Fig. 62) shows the support, very reminiscent of the forked rests which were standard in Europe later on for matchlock muskets.\textsuperscript{5}

Believe it or not, the fire-lance lasted down to our own times on the rivers and round the coasts of the South China Sea.\textsuperscript{6} Cardwell, who got to know well the passenger-carrying and cargo junks of that region in the thirties, as also the pirate ships which preyed upon the traffic, has a remarkable picture (Fig. 63) of the fire-lances used for the defence of the junks.\textsuperscript{7} They were, he said, a kind of Roman candle composed of a mixture of tow, wax, gunpowder and other ingredients, pressed in alternate layers into a length of hollow bamboo bound with rattan. Upon ignition at the muzzle, the tube was aimed at the attacking craft with the object of setting it on fire, or driving the helmsman from his post, by means of the cataract of sputtering fire and burning wads of tow, which could also do great damage to the pirate's sails. Many junks carried a good supply of these incendiary tubes. Another picture (Fig. 64), from a Japanese source, shows a passenger junk from Wuchow or Shao-chow, with fire-lances protruding from the bulwarks outboard ready to repel bandits whether in boats or on the riverbank.

\textsuperscript{3} The illustration specifies two iron coins, one below the gunpowder charge and one on top of it. The latter could have acted as a wad for a ball of less diameter than the bore.

\textsuperscript{4} Elvin (2), p. 55, knew about this, and its seven advantages, from Huo Kung Win Ta (p. 1902), but mistook it for some kind of mortar.

\textsuperscript{5} This is a word not to be found in most military histories, but Hobson-Jobson knew it as a term for swivel- or wall-pieces (of ordnance) though unable to trace its origin. The editor of the second edition, however, felt able to derive it from Ar. al-Jazā'il, a 'heavy Afghan rifle fired from a fixed rest'. Ball (1), p. 44, considered it a musket from 6–14 ft in length, resting on a stand or tripod like a telescope.


\textsuperscript{7} Cf. Reid (1), p. 61, and Fig. 180 below.

\textsuperscript{8} Narratives of the Opium Wars in the eighteen-forties sometimes describe weapons that may have been fire-lances. Thus Ouwerkerkoy (1), p. 262 speaks of long brass tubes, wound round with silk and catgut, found in a captured Chinese fort.

\textsuperscript{9} (1), pp. 378, 794.

\textsuperscript{10} Thanks are due to Mr. Rewi Alley for this document.
Two of long fire-lances, still used in the thirties in the South China seas (photo. Cardwell).  

Muzzles of two fire-lances projecting from the side of a Cantonese river-going passenger junk (1929).  

Fig. 65. Drawing from the Arabic Rzewski MS. of about +1320, showing on the left a soldier with a fire-tube held in the hand, and on the right another soldier with a naphtha flask or incendiary bomb in his right hand and a proto-gun or fire-tube in his left. After Partington (5), p. 207.

Was there now, one may well ask, anything similar to the fire-lance in Europe? There was indeed, and we can learn a good deal by following its fortunes. From the +14th to the +17th century we can recognise it under a variety of names deriving from Latin tromba, a trumpet. The trombe we have already met with; it was a metallurgical blower and mine ventilator, with a cascade of water descending into a closed space, through the outlet of which the air carried down blew forth in a continuous stream. This was as old as the +8th century, and supplied the Catalan bloomyr furnaces. In the +14th 'trumba' was the name used for a bombard, particularly its fore-part, corresponding to the later usage of muzzle and chase. But what we are looking for comes under the name 'trump', or trompe à fen, and it was just as fearsome as the earlier weapons of the same kind in China.

There are fire-lances in the book of Hasan al-Rammāh, c. +1280, just as one would expect if such Arabic circles were the means of transmission of Chinese fire-weapons westwards, and some of them may have had co-axiative projectiles, for there is mention of 'Roman Candles' throwing out 'chick-peas' and incendiary balls of burning materials. The fire-lances appear again in the Arabic Rzewski MS. of about +1320 (cf. p. 43 above), and in the drawings (Fig. 65) as

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1. It is curious that there was no Chinese parallel to this in some term derived from la-pa (nothing to do with Lat. incanum, the imperial standard), or fee chih. The Western name no doubt arose because of the snorting noise made by the tubes when giving out their flames.
3. The principle was just the opposite of the familiar filter-pump. One can feel it in shower-baths today.
7. A related group of words came from Lat. truncus or truncus, a tree-trunk or headless body. A trunk was a wooden support for a cannon, sometimes on wheels, cf. Partington (5), p. 187; Tout (1), p. 685. A truncke was a land-mine (p. 199 above); cf. Partington, op. cit. p. 166; Romoki (1), vol. 1, p. 275, fig. 65. The word 'trun-"cous' has the same origin—two cylindrical metal projections cast on a cannon to give an axis for elevation.

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well as the text. Their first appearance in Western Europe occurs in the Latin MS. studied by Reinaud and Favé,\textsuperscript{b} datable at about +1396; here we have drawings of a fire-lance used by a horsem' (Fig. 66), another borne at the end of a chariot-pole, and another held by a dismounted knight.\textsuperscript{c} The weapon is described again in the De Re Militari of Roberto Valturio, about +1460;\textsuperscript{d} but for the most detailed account we have to wait for the *Pirotecnia* of Vanoccio Biringuccio of +1540.\textsuperscript{e}

Biringuccio gives detailed specifications for fire-lances, 'tongues of fire', he says, 'to be tied on the ends of lances, like squibs'.\textsuperscript{f} They are to be made of carton-paper 'in the form of rockets', and contain, just as in so many of the Chinese formulae, gunpowder plus $x$, $y$ and $z$, for example pitch, sulphur, salt, iron filings, crushed glass, arsenic and other poisons. When lighted, they send out 'a very hot tongue of flame more than two *braccia* long,\textsuperscript{g} full of explosions and horror', and they are as useful at sea as on land (Fig. 67). Parallel with this, in his chapter on fireworks, Biringuccio describes trunks or *trombe di fuoco*, cylinders like Roman candles for the projection of fire-balls.\textsuperscript{h} It was the custom, too, in the +16th and +17th centuries, for state processions to be headed by men like Jack-in-the-green holding 'clubs' which spouted forth fire in a continuous stream; this happened on the occasion of Anne Boleyn's coronation in +1533, and is illustrated on the title-page of John Bate's book of +1635.\textsuperscript{i}

But the *pièce de résistance* of fire-lances in late medieval Europe was the defence of Malta by the Knights of St John against the Turks in +1565.

The trumps [wrote Bradford]\textsuperscript{j} were hollowed-out tubes of wood or metal secured to long poles. Like the pots of wildfire\textsuperscript{k} they were filled with an inflammable mixture,
except that it was made more liquid by the addition of linseed oil or turpentine. 'When you light the trump', wrote one authority, 'it continues for a long time snorting and belching vivid furious flames, and large, and several yards long.' The trump derived its name from the harsh snoring sound it made when alight. A smaller version was attached to the head of a pipe. This often had an ingenious mechanism whereby, when it was almost burnt out, it fired two small cylinders of iron or brass which were loaded with (ordinary) gunpowder, and discharged lead balls.

Such were the trombe de fuego mentioned by di Correggio, writing only a couple of years later. The doctored gunpowder used in the grenades and fire-lances was enhanced by more saltpetre, with the addition of sal ammoniac, sulphur, varnish, camphor and pitch, very similar to the earlier Chinese compositions, and its anti-personnel effect was apparently like that of napalm. The opinion of the Victorian military engineer, Whitworth Porter, was that these trumps must have constituted 'a most formidable obstacle to the advance of any storming party'.

After the siege of Malta, anything would be an anticlimax, so it may suffice to say that the fire-lance in Europe continued in use down to the middle of the 17th century, when it was replaced by more modern guns and artillery. Diego Ufano (1) described it in his military treatise of 1613, and so did the pyrotechnists Appier and Thybourel a few years later. Its final appearance seems to have been at the siege of Bristol in the English Civil War in 1643.

When we survey the origins and development of the fire-lance in the Western world, we are at once impressed by the fact that it seems to have started there with no antecedents. The bombard was in Europe by 1327, and the fire-lance very probably accompanied it since there are several illustrations before the end of the same century. In Europe one cannot trace any long prior development similar to that which takes the fire-lance back in China to the middle of the 15th century. This is surely circumstantial evidence that both weapons came to the West already fully fledged as it were, after which the cannon had a long development yet to undergo, while the fire-lance was probably very similar in the mid 16th century to what it had been like in the mid 14th. And it is interesting that in Europe, just as in China, it was still found useful down to that date, only then succumbing to the new and more efficient firearms of the time.

Another point well worth emphasising here is that the metal barrel did not have to await the coming of the true gun and cannon in China; on the contrary it was specified for many types of fire-lance, where the design was that of a close-quarters incendiary flame-thrower, even when combined with co-axial projectiles. We shall find that the same is true for those large-scale flame-throwers mounted on carriages or trucks, and sending out co-axial objects, even including prao-shells. It is as a brief examination of these that we must now turn.

(14) The Eruptor, Ancestor of all Cannon

So far all the weapons of fire-lance type which we have been considering were wielded by a single combatant, or else stacked in a mobile trolley which could be manoeuvred by several men. But when we come to 'fire-lances' with large-diameter tubes mounted on frames, like the arcabaliastis of old (cf. pt. 6, (f), 3 above), we have to turn over a new page. Several of these are described and illustrated in the military compendia from 1350 onwards, but their character is so archaic that they must surely belong, at any rate in their earliest forms, to the previous century. Let us look at a few examples.

To begin with, there were the 'multiple bullets magazine eruptor' (pai i zu leu chu phao). As we know, the term phao originally meant the trebuchet, and the stone projectile, or later the bomb, which was hurled from it, while later still it came to mean in common parlance any kind of cannon; but there was an intermediate phase when the gunpowder was low in nitrate, and the projectile did not fit the bore. It was for this gargantuan fire-lance that we felt the need to coin

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* Bosio (1), vol. 2, pp. 360–2, a word-for-word translation from the old Italian.

* As if they were wheel-lock muskets', said Bosio, so they seem not to have been co-axial, but it is hard to be sure. This weapon, combining as it did the fire-lance and the gun, is extraordinarily reminiscent of the Chinese triple-function devices described on pp. 248, 251 above, and it is hard to believe that there could have been no connection between them.

* Eng. tr. by Balbi, p. 79.


* Parrington, (4). p. 5. Perhaps the existence of the fire-lance till this time could illuminate certain literary allusions otherwise hard to explain. For example, in the version of 'Tom o' Bedlam's Song' written by Giles Earle in +1615 the madman says:

> With an host of furious fancies
> Whereof I am commander
> With a burning spear, and a horse of air
> To the wilderness I wander;
> By a knight of ghostes and shadowes
> I summoned am to journey
> Ten leagutes beyond the wide world's end——
> Me thinks it is no journey.

There are several other versions of this, as in Percy's Reliquae (+1675), vol. 2, p. 370. Tom was one of the 'Bedlam Beggars', so named after the Reacham Mental Hospital in London, founded in +1557 after the suppression of the abbeys (complete by +1547) which had previously harboured the psychologically deranged. Similarly there was the Knight of the Burning Potts, one of the comedies by Francis Beaumont & John Fletcher, printed in +1625; it was like Don Quixote a burlesque on knight errantry (Bowers, i). Here the Cooer Errant had a burning pestle on his shield, reminiscent of the 'clubs' mentioned on p. 261 above. And in Antonio de Guey, a prose romance printed early in the +16th century, there had been a knight of the burning sword (Hattaway, i). Without overlooking other aspects of this symbolism, one cannot but draw attention, highbrow rather neglected, to the presence of fire-lances among European weaponry in the +15th and early +17th centuries.

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* Not much is heard of Greek Fire petrol flame-throwers after the +12th century in the Byzantine region, and whether they were made use of in the later Crusades is uncertain; there is no reason for the belief that the European fire-lances were derivative from them. The new sector was essentially gunpowder, and the existence of that in Europe before +1350 is hard to substantiate. Cf. p. 374 below.

* 古士潘普洛
the word eruptor, and we use it here. Of this magazine eruptor the Huo Lung Ching says:  

It is made of cast bronze, and measures 4 ft 5 in. in length. It contains 1.5 sheng of 'blinding fire' gunpowder which sends forth (flames) from the muzzle. At the side of the barrel a beak (shaped tube) is cast on, rather more than a foot in length, and it is filled with a hundred or so lead balls. A frame of hard wood is made for the carriage, and on it the eruptor can be rotated in all directions. First the magazine is held horizontal, but when it is turned vertically the lead bullets all fall down into the firing chamber, and are spewed forth at the enemy soldiers one after the other, hitting them and preventing them from assaulting one's camp. One such eruptor can resist as many as fifty determined soldiers of the opposite side.

From the illustration (Fig. 68) one can see that the bronze tube was provided with a tiller (yen wei), and the axis on which it was turned to aim is visible underneath the barrel. From the text we visualise that the magazine was filled while the eruptor was on its side, then immediately after ignition the barrel was turned so that the magazine pointed upwards, allowing the projectiles to slip down and be shot forth with the flames. It would seem quite certain here that the diameter of the balls must have been much smaller than that of the barrel; assuredly they were co-axial.

Perhaps the greatest surprise of this genre is that the eruptors could toss over shells. They must have popped out like the 'stars' from Roman candles or 'pumps', each one lighting the 'blowing charge' of the next one beneath it before leaving the tube, but clearly they were capable of landing on the top of city walls in sieges. Moreover, in some cases they carried 'bursting charges' as well as 'lifting charges', for they would explode when they got to their destination. For example, there was the 'flying-cloud thunderclap eruptor' (fei yin phi-li phao). The text reads:

The shells (phao) are made of cast iron, as large as a bowl and shaped like a ball. Inside they contain half a pound of 'magic' gunpowder (shen huo). They are sent flying towards the enemy camp from an eruptor (ma phao); and when they get there a sound like a thunder-clap is heard, and flashes of light appear. If ten of these shells are fired successively into the enemy camp, the whole place will be set ablaze and his men will be thrown into confusion. [You can use any of the kinds of gunpowder in the shells—

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\* HLC, pt. 2, ch. 2, p. 6a, 6; WPC, ch. 122, p. 154; tr. acc. Cf. Davis & Ware (1), p. 598.
\* The sheng was a liquid and cereal measure often translated as pint, though perhaps better as gill; here it might be equivalent to lb, or rather less.
\* On this translation of sheng see p. 180 above, and HLC, pt. 1, ch. 1, pp. 7a, 8a.
\* See Brock (1), pp. 192–3.
\* Ibid. p. 311.
\* HLC, pt. 2, ch. 2, p. 8a, 6; WPC, ch. 122, p. 154; tr. acc. Cf. Davis & Ware (1), p. 590.
\* Cf. what has been said on pp. 165, 176 above regarding the dan thus in or thunder-crash cast-iron bombs used early in the 13th century.
\* Formula in HLC, pt. 1, ch. 1, p. 6a.

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Fig. 68. An eruptor, i.e. a large fire-lance on a frame. This one, the 'multiple bullets magazine eruptor' (fei lu lu chien she phao) is taken from HLC, pt. 2, ch. 3, p. 6a. The magazine is filled with lead shot when it is on its side, then when the tiller is turned round on its axis they are fed into the barrel and issue forth along with the flames.
blinding powder (fa pao), flying powder (fei hua), violent powder (tak hua), poison powder (tu hua), bruising and burning powder (lan hua), and smoke-screen powder (chen yen), according to the circumstances. These proto-shells can be seen in the illustration (Fig. 69), which shows well enough that they did not fill the bore. Underneath, the rotating axis which allowed of aiming the eruptor in different directions is called the ‘general’s column’ (chian-chun chu).

Here it would be natural to ask when the shell, i.e. the cannon-ball which itself carries a charge of gunpowder exploding on impact, and is therefore essentially a propelled bomb, arose in the history of European warfare. The answer points to the early decades of the +15th century, because while the ‘dracoon’ of Konrad Kyeser in his Bellifortis of c. +1405 is only a bomb, the shell is clearly present and described in the anonymous Feuerwerkbuch of about +1477. After Valtorio’s De Re Militari of +1460 shells become commonplace, but a good deal of time must have passed before they became reliable and effective. From the passage just given, the shells from the eruptors of the Hua Lung Ching also burst on reaching their target. If the second part of this work is dated in the +16th century, developments in China and Europe were going on simultaneously, but we have already mentioned our conviction that the fire-lances and eruptors were archaic devices, to be placed before +1390 and indeed before +1290, so that the proto-shells here described may really have been among the first of their kind.

Other eruptors used shells designed to spread poison-smokes among the defenders of a city wall. The ‘poison-fog magic-smoke eruptor’ (tu wen shen yen phao) is thus described in the Hua Lung Ching (Fig. 70):

If blinding gunpowder (fa hua), flying gunpowder (fei hua), poison gunpowder (tu hua) and spurting gunpowder (phien hua) are filled into a shell (phao) and fired at the top of a city wall, fire will break out and smoke will spread in all directions as the shell explodes. Enemy soldiers will get their faces and eyes burnt, and the smoke will attack their noses, mouths and eyes. If the right moment is chosen, no defenders can withstand such an attack.

The description of the ‘heaven-rumbling thunderclap fierce fire eruptor’ (kung thien phit ming hua phao) is more explicit about the poisons used in the smoke-shell. These include wolf dung, sal ammoniac, arsenical salts, soap-bean

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1. The formulae for the first, second, fourth and fifth of these are all in HLC, pt. 2, ch. 2, p. 9a. The passage in square brackets is in WPCh only.
5. PL, ch. 12, p. 153; WPCh, ch. 112, pp. 218, 220.
6. This produced a particularly heavy smoke, and was therefore used in the signals system of the Ming fort along the northern border, but in the end it became very hard to get, especially in the south; Sertuwai (2), p. 19.
Fig. 70. Other eruptors used proto-shells to give forth clouds of poisonous smoke when fired so as to reach the enemy’s city walls. This one is the ‘poison-fog magic-smoke eruptor’ (ta au shen yen phao), depicted in HLC, pt. 2, ch. 2, p. 92.

powder, pepper and croton oil, among other things, and from the name one would expect that some petrol came in somewhere. The illustration (Fig. 71) shows no discrete bombs or shells, but the text is clear that they were present and contained the poison-smoke ingredients.

After what we have seen for fire-lances, it would be only natural to find eruptors designed to shoot forth arrows as well as flames. Such a missile projector

Fig. 71. Another smoke-shell eruptor, the ‘heaven-rumbling thunderclap fierce fire eruptor’ (hung thien pho-li sheng hue phao), from PL, ch. 12, p. 153. Arsenic, pepper and croton oil were constituents of the smoke, and no proto-shells are shown, but the wad or cradle for them is there.
was the chiu shih tsuan hsin shen tu hau lei phao\(^1\) (nine-arrow heart-piercing magic-poison thunderous fire eruptor) described in the \textit{Wu Pei Chih}.\(^2\) This was designed to fire off nine arrows simultaneously, each tipped with tiger-hunting poison, from a cast bronze barrel 3 ft 8 in. long, mounted on a framework with arrangements for varying altitude and direction of aim. The illustration (Fig. 72) shows that the tiller was of iron. Part of the text is rather obscurely worded, but it seems to say that: ‘sometimes one uses a cloth bag (or bags) full of “flying gunpowder”,' and when they (the arrows) are loaded like this, it has the advantage that the arrows don’t shake about and get into confusion.' This can hardly mean that the bags were used like shells, but if the bags were attached to each arrow like sausages, they might have done something to occlude the whole bore, in which case there would have been an approach to the true cannon, with the projectiles no longer entirely co-viative. And indeed the projector is referred to now and then in the text as a \textit{chihang},\(^3\) which may be significant in understanding how it worked.

It seems fairly clear that in all these strange weapons the co-viative projectiles were more important than the flames of the burning gunpowder, for it would have been difficult to station enough of them in the protective lines of a camp or defensive position, and the hand-held fire-lances would have been more effective for repelling assaults. So we really seem to have here a final stage before the appearance of the true cannon with its ball matched to its bore.

There seem to be references to eruptors in poetry too. Chang Hsien,\(^4\) who was writing about +1341, has in his \textit{Yu sau Chii} (Jade Box Collection) a poem entitled \textit{Thi ch hao Hsing},\(^5\) which might be translated ‘The Iron Cannon Affair.'\(^6\) It starts in this way:

\begin{quote}
The black dragon\(^7\) lobbed over\(^8\) an egg-shaped thing
Fully the size of a peck measure it was,
And it burst, and a dragon flew out with peals of thunder rolling.
In the air it was like a blazing and flashing fire.
The first bang was like the dividing of chaos in two,
As if mountains and rivers were all turned upside down…
\end{quote}

This must surely refer to a shell sent forth from an eruptor, but the rest of the poem shows that people were not very frightened of it, because it did little harm and ‘its bark was worse than its bite'. But it would seem that in certain circumstances eruptors could have been more fearsome weapons.

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\(^1\) Ch. 127, pp. 569-571, 1.e.
\(^2\) Ch. 5, p. 274 (p. 569.) The word \textit{phao} in the title is only a variant of the more usual \textit{phap}.
\(^3\) Black probably because of the black smoke emitted with the flames. Cf. Wang Ling (11), p. 172.
\(^4\) We translate this because the verb used is \textit{phao}, to fall or to let drop, suggesting a mortar-like trajectory.

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\(\text{Fig. 72. An eruptor with a barrel of cast bronze and a filler of iron, designed to shoot forth nine arrows simultaneously along with the flame and smoke. From JPC, ch. 127, p. 83. The arrows were contained in cloth bags.}\)
The time has now come to emphasise that throughout these last two subsections we have been thinking in terms of tubes and cylinders, with solids, liquids and gases passing through them. These were not involved in the preceding uses of gunpowder, as in bombs, grenades or mines, whether incendiary, explosive or detonative. Of tubes for liquids much has already been said in an earlier discussion, with reference to syringes, pumps, piping and the like; here the difference was that the tube had to contain a solid passing into a phase of gas and flame. Nevertheless the transition from the Greek Fire petrol flame thrower (méng huo yu chì) to the low-nitrate gunpowder flame thrower (hùo chìháng) had been remarkably easy and logical, for gunpowder had already been used in the petrol pump as a slow-match for the ignition chamber (p. 82 above). The improvement was that the weapon was made much more portable, needing no crew to man the pump, for the expansion of the solid mixture was automatic once ignited, since it carried its own oxidising agent built in—though the Chinese of the +10th century would not have put it quite that way. Then ultimately the wielder would have noticed the recoil effect, reminding them no doubt of the 'ground-rat' firework (ti lāo shà) and suggesting that the fire-lance or spurting-tube could be allowed to fly free—in the opposite direction. It could be made to carry an arrow-head or any such similar inconvenience to annoy the enemy. Thus would the rocket have been born; but that is another story, which for the present we reserve (cf. pp. 472 ff. below).

But the gunpowder mixture was not the only solid thing put in tubes. The appearance of co-axiative projectiles at once evokes, and was perhaps initially suggested by, a much more ancient apparatus, the blow-gun. This was a weapon, mostly used for hunting, which consisted of a reed or bamboo tube through which a solid object, the projectile dart or pellet, was made to move by the action of human breath alone, derived from the pump of the lung. The development and distribution of the blow-gun, which has been exhaustively studied by Jett (2), is one of those clear examples of a Pan-Pacific technique, uniting aboriginal South America with the islands of the Pacific and the mainland of East Asia, but it also spread in somewhat later times to all regions of the Old World. Blow-guns could be made from reeds, bamboos, palm stems or hored wood. They could fire darts, whether blunt-ended or pointed, whether feathered, rifled, or poisoned at the heads. 'Air-stops' were often used for the rear ends of the projectiles to fill the cross-section of the barrel; and these could be of pith, kapok, cotton war or mushroom cone. Blow-guns could also fire clay pellets, baked or unbaked, as well as pebbles and hard seeds. Clearly they were an important invention in the history of hunting and warfare, but they worked best in forest country where wind would not tend to deviate the projectile. They had the great advantage of being silent, though of course their range was rather restricted, accurate only up to 50 or 60 yards. In essence they were the forerunners of all devices in which solid objects are made to issue from tubes with the intention of hitting something, yet because of their 'air-stops' they are ancestral to the true gun and cannon rather than to the co-axiative projectiles of fire-lances and spurting-tubes. But this somewhat fine distinction would hardly have been appreciated by those who first made the explosive force of burning gunpowder carry objects out with it in order to hit an enemy. One might think of the co-axiative principle as a necessary diversion or loop-line in the evolution of gunnery.

For the relevance of the blow-gun to the first appearance of gunpowder tubes in the Chinese +10th century, we need to be assured that it was in fact known in that civilisation; and this indeed appears from what we can learn of its distribution and development. Its original focus may well have been in the Malaysian-Indonesian culture-area, whence it reached, as Lynn White has shown, the Arabs in the +11th century and Europe in the +14th. The Malay word sunga-tan wandered everywhere, giving rise to zabatãna in Arabic and cerbotâna in Italian by +1425. Though nālīka, a reed, through which dart-arrows or small pellets were shot, is claimed by some to be an ancient Indian name and usage, the words tumbiñān in Malayalam and sungān in Tamil betray the Malaysian influence. Speaking very broadly, the Malaysian-Indonesian culture-area included also Thaiwan, and in earlier centuries South China and even Japan.

Hence the interest of the work of Thang Mei-Chiūn (1), who studied the cross-bows of the aboriginal tribespeople of Formosa in connection with the origins of Strophhanthus spp. Curare came from Strophhanthus toxiferus or causticness (Chondrodendron spp; upas sap, containing a cardiac poison, from Aristium tuscum) and all round the Pacific snake venom and poisonous berries from many trees were brought into play. In South China the minority peoples used aconite; cf. Vol. i, p. 90. In general the use of poisons recalls very significantly the constant recommendations to do this throughout the Chinese military compendia (cf. Ph. 125, 134, 204). Further to their nature see Boser (1).

As we now see (pp. 135 ff. above) that went parallel with the development of war-weapons.
and history of the blow-gun. The reason for the connection was that although today only the Saiatrics and Tsou folk retain the crossbow, it has a tube of bamboo at the head to guide the arrow-dart as it is sent forth;\(^1\) and Thang was therefore led to suggest that the crossbow itself in Asia was the product of a marriage between the simple bow and the blow-gun.\(^2\) However this may be, there can be no doubt that references to the blow-gun occur in ancient Chinese literature. For example, Tso Ssu\(^1\) in his Wu Ta Fu\(^2\) (Ode on the Capital of the Wu Kingdom) spoke in c. +270 of the ‘cinnamon-tree arrows shot from tubes’ (\(\text{kuei chien shè thang}\));\(^3\) and in the Chü Pha\(^4\) (Treatise on Bamboos) about +460 Tai Khai-Chih\(^5\) referred to the \(\text{yùn tang} \) bamboos as useful for shooting-tubes (\(\text{yùn tang} \text{shè thang}\)).\(^6\) Again, Fan Chho\(^7\), in the \(\text{Man Shu}\)\(^8\) of c. +862 in the Thang (Monograph on the Southern Barbarians, i.e. Minority Peoples) mentioned the \(\text{p'ai chi chu} \) bamboos which were useful for making blow-guns (\(\text{chhiu thang}\)). As would be expected, the mentions become rarer in more recent literature. But enough is there to show that the blow-gun was quite widespread among the people of South China and Thaïwan in ancient times,\(^9\) and therefore that the inclusion of projectiles in tubes, when the gunpowder mixture at last became known, was something which had already had a very long history behind it.

There is yet another matter on which something must be said before we can leave the realm of fire-lances, eruptors and co-viative projectiles. More recent centuries have also known volleys of complex and discrete objects—what was the difference then between co-viative projectiles and chain-shot? The answer is that after the +17th century the fragments were always put together in some sort of casing which fitted the bore of the cannon or gun; leaving them free amidst the erupting gunpowder was a much earlier stage of evolution.\(^10\)

‘Chain-shot’ itself, for instance, consisted of two cannon-balls joined together by a chain or iron bar, which, when fired from a gun, rotated at great speed through the air, smashing the spars and rigging of an enemy ship and clearing her upper deck of men.\(^11\) Since the balls issued from the muzzle in succession there was generally no need for a casing. But ‘case-shot’ always had this.\(^12\) In +1644 Manwaring described it as ‘made of any kind of old iron, stones, musket-bullets or the like, which we put into cases to shoot out of our great ordnance’. These cases were made preferably of wood, fitting the bore, or simply canvas bags which would do so. ‘Canister-shot’ was usually the same thing, put in cylindrical tin boxes, while ‘grape-shot’ was a number of iron balls bound together in a receptacle with canvas sides and circular cast-iron plates at top and bottom. Finally ‘langrel’ or ‘language’ consisted of iron bolts, nails, jagged fragments and any old metal pieces, enclosed in a thin cloth bag to fit the bore of the gun; it was a favourite weapon of privateers attacking merchant-ships.\(^13\) In fact, in Chinese waters as recently as the thirties of the present century, merchant junks responded against pirates with just the same coin, as is seen in one of the photographs of Caldwell (Fig. 73). So, to sum it up, all the varieties of case-shot belonged to the era of true guns and cannon when the projectile always fitted the bore and had high-nitrate gunpowder behind it, while the co-viative projectiles were simply mixed with the low-nitrate gunpowder of the fire-lance, spurring-tube or eruptor, and issued together with the flames, obviously with much less force behind them, and consequently a much less range. In fact it was an earlier chapter in the story.

It is noteworthy that the sharp distinction which we draw between the co-viative projectiles of fire-lances and eruptors (even when their barrels were made of metal), and the full application of the propellant force of gunpowder upon projectiles that fitted the bore or calibre of the barrel, would have been fully appreciated in the +14th century by Chiau Yü himself. For in the earliest stra-

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\(^{1}\) This is still often poison-tipped, linking up with a wide area of practice both in the Old World and the New. Probably it was the very weakness of the propulsive force which led to the intensification of the effect caused by a hit.

\(^{2}\) Cf. p. 6, (e) above on the slur-bow.

\(^{3}\) \(\text{Wu Hsün}, \text{ch. 5, p. 64a; tr. von Zach (6), vol. 1, p. 60.}\)

\(^{4}\) P. 44; tr. Hagerty (2), p. 395. Both these scholars took the words \(\text{shè thang}\) to be the name of a species of bamboo. This may well be, but from the commentaries it can be seen that the argument is not affected.

\(^{5}\) It has persisted among the tribal minority peoples of the South-west till contemporary times, and was observed among the Semang people of the Leichow peninsula in Kwangtung early in the present century by Imbert (1).

\(^{6}\) We are grateful to Prof. Robert Maddin of the University of Pennsylvania for raising this point.

\(^{7}\) Kemp (1), p. 150.

\(^{8}\) Ibid. p. 143.

\(^{9}\) 吴郡賦

\(^{10}\) 擲錳射筒

\(^{11}\) 强弩之矢

\(^{12}\) 白翼之矢

\(^{13}\) Ibid. p. 463. For an eye-witness account of case-shot used in the English Civil War (+1648) See Temple (1).
tum of the Huo Lung Ching there is a brief discussion of the composition of shells filled with combustible material calculated to set the enemy's works on fire (huo tan yao). Here we find the remark that 'the size of the (incendiary or poison- ous) shell must be just right to fit the bore of the iron tube; i.e. the gun or cannon (nai yao yu tiieh hung ko thang khao)'. Chiao Yü would certainly have been quite clear about the great divide in this story.

(15) Gunpowder as Propellant (1): The First Metal-Barrel Bombards and Hand-Guns

In modern times the cannon has been commonly known in Chinese as phao or huo phao. But as we have noted earlier (pp. 11, 22) these two terms originally referred to the trebuchet which, from antiquity onwards, hurled large pieces of stone, and then later on incendiary bombs, and finally explosive bombs, into the cities or camps of the enemy. The very word phao for trebuchet was actually a homophone of the verb phao, meaning 'to throw'. The phrase huo phao seems to have appeared first in connection with the conquest of the kingdom of Southern Thang by the Sung army in +675. From then on it recurs constantly in accounts of military battles, at first for gunpowder bombs with weak casings, then later on for bombs with strong casings, e.g. cast iron. The fact is that when it was first introduced, probably in the late +10th century, it was essentially a new technical term, and as such it appears in the Wu Ching Tsung Yao towards the middle of the following century. In just the same way we can trace other technical terms back to their starting-points—for example, pao chang for gunpowder fire-crackers (as opposed to bamboo ones) to +1148 (cf. p. 131 above), and chhing for hand-guns to a date which we shall shortly see (p. 294) somewhere in the +13th century.

A difference between British and American usage needs qualifying here. While in American English the term hand-guns is still applied to all pistols and revolvers (even of the most modern types), in British English it designates only those earliest bombards which were small enough to be wielded by a single man holding the wooden handle or tiller which is projected from their rear end.

An exactly similar step in the evolution of technical terminology occurred in Europe, for Burtt (1) tells us that the word 'gun' was formed unquestionably from mangos, i.e. the mangonel, or trebuchet as we usually call it. Mangonels are now called guns in some +14th-century poems. Similarly, 'cannon' came from canna, a reed or tube, again closely paralleling the word thang, to give hao phao.

And, as we have often seen (e.g. p. 163), the projectile itself was also called hao—causing no small difficulty sometimes.

From Vol. 4, pt. 1, pp. 310, 323, it will be remembered that Chinese chess (hsiang-chi) has a piece called pao equivalent to the knight in European chess. This is generally thought of in artillery terms, but since 'combat' chess (as opposed to the earlier divinatory star-chess) became widely popular already in the Thang period, it must originally have meant the trebuchet, and only afterwards the cannon.

Now by chance it happened that this last period was also the heyday (if a comparatively short one) of the most highly developed form of pre-gunpowder artillery, the counterweighted trebuchet ('the Muslim phao, hui-hui phao'). Earlier on (pt. 6, (f) 5) we had a good deal to say about the confusions which this caused for later writers, confusions only resolved in our own time. The siege of Hsiang-yang and Fan-chheng by the Mongols between +1269 and +1273 provided the chief occasion of stumbling; and even today unwary historians are liable to maintain that the hui-hui phao was a metal-barrel cannon. Paradoxically, this thing may quite possibly have come into existence by that time, but the hui-hui phao or counterweighted trebuchet was definitely something else. The loud crashing noise made by the projectiles as they demolished houses and made fortifications crumble, burying themselves deep in the ground, accounts easily for the idea that gunpowder was involved, yet neither fire nor explosions are ever mentioned in the descriptions.

Another confusing feature was that particular designs for projectile-propelling machines got carried over from the trebuchet era to the cannon era. This was the case, for example, with the 'crouching-tiger phao' (hsun tuan phao). We see it in the Ming edition of the Wu Ching Tsung Yao as a trebuchet with a triangular frame (Fig. 74) so that was what it looked like in +1044. But by the time we get to +1350 (or +1412), we find the name applied in the Wu Lung Chhing to a small metal-barrel cannon weighing 36 lb, and provided with spikes for sticking into the ground to attenuate the recoil effect (Fig. 75).

Similarly with the two bombards substituted by the editors of the Chhing edition of the Wu Ching Tsung Yao (without any explanation) for two of the trebuchets formerly illustrated. These are both called 'mobile trebuchet carriages' (hing phao chh'ai), but in none of the available editions is there any text concerning them. The preceding pages describe and illustrate a curious shielded counterweighted trebuchet (hui-chhia), designed for stationing at the head of a sap in siege warfare, and give no help, nor does the following one, which deals with a mobile bridge (hao chhiao) for crossing moats or other water obstacles. However, the two trebuchets are quite usual projectile-throwers, only mounted on wheels, the first with four, the second with two. But then, instead of the first trebuchet illustration (Fig. 76) the editors give a picture of a long-barrelled bombard jacked up to a high elevation so that the barrel superficially resembled the trebuchet arm (Fig. 77).
Fig. 74. The hu nan po ("crouching-tiger" trebuchet) as it was in 1044, from the WCTT (Ming ed.), ch. 12, p. 43a. A detail of men pulled down suddenly on the ropes to the left, thereby sending the projectile, whether stone or bomb, into its trajectory from the pocket of the sling on the right.

Fig. 75. The same name (hu nan po) applied to a small metal-barrel cannon, 35 lb. in weight, from the HLC, pt. 1, ch. 2, p. 32 (HCT ed., p. 106), therefore about 1350, Note the four anti-recoil pins to be stuck in the ground, showing that the muzzle, contrary to appearances, must be pointing to the right. Note also the bands encircling the barrel, on which cf. p. 391 below.
Fig. 76. The hsing phao chê (mobile trebuchet carriage) as it looked in +1044. The picture is from the WCTY (Ming ed.), ch. 10, p. 144 using the original copy in the library of Dr Hsu Ti-Shan at Canberra.

Fig. 77. In the Chhing edition (ch. 10, p. 134), the arm of the trebuchet is replaced by a long-barrelled bombard jacked up to a high elevation, but the weapon still has four wheels, and bears the same name.

Adjacent to this a parallel substitution took place. Where before there was a trebuchet on a two-wheeled barrow-like carriage (Fig. 78), also called hsing phao chê, we now see another bombard with a long thin barrel carried on a two-wheeled barrow (Fig. 79). But it has had a slight change of name, becoming 'bombard on a high-fronted carriage' (hsien chê phao), and in its elevation slanting like the kind of perspective drawing of the mobile bridge on the opposite page.


** 車砲行

** 行砲車
Fig. 78. The name was also applied to a trebuchet borne on two-wheeled barrow-like carriage, as we see from the Ming edition, ch. 10, p. 148 (again from the Hsi Ti-Shan library original).

After all, it was natural enough that the term huo phao\(^1\) should have continued in common parlance for the metal-barrel bombard and hand-gun after the term chhang\(^2\) had been appropriated for application to them (p. 248 above). In fact the more firearms developed the more natural it was, for the longer the barrel became, as in slings, culverins and muskets, the more reminiscent it was of the arm of the trebuchet, and the more often shells were fired from cannons the more.

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\(^1\) 火砲
\(^2\) 銃
reminiscent they were of the bombs which trebuchets had hurled in the old days of the +12th century. Here too a characteristic of the traditional scholars is very relevant, their predilection for using the most antique expressions possible because of the greater literary elegance one obtained thereby; we saw good examples of this already in connection with crackers and fireworks (p. 131 above). At the same time there was the tendency (often remarked upon in earlier volumes) to use professional wood-block artists (hua kung) for making illustrations, men who knew nothing about what they were drawing, and probably rather despised it as banal. These two features can be seen quite well in ch. 101 of the military section of the Thu Shu Chi Chheng encyclopaedia (+1726) entitled chih chen (chariot-fighting), a heading itself archaic to a degree, but one which could be made to include any military device on wheels. Most of the chapter is concerned with references in the ancient Shu Ching (Book of Documents) and Shih Ching (Book of Odes) of the -1st millennium, and commentaries on them, but the illustrations at the end include a mobile windlass, a battering-ram and a mobile tank-like shield. Finally, a quite reasonable bombard on four wheels is given (Fig. 80), the 'subduing and burying cannon' (mai fu chhung), though it would have been more appropriate in +1326, four hundred years before. But in the last illustration (Fig. 81) a climax of bewilderment is reached, for although the artist seems to have been trying to draw a mobile counterweighted trebuchet, the caption says 'the wonder-working long-range awe-inspiring cannon' (wei yuan shen chhung). Such was the conservatism of the scholars, and the indifference of the artists—fortunately not mirrored in the military compendia, which were clearly intended (like the pharmaceutical natural histories) for practical use.

Nevertheless, this present sub-section differs from almost all the preceding ones in that concrete archaeological evidence is available in support of the texts. To put the matter in a nutshell, several hundred specimens of metal-barrel cannon, large and small, as also hand-guns, have survived in China from the +14th century (even indeed the +13th) and are preserved mostly in Chinese museums. In considering this we have always to bear in mind that the earliest date for bombards in Europe is +1327, the year of the two illustrations in the Oxford MS. of Walter de Milamet's book De Nobilitatibus, Sapientis et Prudentis Regum (On the Majesty, Wisdom and Prudence of Kings), both showing vase-shaped

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\* The encyclopaedia editors were in fact mixing up archaeology, ancient history and popular technological explanation.

\* Unlike some of the other pictures, this is one of those which have no accompanying text. TSCC, fang cheng tien, ch. 101 (chih chen pu), hui chen, p. 148.


\* Ed. James (a).

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Fig. 80. Another bombard on a four-wheeled carriage, the mai fu chhung ('subduing and burying cannon'), from TSCC, CMM chen pu in fang cheng tien, ch. 101, p. 144. From all else that we know, this would have been more appropriate for +1326 or +1426 rather than +1726.
Fig. 81. A further illustration from TSCC, ibid., p. 143. One cannot tell whether it was intended to be a counterweighted trebuchet (tzu-tui phu) or a high-elevation bombard; at any rate, the name given is nei-pao shen chuang ("wonder-working long-range awe-inspiring cannon"). In works of this general kind, the scholars were very conservative, and the artists indifferent to what they were drawing, but such a situation is far different from what pertained in the professional military compendia.

Fig. 82. The oldest illustration of a bombard in Europe, a page from the Bodleian MS., datable at +1327, of Walter de Milamet's De Nobilitaibus, Sapientis et Prudentiis Regum (On the Majesty, Wisdom and Prudence of Kings). A figure in armour on the right is gingerly applying a red-hot rod to the touch-hole of a vase-shaped cannon, out of the muzzle of which appears an arrow. Everything goes to show that the bore of the cannon was uniform, but it was thought wise to strengthen it by thickening the walls over the explosion chamber. The 'carpenter's bench' support for the bombard is worth noting, in view of what we see in Figs. 83, 106, 155 below.

Bombards both of which are firing arrows (Fig. 82, 83). Some specimens of European cannon or hand-guns rather later than this in the +14th century are also preserved in Western museums; but the difference is that many of the Chinese ones are self-dated by inscriptions, either cast or incised. Let it not be thought, as some amateurs of Chinese art objects might be tempted to suppose, that these dated inscriptions could be forgeries; on the contrary, the low estimate in which technology was held by the traditional scholar-officials meant that no possible kudos could be gained by anyone in dating a bombard earlier than it really was. We made the point at the beginning of our work, when

\* This is the iconographic evidence, but in order to get into a picture the thing itself must have been known in Europe at any rate a few years earlier. Yet Partington (5), p. 161, could not adduce any textual evidence older than +1326, the date of a Florentine decree.

\* The question of modern copies is of course another matter. Chinese museums habitually make them, for simultaneous display in several locations, but expert examination easily distinguishes them from the original. Cf. on this Arima (3), p. 73.

\* Besides, no one in China before very modern times had the slightest idea of the comparative history of gunpowder and firearms. For a striking example of the disdainful, almost contemptuous, attitude of the Confu-
these weapons, seven of which were of the +14th century. His oldest specimen dated from +1372, with four others from +1377 and two from the years immediately following. But in 1957 Chou Wei had listed six others, some decidedly earlier in date, for the oldest was of +1356, and two others of +1356 and +1357. It was in the former year, according to Arima, that the Koreans obtained their first bronze cannon from China, and it may be that the transmitter was a Chinese merchant named Li Khang. Again, in 1957, an artilllery exhibition which was mounted in Peking displayed several early bronze cannons, and three of these were afterwards described in detail by Wang Jung. The climax of the series so far was the bronze gun of about +1288 reported and described by Wei Kuo-Chung (i) seven years ago; we shall return to it when discussing Table 1, which lists most of those known that date from before the end of the Yung-Lo reign-period (+1424).

From the illustrations (Fig. 85, 88, 92, 93) it is already possible to sketch one or two characteristics of the successive periods. The early metal-barrel handguns or cannons tend to have a muzzle of blunderbuss type, the later ones are plain or with a single fillet beading but in nearly all cases the wall is made bulbous at the base (or closed breech end), i.e. intentionally thickened, with the bore remaining the same, at the part where the propellant explosion was to take place, and this was in fact called yao shih (the gunpowder chamber). Behind this they all have a hollow projection into which a wooden tiller or handle could be fitted. Towards the end of the +14th century the vent or touch-hole was elaborated to include a priming-pan, the hinged lid of which has in a few cases been preserved. The bulbous strengthening (or reinforce) of the barrel (or chase) at the breech end (cf. Fig. 84, 90a, b, 91, 93) brings up the question of the vase-shaped or bottle-shaped character of many of the early bombard both in East and West, indeed a significant common trait, and we shall return to it presently (p. 329). Later on, in the +15th century and the +16th, the chase or barrel of cannons was strengthened by very rugged rings or bands included as part of the casting, as we shall see (p. 331). This form continued into the era of breech-loading cannon with removable powder-chambers held in place with wooden wedges (cf. p. 365 below).

Speaking of scientific texts we said: 'One may feel confident that these have never been intentionally interfered with, partly because the Confucian scholars considered them too unimportant, and partly because until modern times it would never have occurred to any Chinese scholar that the slightest interest attached to placing of scientifc knowledge or a technical process earlier than its proper date.'

From here onwards, the first thing to do will be to present a list of the earliest Chinese bombards and hand-guns now known, adding some commentary on the most interesting and important pieces; after which we may take a glance at some of the textual evidence for their use during the +13th and +14th centuries. Lastly we can have recourse to the descriptions and illustrations of bombards and hand-guns in the military compendia, which, sometimes irrespective of their date, belong clearly to the archaic period of artillery.

In 1962 Arima Seio was able to list twenty-eight early Chinese examples of...
<table>
<thead>
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<th>Year</th>
<th>Provenience and where preserved</th>
<th>Length overall cm</th>
<th>Dimensions muzzle bore diameter cm</th>
<th>Weight kg</th>
<th>Metal</th>
<th>Inscription</th>
<th>References</th>
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<td>c. 1288</td>
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<td></td>
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<td>15.75</td>
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<td>Goodrich, in Goodrich &amp; Feng Chia-Shêng (1), p. 122</td>
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<td>Collection of Prince Chichibu</td>
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<td>1.5</td>
<td>2.27</td>
<td>bronze</td>
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<tr>
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<td>Collection of Fujisawa Teiki</td>
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<td>H. Blackmore (p.c.); Figs. 95, 96</td>
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<td></td>
<td></td>
<td>Okada Noborn (p.c.), but date is hard to be sure of</td>
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<td>Kuroda (1); Arima (1), pp. 120-1, 137</td>
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Table 1. (cont.)

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<th>Year</th>
<th>Provenance and where preserved</th>
<th>Length overall cm.</th>
<th>Dimensions muzzle bore diameter cm.</th>
<th>Weight* kg.</th>
<th>Metal</th>
<th>Inscription*</th>
<th>References</th>
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<td>bronze</td>
<td>Kuroda (1); Arima (1), pp. 122, 130</td>
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<td>1.5</td>
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<td>-</td>
<td>-</td>
<td>cast iron</td>
<td>Goodrich (24); Naganuma (1), ch. 5</td>
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</table>

*As regards the distinction between bombard and hand-guns, an individual soldier could be expected to carry a weight of some 20 lb. or about 9 kg., so most of the specimens listed in the table are of the smaller arm. When the weight has not been recorded, the photograph will clearly show which variety of firearms is in question.

The presence of an inscription, incised or cast, on the bombard or hand-gun, is indicated by the sign I. Generally, though not always, this includes the date of production, together with other details about the military unit for which it was intended. Cf. the inscription on the crossbow or armillas of trigger given in pt. 6, (c.f.) above.

This hand-gun contained a mass of material black because of its charcoal content (18-24%), and hence assumed to be the remains of a gunpowder charge. Naturally all but a trace of the saltpetre had gone, and there was only 2% of sulphur left. According to P'eng Chia-Shing (6), p. 31, a pottery jar containing similar material was discovered in Chiah province in 1943 by Pai Wun-Yü, a member of the Peking Academy. He believed it was of the late 14th century, and in fact a local form of the kind referred to on p. 166 above. Cf. Lo Ch'ê-Wen (1).”

"The two weights given are those of the examples in the Nantung Museum. The general range of weight runs from 60 to 300 kg.

This find was particularly interesting, because it included a large number of cast bronze cannon-balls or hand-gun projectiles, ranging in diameter from 1.9 to 2.5 cm. diameter. Cf. Lo Ch'ê-Wen (1).”

Note: There were two of these, and each has two pairs of trunnions.

Of the year +1390 rather exact figures for firearms equipment have been preserved, as was noted by Goodrich & P'eng Chia-Shing (1), p. 122. For example, the Ming Shi Lu, Thaci Tzu sect. ch. 129, p. 74 (p. 2055) specifies 10 hand-guns (ch'hung) and 10 fire-lances (chung) for every 100 men. To ch'ing Hsi Tian (ch. 132, p. 634) confirms this, but gives the wrong date of +1393. The Hsi Wei Hsin Chun Kong (ch. 134, p. 3994-2) mentions for +1410 several kinds of ch'ung, ch'ihung and phuh⁵, clearly of different sizes from hand-guns to cannon, including ch'un kha phuh⁶ (blunderbuss muzzle gun), cf. p. 259. Every three years from +1390 the arsenals turned out 2000 bronze cannon with a bore as large in diameter as a rice-bowl (wan kha kung ch'ihung) and 3000 bronze hand-guns (ch'ung kha chung ch'ihung). In +1433 each warship was equipped with a bowl-size bore cannon, 16 hand-guns, and 20 fire-lances, as well as much other ammunition and bombs (ch. 134, p. 3995-1).”


Note: All the armament was in bronze. The cannon were of varying diameters, but all were more than 1 foot in length and weighed nearly 8 lb. In addition, there were no inscriptions as to the place of manufacture.

In the Table, the deepest interest naturally attaches to the first entry, that for the small bombard or hand-gun, ascribed to the +1410 period. While the Mactan MS illustrations, it is necessary to scrutinize cardinally the find rather than the Mactan MS illustrations. In all the existing works, the ability to read and understand these texts is absolutely essential. The archaeological evidence is

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Fig. 44. Bronze cannon. D. +1390. From Hsingping excavations, after Wei Kuo-Chang (1).
without a good deal of trouble, by Li Thing, a commander in the Yuan service who came of an old Jurchen Chin family called Phuchua. Nayan was a Christian prince, the descendant of Belgutai, half-brother of the great Chingiz, and after his revolt against Khubilai, a revolt which a Korean brigade helped Li Thing to defeat, he was bloodlessly executed.

It is quite clear that during this campaign gunpowder weapons were much used. The *Yuan Shih* text tells us that towards the end of +1287 Li Thing equipped and led groups of foot-soldiers carrying and using huo phao, so these could evidently not have been the heavy and unwieldy trebuchets of former times. We read that:

Li Thing personally led a detachment of ten brave soldiers holding huo phao, and in a night attack penetrated the enemy's camp. Then they let off the phao, which caused great damage, and such confusion that the enemy soldiers attacked and killed each other, flying in all directions.

This could of course be interpreted as an assault with grenades, but on the immediately following page there is a further statement concerning some time early in +1288. It goes as follows:

Li Thing chose gun-soldiers (chung wa), concealing those who bore the huo phao on their backs; then by night he crossed the river, moved upstream, and fired off (the weapons). This threw all the enemy's horses and men into great confusion ... and he gained a great victory.

Here we have such an explicit statement that hand-guns or portable bombardeiros must have been involved rather than grenades or small bombs. Indeed this must be one of the earliest occurrences of the term chung anywhere in the literature. Consequently, one may say that Wei Kuo-Chung's interpretation is supported by remarkably interesting textual authority, for after all the *Yuan Shih* was under preparation almost as soon as the Ming dynasty had begun. His find will long remain of capital importance, since it is the only metal-barrel hand-gun so far discovered which almost certainly belongs to the +13th century.

There is room for a good deal of further research on these earliest bombardeiros and hand-guns of the Mongol period before the second half of the +14th century which has left us so many surviving examples. To what extent 'fire-barrels' (ho tung) were used during the invasions of Japan in +1274 and +1281 remains uncertain, but Arisaka Sho'go firmly maintained that much evidence of their employment exists. For example, the book *Nihon Kokujokushi* (History of Japan's Humiliation), written about +1590 not long after the invasions, makes many mentions of the huo tung, referring not only to the Battle of Tsushima in +1274 when the Mongols were commanded by the general Hu-Tun, but also to the coastal assaults of +1281. The uncertainty here lies in the fact that fire-lances could have been meant. But the *Buchiman Gado-Ka* (Tales of the God of War told to the Simple) of +1360 speaks of iron phao (teppei) 'which caused a flash of light and a loud noise when fired'; and the *Taiheki* (Records of the Reign of Great Peace) of +1370 mentions 'iron phao (tseh phao) shaped like a bell' which made a noise like a thunder-clap and shot out thousands of iron balls as projectiles. These descriptions certainly look rather more like hand-guns and bombardeiros than fire-lances; but the first could mean only cast-iron bombs such as we have seen in the *Mioko Shihai Ekiho* (p. 176 above), and the second rather suggests eruputors with their flocks of co-axial bullets. But the subject requires further investigation. Poems of the Yuan period might also be a source of useful knowledge; Wang Ling quoted two from the *Yu Sia Chi* (Jade Box Collection) of Chang Hsien, who was writing about +1341, but we have thought it more fitting to place one of them with fire-lance flame-throwers (p. 228 above), and the other seems rather to belong with shell-throwing eruputors (p. 270 above). Still, it is likely that poems which were being written during the last quarter of the +13th century and the first quarter of the +14th may contain valuable information on true metal-barrel guns and cannon.

Returning to Table 1, our attention is attracted to the ninth of the items, a find remarkable for many reasons: (a) the weapons are the oldest cannon in the list, as opposed to hand-guns; (b) several hundred of them exist, nearly all inscribed; and (c) they were made for a transient principality the name of which no longer would have thought of using. They belong to the years +1356 and +1357, and their background needs a little explanation. Chang Shih-Chihêng...
the ruler for whom they were cast, was one of those adventurers who acquired power in a limited area during the struggles between the Yuan Mongols and the forces of Chu Yuan-Chang which eventually brought all China under the sway of the Ming dynasty. Originally he was a smuggling salt merchant of Thaichow in Chiangsu, but in +1353 he led a rebellion of saltmen workers and farmers, taking first Kaoyu and then establishing his rule in Suchow and Hangchow. First he called himself the Sincerity Prince (Chihch'eng Wang) but later he founded a 'dynasty' called Ta Chou, with its first (and only) reign-period Hsien-Yu, and it was in the 3rd and 4th years of this that the technically minded potentate caused so many iron cannon to be cast for his army. Towards the end of +1357 he surrendered, however, only to declare independence once again, in +1365, taking the title of Prince of Eastern Wu (Wu Wang). In the end he was overcome by Chu Yuan-Chang’s general Hsiu Ta (+1329 to +1383), fled to Nanking, and hanged himself there or was put to death in +1367. An ephemeral ruler indeed, but decidedly interesting. From one of the poems of Chang Wên-Hu in his Shu I Shih Shih T’suan we know that the cannon were all unearthed together in Nanking, where Hsiu Ta must have buried them, about the middle of the nineteenth century, when the old grounds of the academy were being made into a public park or playground (Hsiao Ch’ih-chang). Some of them were then taken to the Museum at Nantung, where they still are. They have one pair of trunnions each, and a little bulge over the explosion chamber. Typical inscriptions read like this: 'Cast in the third year of the Chou Dynasty, weight 500 catties,' or 'Cast on the first day of the sixth month of the fourth year of the Chou Dynasty.'

This puts us in mind of the many other inscriptions on the Chinese hand-guns and cannon of the +14th century; but it will suffice to give only a few. For example, the gun of +1332 bears the following words: ‘Made on the 14th day of the second month of the 3rd year of the Chih-Shun reign-period. Border-pacifying anti-bandit forces, no. 300. Ma-shan. One of those of +1372 was manufactured for use at sea. It reads:

1. There is no mention of either dynasty or reign-period even in Moule & Yetts (1), so they were always little known, and the authenticity of the finds incontestable.

2. It will be remembered that he was the one who tested out Chiao Yu's fire-weapons; cf. p. 27 above.

3. Cf. Mêng Sen (1), pp. 16–17; Dardess (1). He was good at promoting commoners.

4. The text is in ch. 2, p. 22a.

5. A couple of them were photographed by Goodrich (24). Han Kuo-Chiu (1), in his monograph on Chang Shih-ChiHung, gives in ch. 100 a reconstruction of the prince’s cannon-foundry. Cf. Fêng Chia-Shên (6), p. 39.

6. It happens that Nantung is the home town of our first collaborator, Wang Ching-Ning, and I suspect that it was this ancient cannon in the Museum that inspired him to work on the history of artillery in China.

7. Wang Jün (1), tr. Goodrich (25). Ma-shan is obviously a place-name, but it may also have designated a brigade or division.

8. This is especially interesting because many of the convoy warships on the great +15th-century voyages of the admiral Chih Ho (cf. Vol. 4, pt. 3, pp. 487 ff.), with their equipment and the marines who sailed in them, came from that Left Naval Station. Already in an earlier volume (Vol. 4, pt. 3, p. 710) we drew attention to this

- **The Gunpowder Epic**

Fig. 85. The Yuan bronze gun or bombard of +1332 (photo. Nat. Historical Museum, Peking).

Left naval guard squadron, Chin 1 Division, no. 42 (fire-barrel with large bowl-shaped muzzle (ta wan khou thung)), weight 26 catties. Cast on a fortunate day in the twelfth month of the 5th year of the Hung-Wu reign-period by the Pao-Yuan (Foundry) Office. This description of the blunderbuss-like mouth is particularly interesting in view of the fact that many of the early cannon had this shape, almost as if to receive a heavy ball of stone or iron greater in diameter than the main bore (cf. Figs. 85, 88, 92, 93). Very shortly afterwards, from the beginning of the following year, +1373, we have another inscription, as follows:

Chung-shan Garrison, no. 130. Long êkchung barrel, weighing 3 catties, 6 oz. Cast by the Pao-Yuan (Foundry) Office on a fortunate day in the twelfth month of the 5th year of the Hung-Wu reign-period.

context. The question of the use of naval cannon on Chih Ho’s voyages was discussed in some detail by Duyvendak (19), though with various misunderstandings, and partly on the basis of evidence from a later work of fiction. Still, we have no doubt at all that naval guns were carried by the Grand Treasure Fleets of +1405 to +1453. We gratefully record here interesting discussions with our collaborator Lo Jung-Pang on this subject in 1928.

9. Wang Jün (1), tr. auct. The Pao-Yuan Office was responsible for making all kinds of military equipment, even drums.

10. This was the Purple Mountain, just north-east of Nanking.

11. Tr. Goodrich (15). The difference in the dating arises because the Chinese year included nearly all of January.
All these labellings may be compared with that on the crossbow or arcuballista trigger mechanism of bronze depicted and described above (pt. 6, 30 (e) 2, (f) 3). For reasons already given, there can be no doubt of their authenticity.

The find reported by Li I-Yu (t) from inside the east gate of the old city of Tokoto in Inner Mongolia, at the junction of the Black River with the Yellow R., are interesting for a number of reasons, such as the large pile of bronze-ball ammunition that was with them. But several of the Ming examples of hand-bombards (+1377, +1379) have inscriptions showing that they were intended for gunnery practice. Thus one says:

Hand-gun made on a fortunate day in the 10th year of the Hung-Wu reign-period, for Training Officer (Chiao Shih)' Shen Ming-Erh and Instructor (Hsi Hsieh Chien) A Te', at the Left Naval Station, for teaching the troops, wt. 3 catties, 8 liang.2

Another mentions by name Training Officer Chu I and Instructor Shang Shih-San belonging to an Assault Guard Unit (hu pen tso woe'). A third city the names of the makers, Artisan Hsi Hheng and Apprentice Military Artisan

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Fig. 86. Another view of the dated gun or bombard of +1332 (orig. photo.). The inscription can be seen in both these pictures.

Fig. 87. Rubbing of the inscription on this gun, specifying the third year of the Chih-Shun reign-period. Translation on p. 296.

Wang at the Yuanchow Arsenal, working in this case for Local Commander and Battalion Judge Ho Hsiang. What a strange and unexpected form of immortality it was to have one's name and title inscribed on a bronze gun which archaeologists six centuries later would uncover.8

It is not really possible as yet to pinpoint the origin of the true metal-barrel

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* Transcribed names are as follows:
- Nien Hui
- Hsi Hsiang Chia
- Hsii Heng
- Shen Ming-erh
- Chien A Te
- Chu I
- Shang Shih San
- Hsi Hheng
- Apprentice Military Artisan

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* Illustrations of guns came down, of course, in song and story too. For example, the famous novel Shih Ho Chien (Stories of the River-Banks) tells how Sung Chiang managed to lure and capture Ling Chen, the greatest artillerist of his age. The work was first collected from older plays and tales just about this time. The incident is related in Hsi 54.

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* Transcribed names are as follows:
- Hsi Hsiang Chia
- Shing Hui
- Chen Mong
- Hsi Heng
- Shen Ming-erh
- Chien A Te
- Chu I
- Shang Shih San
- Hsi Hheng
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Fig. 88. A reconstruction of the probable housing of this bombard, together with a cross-section, after Wang Jung (t). Note again the ‘carpenter’s bench’ type of mounting.

Fig. 89. The +14th-century cast-iron Chinese gun in the Rotunda Museum at Woolwich (Class I, 30). Calibre 4.15 in., overall length 18.7 in. Photo. Blackmore.

Fig. 90. Bombard or hand-gun dated +1351 and made of cast bronze, in the Nat. Historical Museum, Peking (orig. photo.)

Fig. 90b. Another view of the same gun (photo. Nat. Historical Museum).
Fig. 91. Cross-section of the gun of 1351, with a reconstruction showing how the wooden tiller was fitted into the recess at the end opposite the muzzle. This recess will have been evident in all the early guns so far depicted.

Fig. 92. A gun dated 1372 with a blunderbuss muzzle (in man háu slang) after Wang Jung (7).

Fig. 93. Cross-section of the Ming bombard dated 1372 (the fifth year of the Hung-Wu reign-period), with a suggestion from the Ping Lu as to how it was mounted (cf. Fig. 106 below). Such a ‘Mr Facing-both-Ways’ device could certainly have doubled the rate of fire, but might not have been very comfortable for gunners standing behind it. From Wang Jung (7).

Fig. 94a. A cast-iron mortar or bombard dated 1377 with two pairs of trunions, in the Provincial Historical Museum at T'aiyuan in Shansi (orig. photo.).

Fig. 94b. Another view of the same mortar (orig. photo.). The touch-hole is very clear.
Fig. 95. Chinese bronze gun conserved in the Rotunda Museum at Woolwich (Class II, 261). The inscription dates it as made in the 7th year of the Yung Lo reign-period (+1409). Length c. 2 ft. Photo. Blackmore.

gun. But we have seen that metal barrels were first introduced for fire-lances and eruptors, quite a long time probably before single bore-fitting projectiles made full use of gunpowder’s propellant force. We also noted that the term huo thung’s (fire-tube) goes back at least as far as Thang times (p. 221) when it meant only a fuse in a tube for lighting signal-fires on the roofs of outpost-towers. Then, from the beginning of the +13th century we shall remember the Hsing Chiu Hi Chih and its references to huo thung1 about +1230; here the difficulty is to be sure whether ‘tube’ or ‘barrel’ meant real barrel-guns or simply the tubes of fire-lances and eruptors (proto-cannon). When we get to +1288 we do really meet with the metal-barrel gun, and under its subsequent name of chung2, in the affairs of Li Thing in the far north, making surprise attacks on the camps of Nayan (p. 294). Accordingly we can only suppose at present that the middle of the +13th century would be the time of origin of the weapon, and it may be hoped that further study of the literature, together with fortunate archaeological finds, may help in due course to make the conclusion more precise.

The next item on the agenda would be the battle accounts which describe the use of the earliest fire-arms, but since by the +14th century these were becoming so widespread all over the Old World, we may be content with but a few examples. By +1353 the Yuan Mongol forces were using ‘fire-tubes’ (huo thung3) against the armies of Chang Shih-Chhêng,4 and they were firing huo tsu4, lit. ‘fire-bars’ or ‘javelin-heads’, but by now these can hardly have been either the fire-arrows (huo chien5) of antiquity, nor yet the rockets so prominent later—rather they were arrows shot from guns, exactly as we see in the famous pictures

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1 huo thung
2 chung
3 huo thung
4 huo tsu
5 huo chien
30. MILITARY TECHNOLOGY

of Walter de Milamete (Figs. 82, 83). In +1358 and the following year Lü Chen, one of Chang's generals, successfully defended the city of Shao-hsing against a siege train commanded for Chu Yuan-Chang by Hsü Ta and Hu Ta-Hai. From the Yung Yüeh Lu written soon afterwards by Hsü Mien-Chih, we know that cannon and hand-guns (huo chang) were liberally used by both sides, firing not only stone balls (shih chi) but iron ones too (thih kuan). Actual cannon-balls of those times have been recovered by the Japanese archaeologists excavating the Mongol summer capital of Shang-tu at Dolon Nor. Both were of stone, 3 and 4 in. in diameter, and since the palace was destroyed by fire in +1358 they are not likely to be much later. Then the term huo chang comes in again during the internecine strife among the Mongol generals at the close of the dynasty, as when Ta-Chhia-Ma-Shih-Li was fighting (and defeating) Polo Timur (Po-Lo Thieh-Mu-Erh) near Peking. The latter was loyal to the last Yuan emperor, Shun Ti (Toghan Timur), but he was not to attain; in the fifties and sixties both Mongols and Chinese fought among themselves in kaleidoscopic alliances until finally Chu Yuan-Chang won everything. By the end of that time quite large cannon were coming into use, like the 'bronze general' (thang chiang-ch'an) used by Hsü Ta in +1366 when attacking Chang Shih-Chheng's capital of Suchow. Beyond this point we need hardly pursue the story.

Yet there are a few matters of interest in the late +14th century which refuse to be passed over in silence. For example, we hear, as we rarely do, of a gunner in person; his name was Yang (Yang Phao-Shou) and he deserted from the Mongol side to that of Chu Yuan-Chang in +1356. He was then put in charge of a detachment of soldiers armed with hand-guns (chung shou) in the engagements leading to the defeat of Chhen Yu-Liang, one of the provincial rulers who resisted the rise of the Ming — this was in +1363. The campaign depended much on firearms. Teng Yu defended Nanchiang successfully with hand-guns.

3 Cf. his biography in Ming Shih, ch. 175, p. 38.
5 See p. 16.
6 Hsu Ta and Hu Ta-Hai, ibid., pp. 18, 45 for the Ming side.
7 Ibid. p. 43. Cf. Feng Chia-Sheng (6), p. 75.
8 Harada Yoshito & Komai Kazuichi (2), pp. 24, 67, fig. 21.
9 The best account of the period from the present point of view is that of Goodrich & Feng Chia-Sheng (1), pp. 189-190.
10 Song Hui Shih Chia Chi Fu, ch. 3 (p. 145). Cf. pp. 30-1 above.
11 Hsü Mien-Chih (1), vol. 2, p. 362. His biography is in Yung Shih, ch. 95, ch. 96, p. 48, and ch. 97, p. 49.
13 The term chung shou is used by Polo Timur see Cordier (1), vol. 2, p. 362. His biography is in Yung Shih, ch. 98, p. 38, and ch. 98, p. 39.
14 See the commentary in the note above.
16 Miyazaki Kiyoji (1), vol. 2, p. 362. His biography is in Yung Shih, ch. 95, p. 48, and ch. 96, p. 49.
17 Chiang Shih-Chheng (1), Ka Chi Ku Wei, ch. 5, p. 11b.
including tests of guns with larger barrels for shooting incendiary arrows against the pirate ships.\textsuperscript{a} Then in +1373 a new mission, led by Sang Sa-on\textsuperscript{1} was sent to the Chinese capital asking for urgent supplies of gunpowder.\textsuperscript{b} The Koreans had built special ships for repelling the Japanese pirates, and these needed gunpowder for their cannon. In the following year another request was made to the Ming emperor after the military camps at Happo\textsuperscript{2} were set ablaze by Japanese pirates, with over five thousand casualties. At first Thai Tsu was reluctant to supply powder and arms to the Koreans, but in the middle of +1374 he changed his mind, and besides supplying what was sought, he sent military officers to inspect the anti-pirate ships built by the Koreans. The \textit{Koryó-sa} records the first systematic manufacture of hand-guns and bombards in Korea in +1377, saying that the arsenal was directed by a ‘Fire-Barrel Superintendent’ (Huo Thung Tu Chien\textsuperscript{3}).

\textsuperscript{a} \textit{Koryó-sa}, ch. 44; cf. Arima (4), p. 228.
\textsuperscript{b} \textit{Heic'hen Ryosa}, ch. 6; cf. Arima (4), p. 229. One has to remember also that this was just before the disintegration period of the Koryó kingdom, and the establishment of the Choson kingdom under a new dynasty in +1392.
whose new post was established at the suggestion of Choi Musun. After this the Korean artillery never looked back, and played a quite important part in the campaigns of the +10th century.b

During the following couple of centuries the knowledge of firearms was a ‘restricted’ item in the Ming dynasty. Hence scholars were not sufficiently acquainted with guns and cannon to deal with them adequately in their writings. Such a lack of knowledge on military affairs and weaponry under the Ming is clearly demonstrated by the compilers of the official history in the +17th century. The sub-section on military writings in the bibliographical chapters of the Ming Shi, for example, contains fifty-eight titles but misses out more than half the list of Ming military works mentioned by Chiao Hsi in his preface to the "Huo Kung Chihhie Tsao" in +1643.2

Chang Ting-Yü in the "Ming Shi" spoke thus about firearms:3

What the ancient people called phao was a trebuchet for hurling stone projectiles. At the beginning of the Yuan dynasty a phao (introduced) from Western parts (hu t'ieh') was used to attack Ts'hai-Chou, a city held by the Jurchen Ching Tartars. This was the first use of the phao as a form of fire-arm, but the technique was not handed down and the weapon was little used. Afterwards, the technique of the shen chi chih hieh phao was acquired during the conquest of Annam in ChihHung Tsu's time, and he set up a special establishment (shen chi ying) so that the army could learn how to make them. They used bronze, brass, and copper, in layers, as also iron.5 They were made in several different sizes, the largest being placed on carriages, the smaller ones on frameworks, and the smallest on posts or other supports. Their chief value was for defence, but they could be used also in the field.

This was all a muddle. The first sentence was right enough, but the reference to the counter-weighted or ‘Muslim’ trebuchet (hui hui phao)4, which the writer evidently thought was a cannon, was misguided in another way as well, for the Jurchen Ching State was extinguished in +1234 and the Yuan dynasty did not begin till +1280.6 Understandably perhaps in view of the fluctuating terminology already described (p. 248), the confusion then becomes worse confounded, for the shen chi chih hieh (magical trigger machine) was the term used for a musket, while a chihiang was a fire-lance,7 with or without co-axiative projectiles, and a phao could be a cannon but not usually a hand-gun. The writer was also weak in metallurgy, for otherwise he could hardly have written as he did about the materials used. After this, the concluding sentences clearly refer to bombards and early cannon (known since +1320 or so), hand-guns (from +1290 at least), and even muskets with their forked supporting sticks. In sum, the writer had no clear idea of what he was talking about, and we must try to unravel what we can from his words.

The fourth sentence in the passage was liable to convey the false impression that something called a shen chi chih hieh was the first barrel-gun. Chiao I, for example, interpreted it in this way in +1700,8 and he was followed by many Westerners such as Mavens' and H. A. Giles,9 who all supposed that metal-barrel guns had first entered China as a Vietnamese invention. Arima tried to save the situation by rendering the same sentence: 'When it came to the time of the Ming emperor ChihHung Tsu, (new) techniques of (using) the shen chi chihhieh were developed during the conquest of Annam.'10 And indeed it is true that the "Huo Lung Ching" describes the shen chi chihhieh chen (magical fire-lance arrow) (Fig. 96) as tchhu phing An-Nan chih hieh yeh, i.e. 'this is the very weapon (used in) the subduing of Annam.'11 It was in fact a fire-lance made of ironwood, which sent out an arrow and a number of lead bullets as co-axiative projectiles. However, one cannot exclude the meaning that 'this is the very weapon (acquired during) the conquest of Annam.' Moreover, one can find a statement in the "Ping Chi Pui Chiu Fang" (+1626) that during the Yuan-Lu reign-period (+1290 to +1242) when Annam was conquered, the Annamese were found to be skilled in making this type of fire-lance, whereupon the Ming emperor ordered it to be copied and manufactured.12 Thus what came up from Vietnam was only one of the many fire-lances described in Chinese sources.13

Without wishing to diminish in any way the ingenuity of the Annamese mili-
tary technicians, it is a fact that the Southern Sung people had been moving further and further south under pressure from Mongolian troops, from the middle of the 13th century onwards. Remnants of the Sung soldierly could have crossed over into Annam to escape the onslaught of the Mongols, and some of them could have brought along their fire-lance designs. The Annamese could well have developed their *shen chiang chien* from these, using the very hard local wood. The Chinese of the Ming did not regard scientific and technical inventions and discoveries as a matter of national prestige; no controversies arose paralleling that concerning the invention of the calculus, or the discovery of Neptune, in Europe. On the contrary, the Chinese were always ready to acknowledge the foreign origin of any product or device, often using words like *ha* and *yang* before the names of objects. So the Annamese origin of the *shen chiang chien* would have caused them no difficulty.

Chi Chi-Kuang mentions in his *Lien Ping Shih Chi* (Treatise on Military Training) of 1568 that the 'crouching-tiger cannon' (*hu tun phao*) was already put into service at various points along the Chinese border at the very beginning of the Ming dynasty (+1368). This is only what one would expect, and throws useful light on the general development. The *Lien Ping Shih Chi* itself is listed in the bibliographical chapters of the *Ming Shih*, so it appears that the editors did not have time to read all the books they listed. Surely it was the lack of knowledge of firearms on the part of the compilers of the military monograph of the *Ming Shih* that made the passage so muddled. To understand more clearly about the earliest bombards and cannon we have to turn once again to the military compendia.

But first let us follow further the *Ming Shih* text as it deals with developments in the first half of the 15th century. The writer, whose terminology now becomes more consistent and comprehensible, tells us that in 1412, just after the campaigns in Annam, and the same year that saw the first printing of the *Huo Lung Ching*, an imperial edict ordered the stationing of batteries of five cannon (*phao*) at each of the frontier passes as a kind of garrison artillery. In 1422 Chang Fu, one of the generals who had been victorious in Vietnam, petitioned that the system be extended to the northern frontiers, e.g. in Shansi, and this was done, though great secrecy was enjoined. In 1430 another officer, Than Kuang, suggested that hand-guns (*shen chiang*) should be supplied to all frontier guard towers and fortified villages. So also in 1441 two border command...
ders, Huang Chen1 and Yang Hung2, began to establish arsenals for these weapons (shen chung chi) near the frontiers, but now the emperor Ying Tsung stepped in and forbade the decentralisation of gun foundries on security grounds. Next, in +1448, a Warden of the Marches, Yang Shan, petitioned for leave to make more double-ended bronze bombard (liang thu thung chung), which must have been the same as the rotating double-bowl-muzzle bombard (sean kho thung chung) which we shall encounter presently (Fig. 106)—and presumably he got it. Then comes another interesting sidelight on southerners, for in +1540 an official named Chiang Chhiao3 recommended the manufacture of triple-barrel iron fire-lances (san thung thieh huo-yao chhing) such as were used with shields (sho san)4 by his military colleague Phing An5, and made especially well by Shih Ao6 and the people of Ying-chou7 in Kwei-chou province. Tested and approved.8 Arrow-firing guns were still in use, for in +1464 Fang Neng8 reported gratifying results in border combat with ‘nine-dragon guns’ (chiau lung thung)9 which shot nine arrows at a time when ignited only once. The nervousness about frontier arsenals continued all through the century, for in +1496 it was again insisted that the centralised Ministry of Works (Kung Pu)10 alone should manufacture guns and cannon, and send them out to the various border unions. Finally, with relation to +1529, the text begins to tell about the Frankish cannon (fu-lang-chi)11 or Portuguese breech-loading slings, and that is another story which for the moment we must postpone.12

For a clear picture of the various types of early bombard and cannon we have to fall back on the Hsiao Lung Ching. The Fire-Drake Manual describes them as follows. The ‘crouching-tiger cannon’ (ku tun phao13, Fig. 75) we have already had occasion to mention several times (pp. 21, 277). The text says:

This is so called because of its shape. It measures 2 feet in length and weighs 36 catties.1 Each of the (iron) staples (used to pin down the cannon in position) weighs 3 catties and measures 1 ft 2 in. in length. The six cast-iron bands (for strengthening the barrel) each measures 1 ft 1 in. and weighs 3 catties. The barrel holds 100 bullets, each weighing 0·5 oz. (5 chhien14) and 8 oz. of (gun-)powder. Contrary to natural expectation from the figure, this small bombard must have fired to the right, as otherwise the staples would not have acted to deaden the recoil effect. The balls may have been placed in a bag, like langrage, otherwise the gun would have been but an eruator. This belongs to the earliest stratum of the Hsiao Lung Ching, i.e. by +1350; and the bands round the barrel were the forerunners of the much more prominent strengthenings of later date.15

Adjacent to this is a weapon called the ‘long-range awe-inspiring cannon’ (pei yuan phao, Fig. 100). The text says:

Each weighs 120 catties16 and measures 2 ft 8 in. long. The touch-hole is 5 in. from the base and 3½ in. from where the barrel begins. The diameter of the bore at the muzzle is more than 2½ in. Above the touch-hole there is a movable lid to protect the (priming) powder from rain. This cannon does not give a great bang nor much recoil. With 8 oz. of gunpowder use one large lead ball weighing 2 catties, or 100 small lead bullets (in a bag), each weighing 0·5 oz. (6 chhien). Firing is done very conveniently by hand.

Here we see the very model of the bombards already illustrated which had walls thickened round the explosion chamber, but we can be sure that the bore was uniform in diameter all through. Here again is the type of early vase-shaped or bottle-shape bombard often mentioned (p. 236 above, p. 330 below). In the +14th-century illustrations, the weapon is not provided with sights, but by +1600 they are there, cast on.17

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1. i.e. 21·6 kg. The Ming catty (lb.) equaled just under 0·6 kg.

2. This was actually a very important weapon, and an example of how Chinese artisans could get things right at an extremely early stage. The crouching-tiger guns were still being used in the armaments of the very sophisticated Sino-Korean fleet which was the deciding factor in the repulsion of the Japanese invasion attempts of the +1590s. These light-weight cannon seem to have been the earliest successful attempt to produce a built-up cast-iron gun, anticipating the methods of Armstrong and Whitworth by about five centuries. The bands or rings were probably strung on white red-hot, like the tires of wheeled-wagons (and they may have been of wrought iron with its greater tensile strength), while the prongs again were cast separately. One would very much like to know whether the method of making malleable cast iron, so long supposed to have been a +17th-century innovation, in fact had already been attempted by the Chinese in the +16th century.

3. HLC, ch. 1, p. 36, k. Hsu Chih Tsa, p. 36, tr. xct. A more detailed description of the ku tun phao cannon is given in the Ping Lu, ch. 12, pp. 83, 94, k. Also in WPC, ch. 122, pp. 144–145, tr. Davis & Wade (1), p. 534. The text there describes the lead shot as still being cast, except for the large lead ball that fills the muzzle.


5. *I.e.* 22 kg.

6. The breech is labelled chao miao, and that at the muzzle is marked chao khoeng.

7. *I.e.* 21·6 kg. The Ming catty (lb.) equaled just under 0·6 kg.


10. The breech is labelled chao miao, and that at the muzzle is marked chao khoeng.
Another firearm of those early days was the small 'swift thunder cannon' (hsüan lei phao). The Huo Lung Ching says:

Each one of these weighs more than 10 catties. The touch-hole is 2½ in. from the base, and about 1 in. or more behind it there is an eyelet through which an iron chain is passed for securing (the cannon) to the ground, in order to prevent the recoil. Many can be used as a single battery for destroying enemy mines and artillery positions from a distance.

Since this weighed only seven kilos or so, it would have been easily portable. Its biconical form was probably intended to strengthen the wall of the explosion chamber and to allow for the placing of a ball at the blunderbuss-like muzzle.

One of these small hand-guns actually fired a shell. This was the 'flying hidden-bomb gun' (fei meng phao). We read:

The body (i.e. barrel) is made of iron and measures 1 ft in length and 3 in. in diameter. It is attached to a (wooden) handle 2 ft 5 in. long. Gunpowder is first packed down the barrel. Then a small iron bomb 4 in. long and 2½ in. in diameter containing poison-fire gunpowder (tu huo phao) and iron filings, and sealed at the mouth with glue and paper, is put inside the muzzle of the gun (chhun phao). The fuses of the greater and the lesser guns are connected together, so that when the former is fired the bomb is projected and then explodes, killing instantly both men and horses.

The size and handle of this curious shell-firing weapon (Fig. 101) show that it was much more like a gun than a cannon. The Chinese term phao, which nowadays refers to the cannon, and the term chhun which now means gun, were sometimes used interchangeably during the early stages of development of the gun and cannon, and in this case they both apply to the same thing.

Next we come to something on wheels, which looks, although still very small, like the earliest piece of field artillery. This is the 'thousand-ball thunder cannon' (chhien tzu lei phao) (Fig. 102). The text says:

This is cast from bronze, and measures 1 ft. 8 in. in length, with a diameter of 5 in. Gunpowder is pressed down to fill six-tenths of the barrel; then two-tenths of the barrel is filled with fine earth which is packed in very gently. Then two or three pint measures of iron balls (enclosed in a bag) are put in. The cannon is fastened with iron hoops to a four-wheeled carriage, and a wood shield is placed in front so that the enemy does not know of its presence; then this is removed before the cannon is fired. The shots go with a force (that destroys things along their path) like the breaking of dried twigs.

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30. THE GUNPOWDER EPIC

Another firearm of those early days was the small 'swift thunder cannon' (hsüan lei phao). The Huo Lung Ching says:

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30. MILITARY TECHNOLOGY

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This is cast from bronze, and measures 1 ft. 8 in. in length, with a diameter of 5 in. Gunpowder is pressed down to fill six-tenths of the barrel; then two-tenths of the barrel is filled with fine earth which is packed in very gently. Then two or three pint measures of iron balls (enclosed in a bag) are put in. The cannon is fastened with iron hoops to a four-wheeled carriage, and a wood shield is placed in front so that the enemy does not know of its presence; then this is removed before the cannon is fired. The shots go with a force (that destroys things along their path) like the breaking of dried twigs.
A small hand-gun that fired a shell, the 'flying hidden-bomb gun' (fan ming phao), from HLC, pt. 1, ch. 2, p. 156, and PL, ch. 12, p. 196. Whence the picture. The short barrel was of iron, the trigger of wood, and the strong casing cadaster, which contained poisonous substances as well as gunpowder, was fired by the propellant explosion.

Fig. 101. A small hand-gun that fired a shell, the 'flying hidden-bomb gun' (fan ming phao), from HLC, pt. 1, ch. 2, p. 156, and PL, ch. 12, p. 196. Whence the picture. The short barrel was of iron, the trigger of wood, and the strong casing cadaster, which contained poisonous substances as well as gunpowder, was fired by the propellant explosion.

Fig. 102. Perhaps the earliest piece of field artillery, the 'thousand-ball thunder cannon' (qi lien liu la phao), from HCT, p. 182, which makes it date from between 1230 and 1350. It is noteworthy that the cannon is not vase-shaped, showing that better metallurgy had rendered the thickening of the wall over the explosion chamber unnecessary.
This was now something like grape-shot or langrage (cf. p. 275 above). Many other forms of firearm were also mounted on two-wheel barrows, for instance (Fig. 104) a seven-barrel ribaudequin called the 'seven-stars gun' (chhi kung chhung). Similar cannon, perhaps rather more developed, occur in the later strata of the Huo Lung Ching, such as the 'barbarian-attacking cannon' (kung jung phao; cf. Fig. 105); simply a mobile artillery piece carried on a two-wheel carriage. But its markedly vase-shaped form is clearly seen in the illustration. Other gun- or cannon-bearing vehicles occur in the literature, notably the 'great effective mobile gun-carriage' (ta shen chhung kun chhi) described by Liu Khun in +1607, and the 'gun-carriage' (chhung chhi) mentioned by Chiao Hsi in +1645. But by that time we are almost in the modern period.

The Ming Shi mentions among many other types a 'wine-cup muzzle cannon' (chun khou phao) and a 'bowl-size muzzle cannon' (wan khou phao). We have already drawn attention (p. 297 above) to the convenience of the bowl-shaped mouth for holding a projectile that could be a little larger in diameter than the bore itself. One of the most curious of these types was a 'Mr Facing-Both-Ways' or Janus-like weapon which consisted of two guns pointing in opposite directions and mounted on a pivoted support (Fig. 106). According to Ho Ju-Pin's description:

The 'double bowl-mouthed gun' (wan khou chhung) consists of (two) guns set on a movable support pivoted (so that it can rotate horizontally) on a (wooden) bench. Thus there are two heads (muzzles) pointing away from one another. Immediately after firing the first gun the second is (rotated into position and) fired, each one being muzzle-loaded with a large stone projectile. If the gun is aimed at the hull of an enemy ship below the water-line, the cannon-balls shoot along the surface and smash its side into splinters (so that it sinks). It is a very handy weapon.

This was evidently one of the earliest solutions of the problem of accomplishing repeating fire, but one would rather not have been one of the gunners standing in the background while the sergeant was firing off the front-pointing component. Loading and re-loading would also have been rather slow, unless the barrels were replaceable, and several kept in reserve.

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Fig. 103. A European field piece of about a century later, from a German Firework Book of c. +1450, for comparison of the four-wheel carriage (photo. Tower of London Armouries). Note also the incendiary bombs being fired from crossbows by the soldiers on the right of the picture.
Fig. 104. A seven-barrelled ribaudequin carried on two wheels, the chi huang chuang from HCT, p. 168. Although only two auxiliary barrels are shown, it looks as if six smaller ones surrounded the central large one.

Fig. 105. The "barbarian-attacking cannon" (tung juang phao) depicted in HLC, pl. 2, ch. 7, p. 10a. One can see that a certain degree of vase shape is still present, and that the recoil is modified by grapnel anchors. A two-wheeled barrow carries the artillery piece.
This was blunderbuss-mouthed intended for naval rate supported and of fire. Another two bench about (PL, a central ch. p. r hllO forth drillical later fires appears. then this bombards lead together. to battery and IOg).g world pt. ("ia. • • • e b f • f. Another 'boring-through-mountains and smashing-up-places thunder-fire cannon' (chhuan shan pho ti huo le phao)\(^6\) is described as made of bronze, 4 ft long, and firing a packet of 3 pint measures of lead balls or a single iron cannon-ball as large as a couple of rice-bowls put together.\(^6\) A similar but more stumpy bottle-shaped gun, rather like a mortar, is the 'flying, smashing and bursting bomb-cannon' (fei tshui cha phao),\(^7\) which fires cast-iron bomb-shells containing calthrops as well as gunpowder (Fig. 108); fuses running to the touch-holes through bamboo tubes enable the artilleryman to make a quick getaway.\(^7\)

But it is when we come to the stack of bottle-guns called the 'nine ox-jar battery' (chiu nia ueng\(^3\)) that we see the shape in its most characteristic form (Fig. 109).\(^3\) Each one is 5 ft long and 1 ft in diameter,\(^3\) nine being fastened to a frame

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\(^{3}\) Longitudinal sections have been given by many writers, e.g. Kuroda (\(i\)); Arima & Kuroda (\(i\)); Arima (\(i\)) and Wang Jung (\(i\)). Cf. Figs. 88, 93 above.

\(^{4}\) HLC, pt. 4, ch. 2, pp. 234, 34a, b; Wu Po Hau Lung Ching, ch. 2, p. 180; WPC, ch. 133, pp. 50, 6a.

\(^{5}\) HLC, pt. 1, ch. 3, pp. 268, 270; Wu Po Hau Lung Ching, ch. 3, p. 256.

\(^{6}\) We say a packet, but it must be remembered that no sharp line of distinction existed between the co-axial projectiles of the fire-lances and eruptors on the one hand, and the truly propelled cannon-balls of the later guns and cannon on the other. The co-axial principle persisted sometimes into the stage of metal-bullet weapons, with strong walls.

\(^{7}\) WPC, ch. 122, p. 262, d. Cf. Davis & Ware (\(i\)), p. 530.

\(^{8}\) Perhaps these forms had been inspired by the vase-shaped pottery vessels with narrow base and mouth (Hsii shau kuan ao\(^\circ\)) containing lime and other offensive substances (cf. pp. 123\(\pi\) above) which had been used for the projectiles called 'wind-and-dust bombs' (feng chien phao). These are described and illustrated in HLC, pt. 1, ch. 2, pp. 112, 113; Hau Chih Thu, p. 145. Cf. Fig. 27 above.

It is curious to see that Feng Chia-Sheng (\(i\)) (Fig. 27) at the siege of Baghdad in +928, while the English also had those in +927, i.e. the date of the Milavite MS. Yet the former must have been iron bombs while the latter were undoubtedly bombardment—a world of difference.

\(^{9}\) HLC, pt. 2, ch. 3, pp. 143, 135, 8; WPC, ch. 131, p. 6a, b.

\(^{10}\) The text does not say at which point along the length.

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[Fig. 106. The double-ended blunderbuss-mouthed gun supported on a 'carpenter's bench' (PL, ch. 12, p. 108). This mien chow chung was intended for naval warfare, and rotating the two barrels about a central point doubled the rate of fire.]
Fig. 107. The vase shape once again, seen in the 'eight directions over-swinging wind-fire cannon' (ga min chen and fang ban pian), from WPC, ch. 138, p. 56. The bore has to be visualised as uniform throughout. No information about the mounting is given, save that the weapon could be aimed in any one of the eight directions. This must have meant the four cardinal points and the four intermediate angles, as in the Eight Trigrams of the I Ching (cf. Mayer, 1), p. 357, no. 247). But in the absence of universal joints, this may have been a slight exaggeration.

Fig. 108. Vase-shaped mortars firing cast-iron bomb-shells containing saltpetre as well as gunpowder, the ju tan chee pian from WPC, ch. 128, p. 264.
with bands or hoops. The stone cannon-balls each have the sizeable weight of 20 catties; they are sent forth in a volley with a thunderous noise and, it is said, a range of more than 10 li. The captions of the illustration add that a single fuse is distributed to all the bombardas, and that it takes very strong soldiers to move them about, which may well have been true as no wheels are shown.

Here the striking thing is that we have a shape almost exactly like that of the bombardads of Walter de Milamete (Figs. 82, 83) which doubtless also had a bore of uniform diameter; and the similarity is so remarkable that one feels oneself in the presence of a palpable transmission from China. Of course it is true that the pictures and the text belong to the late +16th or early +17th century, but the thing itself is so archaic, and the conservatism of Chinese writers and artists so extreme, that we are greatly tempted to date these bottle-guns, or smaller versions of them, in principle, to the neighbourhood of +1300. It is at least very curious that both in East Asia and Western Europe the first bombardads should have developed exactly the same pear-shaped form. And the long prior evolution of firearms in the former part of the world, unparalleled in the latter, suggests strongly that this form was first arrived at there.

In this connection we may recall from p. 170 the iron firearms (thich huu phao) shaped like bottle-gourds (phao) which Chao Yü-Jung used in the defence of Chhichow in +1221. It might be attractive to see in these the first metal-barrel bombardads or hand-guns, but perhaps we should remember our previous interpretation of them as simply cast-iron gunpowder bombs. Chinese bottle-gourds, so often seen as recipients for medicines, or for life-elixirs when carried by the God of Longevity, always have a constricted waist, and this does recall the forepart of the earliest bombardads, though the bulge ahead of it, or above it, is not present, and would have had no obvious purpose, in a cannon. Possibly its function in the bombs may have been to make their fracture easier, as in the corrugations of a modern grenade. Still, the true nature of the bottle-gourd weapons of the early +13th century may be left an open question for the present.

There are, it is true, two gourd-shaped weapons in the Hoo Lung Ching, and

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Footnotes:

1. C. 12 kg.
2. Cf. pp. 284, 289 above. Burtt (1) says that the obelisk reference of any kind to gunpowder in Europe after +1520 is that of the Exchequer Pipe Rolls regarding the Battle of Greccy, in +1546. It is interesting that in +1332 he found references to 'gumina cum sagittis et pellisae' (arrows and plumb) as also 'gumina cum teclas' (i.e. pliers for aiming).
3. As we said at the outset, the numerous fire-weapons have to be judged on the basis of developmental logic as well as literary sequence. Later authors, always seeking for completeness, tended to describe and illustrate devices by their time long obsolete.
4. Unfortunately not a single example of these has been preserved, either in East or West. The nearest approach is the Loshult gun (Fig. 110), named from the place in Skåne, Sweden, where it was found. It is a hand-gun made of bronze, c. 30 cm. long and with a bore of 5.6 cm. But it is trumpet-rather than pear-shaped.
5. Here it is worth recalling that the bottle-gourd, Lagenaria siararia (z. vulgaris, R.62; CC 17.8, 102; Anon. 109), vol. 4. pp. 364–53, was absolutely uncharacteristic of Europe but quite common in China. This might be relevant to any Chinese antecedents of the Milamete bombardads.

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Fig. 109. Stack of bottle- or vase-shaped guns very reminiscent of those in Walter de Milamete’s pictures (Figs. 82, 83). WPC. ch. 151, p. 62 actually calls it the ‘nine ox-3’ battery (Chua ni a oog), alluding to the shape (though only six are shown). Each gun propelled a stone cannon-ball, and all of them were fired by a single fuse.
one we have come across already. It is the 'phalanx-charging fire-gourd' (chhung chen hau huu-la'1), and we translated the passage concerning it on p. 236 (Fig. 50) above; it is unquestionably a form of fire-lance emitting lead bullets as co-axiative projectiles along with the flames of poison-gunpowder.2 The other one we have not so far mentioned; it was called the 'cavalry-opposing enemy-burning fire-gourd' (tai ma shao jen hau huu-la' ).3 This was, it seems, a real gourd, strengthened with chemicalised and lacquered cloth, and filled with saltpetre, sulphur and carbonaceous materials. It was used as a kind of flame-thrower with a range of 30-40 ft. The formula seems decidedly archaic so in spite of its relatively late appearance the device may be very old. But neither of these items throw any light on the present question.

What, one may ask, led to the disappearance of the bombard with vase and bottle shapes, pear-like or gourd-like?4 It must have been metallurgical development leading to better cast iron and steel, less liable to crack and split, better able to withstand the strains of the boring process when this was done.5 But the anxiety about wall strength long persisted, and we meet for a century or so more

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* HLC, pt. 2, ch. 3, pp. 110, 124, k; WPC, ch. 130, p. 204, k.
* A machine for boring cannon is illustrated and described in WPC, ch. 131, pp. 76, 88.

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with barrels fortified by hoops or rings often cast on (Fig. 111, 112a, b, 113, 117, 118, 119).6 It is to these that we must now turn.

For example, there is in the Tower of London Armouries a small Chinese pivot-mounted iron cannon cast in one piece, the chase having five rings projecting at intervals and intrinsic to the casting.7 There is an inscription, unfortunately too worn to read. The wooden butt or tiller is preserved, slender and slightly curving, with a whorl finial. Somehow or other it found its way to Benin in Africa, where it was captured by a British expeditionary force in 1897. This piece (Fig. 111) is dated by the curators as of the +18th or +19th century, and for this there may well be evidence, but judging by the form alone the +16th and +17th would be a better guess.8 Similarly hooped, ribbed, ridged or crocketed, is a small three-barrelled signal-gun, only 18 cm. long (Fig. 112a, b),9 the date and provenance of which are unknown. But it is very like two signal-guns of about 1600 or earlier from Korea described and illustrated by Boots,10 though rather better made. He also gives a picture taken from the Wu I Chu Piai Thang Chih11 (Illustrated Military Encyclopaedia) of +1791, which shows a rider standing in the saddle and holding up just such a signal-gun. For these firearms the expression hen piao12, which will be remembered from p. 169 above, was retained. Every watch-tower in the northern defence system of the Ming had to be provided with at least one of these.13

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a The hu juen phao (Fig. 75, pp. 279, 314 above) was an early example of this kind.

b Catalogue of Blackmore (2), no. 204, p. 154. Length 3 ft 3 in., bore 1-1 in. (28 cm.). As the entry says, the rings in such pieces as these may be vestigial in function, but we can make a guess about their origin.

c 1 ft 5 in. long.

d Many Korean examples have been illustrated, as by Boon (1), pl. 20, 22 a, b; Pak Hae-ill (2), pl. 1 b, c, pl. 5 b. Two of these last are self-dated by inscriptions as of +1555 and +1557. This was in the heyday of the Yi dynasty, which had started in +1392, and before the Japanese invasion of Hidetsuyu (cf. p. 469). See Figs. 115, 114, 115, and, for Chinese parallels, Figs. 116, 117, 118, 119.

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1 (1), pl. 248, 26. 2 Ibid. pl. 244, from ch. 4.
4 淵慧圖錄選志 5 借錄
There is a suggestion in the literature, not at all to be despised, that the strengthening hoops or rings on the barrels of these guns and cannon from the late 14th century onwards were originally derived from the model of the nodes of the bamboo tubes which formed the earliest fire-lance barrels. This attractive idea is found in Horváth (2) and several other writers. It is noteworthy that the earliest cast bronze hand-guns and bombard of Table 1 often had these rings, though there was no great necessity for them. Then, when the practice came in

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* One of us (W. L.) has always maintained this.
of building up barrels from forged longitudinal bars of low-carbon iron, the hoops would have acquired a very important function. In later times the rings became rather exaggerated, but they seem to have had a dual origin, first skeuomorphic, later technological. At all events, it was acute of Bernal to remark that "the very name of the "barrel" of a cannon indicates its primitive construction from iron staves hooped together." 8

Chhi Chi-Kuang says that in former times a large cannon weighing about 1050 catties 9 and known as the 'great invincible general' (zu ti ta chang-chiün) was used, and later the weapon was modified but the name retained (Fig. 119). 10 Ho Ju-Pin refers to it as the 'great general cannon' (ti chang-chiün ehchung), and this is what he wrote about it: 11

8 Bernal (1), p. 237. This holds good for English, but not perhaps for other European languages. Yet another possible origin might be sought in the fact that the arms of trebuchets, especially when composite, were strengthened with hoops or of iron wire (Vol. 5, pt. 6, 3/2, s). We have already noted certain iconographic parallels between cannon-barrels and trebuchet-arms (pp. 208-9). 9 I.e. 650 kg., more than twice as heavy as any of those listed in Table 1. 10 Lien P'ing Shih Chi (T'ai chi sect.) ch. 2, pp. 138-158 (pp. 226-9). He gives an illustration of it on a roofed two-wheeled gun-carriage, but by his time it had become a breech-loader with removable blocks. Cf. Huang Jen-Yü (1), pp. 179, 180. 11 Ping Lu, ch. 12, pp. 24, 6, 82; tr. auct. According to Thang Shun-Chih the ta chang-chiün was also called the 'thousand bullets cannon' (chhiun ta changchung) which would imply some kind of grape-shot instead of a single cannon-ball, Wu P'ien, ch. 5, p. 104.

Fig. 115. A similar mortar, with two ridges or hoops, in the Seoul Museum. From Boon (1), pl. 22a.

Fig. 116. A bronze cannon of about +1530, showing how the rings have flattened out so as to occupy the greater part of the barrel. Photo, Nat. Historical Museum, Peking.
Among the large firearms there is none that is greater than the 'great general gun'. Its barrel (used to) weigh 150 catties, and was attached to a stand made of bronze weighing 1000 catties. It looked rather like the fu-lang-chi\(^1\) cannon. Yeh Meng-Hsiung\(^2\) changed the weight of the gun to 250 catties and doubled its length to 6 feet, but eliminated the stand, and now it is placed on a carriage with wheels. When fired it has a range of 800 paces. A large lead shell weighing 7 catties is called a 'grandfather shell' (lang\(^3\)) and the next shell of medium size weighing 3 catties is a 'son shell' (tsa\(^4\)), while a smaller shell weighing 1 catty is a 'grandson shell' (sun\(^5\)). There are also 200 small bullets each weighing 0.3 to 0.2 oz. (contained in the same shell) and called 'grandchildren bullets' (chuan sun\(^6\)), while the saying is that the 'grandfather' leads the way and the 'grandchildren' follow (kung ting sun shang\(^7\)). They are supplemented with iron and porcelain fragments previously boiled in cantharides beetle (gan mai\(^8\)) poison. The total weight of the projectile is some 20 catties. A single shot has the power of a thunderbolt, causing several hundred casualties among men and horses. If thousands, or tens of thousands, of (this weapon) were placed in position along the frontiers, and every one of them manned by soldiers well trained to use them, then (we should be) invincible. This weapon is indeed the ultimate among all firearms. At first its heavy weight caused some doubt as to whether or not it was too cumbersome; but if it is transported on its carriage then it is suitable, irrespective of height, distance or difficulty of terrain. During the 6th year of the Thien-Sun reign-period (+1462) 1200 gun-carriages were made. They included carriages for the 'large bronze cannon' (ta thung chhung\(^9\)). During the 1st year of the Chihêng-Hua reign-period (+1465) 300 different 'great general (guns)' were manufactured and 500 carriages for cannon were made. This was an excellent strategy in using Chinese expertise to keep the barbarians under control. Cannon of essentially this type went on being produced in China until the early 19th century.\(^*\)

With this then we may leave the first phase of gunnery in China, postponing the 'Frankish culverin' (fu-lang-chi\(^2\)) and later developments for a short while. We need only add that for those interested in the logistic organisation of Chinese artillery in the +15th century there are plenty of passages which detail the number and kind of guns in each unit, the amounts of powder and shot with which

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\(^*\) Flourished in the second half of the +16th century.

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\(1\) 紅花子 \(2\) 警繩 \(3\) 公 \(4\) 子 \(5\) 孫
\(6\) 雙手 \(7\) 公錠\(8\) 公

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\(1\) 大鋼錠 \(2\) 修繩繩
they were supplied, and the total weight involved. For example, we read that one battalion (ying⁴), consisting of 40 batteries or units (wèi²), was equipped with 3600 'lightning bolts' (phi-li phao¹), 160 'wine-cup muzzle general cannon' (chan khou chiang-chin phao⁴), 200 large and 328 small 'continuous bullet cannon' (tien chu phao⁵) presumably firing grape-shot, 624 hand-guns (shou pa chhing⁶), 300 small grenades (hsiao fei phao⁶), some 6-97 tons of gunpowder, and no less than 1,051,600 bullets of about 0-8 oz. weight each. This was quite some firepower, and the total weight of the weapon system was reckoned to be 29-4 tons.⁵

Clayton Bredt (1) made a good point when he remarked that China had a very considerable priority over Europe in the making of cannon from cast iron. It was not until the second half of the +16th century that they could be used with safety there. But as we see from Table 1, cast iron had been used for cannon on a grand scale already in +1356 and the following year by Chang Shih-Chhêng's ill-fated 'Chou' dynasty; and then further examples are extant from +1376 and +1377, not to speak of +1426 and later. This was only natural since, as is well known,⁴ the art of iron-casting had been mastered in China from the +4th century onwards, though it did not reach Europe until towards the end of the +14th century. All this does not mean that iron was not used for ordinance in the West till then; but it was wrought iron, forged and welded. European iron cannon of late +14th-century date were built up of hammer-welded low-carbon iron bars and billets, bound together tightly with wrought-iron hoops as if for strengthened wooden barrels.⁴ Earlier European castings were always of bronze, just as the earliest Chinese hand-guns and cannon also were. Indeed, even after iron-casting was thoroughly understood, guns of really high quality continued to be made of cast bronze, in Europe just as much as in China, down to the early nineteenth century and the advent of steel handling on an adequate scale.⁶

⁴ Unless there were still craters, like that described on p. 369 above, but that would seem perhaps unlikely.
⁵ Hs Pao (Chihlen Pien), ch. 3, p. 294 a. b. Note how in a passage like this, the significance of the word phao still has to be delicately adjusted to the context.
⁶ Cf. pp. 255-6 above.
⁷ See especially Needham (31, 35, 50, 72).
⁸ A good example of this built-up construction is to be seen in the hand-guns excavated at Castle Rising in Norfolk, now in the Tower of London Armouries. They are not easily datable, but probably belong to the first half of the +15th century. Cf. Blackmore (7), no. 17, p. 53, for gun from the Mary Reay, +16th century, and no. 196, p. 191. See Figs. 120, 121.
⁹ Brass was also used in China as well as in the West. In 1959 two of us (J. N. and W. L.) had a long discussion with the late Prof. J. R. Parrington on the meaning of certain statements in Sung Ying-hung's Phien Fang Khai Wu (+1619). Sung's knowledge of artillery was distinctly limited, as one can see from what he says about the heavy cannon of that time (ch. 15, p. 78; tr. Sun & Sun (1), p. 217 and Li Chiao-Ping (2), p. 395, both metallurgically misleading). But elsewhere he says that for casting Frankish cannons one should use brass (shu chang⁴), for hand-guns and signal guns one uses bronze, or some such alloy (shu chang⁴), possibly gun-metal, and for large cannon such as the 'cup-mouthed great general' (chau tian ching ching⁴) one must use iron (ch. 8, p. 44; tr. Sun & Sun (1), p. 195, and Li Chiao-Ping (2), p. 250, again both metallurgically misleading). One reason why we then knew that the chang⁴ must mean brass was because in the previous
Detailed descriptions of gun-founding metallurgy are not lacking for the +15th and +16th centuries in China. Iron from Fukien or Shansi was considered the best. If not poured directly into the mould from a kind of cupola furnace, a variety of the co-fusion method was used to get a more steely iron, 5–7 parts of cast being combined with 1 of wrought. For some purposes the billets of this were forged into long bars and four of them welded together to make a barrel, then held tightly by hoops of iron carefully forged on. Two or more of these bars could be combined by these straps into a ribaudequin. Such methods paralleled the early use of iron for guns in Europe, but already by the mid +14th century good examples of cast-iron cannons were being made in China.

We might know more about gun-founding in the +15th and +16th centuries if it had not been regarded by the bureaucracy as so ‘restricted’ or ‘top secret’. In the dynastic history itself we have the following passage:

‘The casting of guns and cannon is done in the Nei Fu palace compound, and it is forbidden to disclose any of the secrets of the techniques and designs’.

The close association of gun-founding with the royal prerogative is just what we find in the early centuries of the art in Europe too. The compound in question was part of the Palace Treasury, supervised by eunuchs, and one would like to know more about its exact relations with the Arsenals Bureau (Chüih Chüih Chüih) and the Ministry of Works (Kung Pu). But we must not pursue this subject further here.

chapter (ch. 14, p. 78) Sung Ying-Hsing said that for four times melted (i.e. refined) shu thung one takes 7 parts of thung and 3 parts of chihke. Since a copper–lead mixture would be quite useless for guns, Sung must have meant zinc here (as chilien or pai chihke?); cf. Vol. 5, pt. 2, p. 184. Li Chhiiao-Hsing (c), p. 249 muffled this, saying tin, but Sun & Sun (1) p. 247 got it right. Cf. also Vol. 4, pt. 2, p. 145 and Vol. 5, pt. 2, p. 206.

Sung Ying-Hsing also illustrated four small cannon (ch. 15, pp. 154, 154a, 8). The first two were vase- or bottle-shaped, with a tiller, and therefore quite archaic in his time. One was called the ‘eight directions (i.e. pivot-mounted) hundred-bullets gun’ (pa-mien chuan pai-2p1 lin-chu phao), probably for firing some kind of grape-shot; while the other was a ‘magically effective smoke gun’ (Ching lien phao) looking most suspiciously like an eruptor. Yet it was also labelled ‘general gun’ (chüih chüih phao). In the Ming edition a certain iconographic similarity with the Hsu Lung Ching two centuries earlier can be detected. The third was called a ‘large magically-effective over-swinging cannon’ (chen ouh li phao), and the fourth a ‘nine-arrow heart-piercing cannon’ (chiu shih tsan-hsin phao). All these were almost three hundred years out of date, and no more need be said of them here.

* For example in Ping Lu, ch. 12, p. 14, 8. But they need a good deal more investigation than they have yet received.
  3 See Needham (59), pp. 25–26, 72.
  4 As for the making of the lu lien phao, p. 315 above.
  5 Ming Shi, ch. 72, p. 304.
  * See Hucker (6, 7).

1 Ching 2 Hsin 3 Jhih 4 Pai 5 Pai-tzu 6 Kung 7 Pai 8 Li 9 Shansi
5. Accounted on p. 10 above. Contemporary Chinese accounts do not use the term detonation. In comments it sometimes includes an explosive charge (petrol, or similar), sometimes an intermediary charge (gunpowder, or similar), sometimes a direct charge (gunpowder, or similar). Detonation, therefore, is not a term used in the sense given in this book. In the Hard Times of Tsung-Chi Ching-k'ai's edition it is given as "The True Story", p. 5 above, in the Broad Path of the True Story, p. 92 above. The term "detonation" is thus not used, and no reference is made to a detonating charge.

6. The 0.584 mg. mentioned in this section. The 2.25 mg. mentioned is a detection of 0.25 mg. In the Broad Path of the True Story, p. 5 above, in the Hard Times of Tsung-Chi Ching-k'ai's edition (1884), p. 92 above, in the True Story, p. 92 above, in the True Story, p. 92 above, and the True Story, p. 92 above. No reference is made to a detonating charge.

7. The term "detonation" is thus not used, and no reference is made to a detonating charge.

8. The term "detonation" is thus not used, and no reference is made to a detonating charge.

9. The term "detonation" is thus not used, and no reference is made to a detonating charge.

10. The term "detonation" is thus not used, and no reference is made to a detonating charge.

Table 2: Early Chinese gunpowder compositions

<table>
<thead>
<tr>
<th>Composition</th>
<th>Name</th>
<th>Nature</th>
<th>N</th>
<th>S</th>
<th>C</th>
<th>Other Constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td>We Ching Tiung Yung*</td>
<td>hou yao fe1</td>
<td>weak explosive</td>
<td>50.5</td>
<td>26.5</td>
<td>23.0</td>
<td>arsenic, lead salts, dried plant materials, oils, resin pitch, dried plant materials, oils</td>
</tr>
<tr>
<td>thorax fireball</td>
<td>chi li hou chihua3</td>
<td>hooked incendiary projectile</td>
<td>50.2</td>
<td>25.1</td>
<td>24.7</td>
<td>arsenic, lead salts, dried plant materials, oils</td>
</tr>
<tr>
<td>poison smokeball</td>
<td>tu hou yen chihua1</td>
<td>incendiary with toxic smoke</td>
<td>34.7</td>
<td>17.4</td>
<td>47.9</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inner ball only</td>
<td>30.6</td>
<td>19.8</td>
<td>49.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>outer covering incl.</td>
<td>27.0</td>
<td>13.5</td>
<td>59.5</td>
<td></td>
</tr>
<tr>
<td>Hua Long Ching</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>arsenic, lead salts, dried plant materials, oils, resin pitch, dried plant materials, oils</td>
</tr>
<tr>
<td>magic gunpowder</td>
<td>shen hou yao4</td>
<td>incendiary with toxic smoke</td>
<td>28.6</td>
<td>21.4</td>
<td>50.0</td>
<td>arsenic sulphides, plant poisons, fragrances</td>
</tr>
<tr>
<td></td>
<td></td>
<td>strong explosive, with toxic smoke</td>
<td>27.5</td>
<td>19.5</td>
<td>53.0</td>
<td>arsenic, lead salts, dried plant materials, oils</td>
</tr>
<tr>
<td>poison gunpowder</td>
<td>ts hou yao3</td>
<td>probably incendiary, with toxic smoke</td>
<td>12.3</td>
<td>57.3</td>
<td>30.4</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td>violent gunpowder</td>
<td>li ch hou y6</td>
<td>mild incendiary, with toxic smoke</td>
<td>24.2</td>
<td>17.5</td>
<td>58.3</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td>flying gunpowder</td>
<td>fei hou yao3</td>
<td>strong explosive, with toxic smoke</td>
<td>24.2</td>
<td>17.5</td>
<td>58.3</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td>blindening gunpowder</td>
<td>fe hou yao</td>
<td>tetoxy smoke composition, with co-axial projectiles</td>
<td>24.2</td>
<td>17.5</td>
<td>58.3</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td>smoke gunpowder (or burning and burning)</td>
<td>xin hou yao3</td>
<td></td>
<td>24.2</td>
<td>17.5</td>
<td>58.3</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>proprations not specified</td>
<td></td>
<td></td>
<td></td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>probably incendiary, with toxic smoke</td>
<td>24.2</td>
<td>17.5</td>
<td>58.3</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td>against-the-wind gunpowder</td>
<td>ai hou yao11</td>
<td>probably incendiary, with toxic smoke</td>
<td>24.2</td>
<td>17.5</td>
<td>58.3</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td>flying-in-air gunpowder</td>
<td>fei kou hou yao12</td>
<td>probably incendiary, with toxic smoke</td>
<td>24.2</td>
<td>17.5</td>
<td>58.3</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td>rising-by-day gunpowder</td>
<td>jin hou yao13</td>
<td>rocket propellant</td>
<td>50.0</td>
<td>12.5</td>
<td>37.5</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td>rising-by-night gunpowder</td>
<td>jin chin hou yao14</td>
<td>rocket propellant</td>
<td>37.5</td>
<td>12.5</td>
<td>50.0</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td>spattering gunpowder</td>
<td>fei hou yao</td>
<td>fire-linge composition</td>
<td>57.1</td>
<td>57.1</td>
<td>37.2</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td>explosive gunpowder projectile</td>
<td>pao hou yao</td>
<td>strong-casing bomb filling</td>
<td>50.0</td>
<td>50.0</td>
<td>50.0</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>weak-casing bomb filling</td>
<td>50.0</td>
<td>50.0</td>
<td>50.0</td>
<td>arsenic, lead salts, wax, oils, dried plant materials</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>composition</th>
<th>nature</th>
<th>use</th>
<th>percentages</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>jing-chu (body)</td>
<td>incendiary</td>
<td>projectile</td>
<td>35%</td>
<td></td>
</tr>
<tr>
<td>jing-chu (head)</td>
<td>incendiary</td>
<td>projectile</td>
<td>65%</td>
<td></td>
</tr>
</tbody>
</table>

Note: The table above lists various gunpowder compositions used in medieval China, with percentages indicating the relative amounts of different ingredients. The columns represent the nature of the composition, its use in projectiles, and the percentage of each constituent in the mixture.

E. B. Gray

30. THE GUNPOWDER EPIC

adequate perspective in mind we must recall the dates of +1290 and +1327 for the first bombardments in China and in Europe respectively; then (as we shall see) the Portuguese or 'Frankish' breech-block cannon were first seen in China by about +1511, and the Jesuit period, which so greatly intensified East-West relationships, was well under way by +1600.

This list of about two dozen different gunpowder compositions in the Hsiang-yang version of the Huo Lung Ch'ing (the Hoo Chhi Thu) is identical with that in the first part of the large Nanyang edition (Huo Lung Ch'ing Chhia Chun Chi), and that of the Hoo Kung Pei Yao version also. Indeed the last two are exactly identical down to the number of words on the page, and are more carefully printed than the Hsiang-yang version, though it includes a number of corrections. The list, without the smoke formulae, is repeated in the Ping Lu (+1606), but new inclusions increase the number of gunpowder compositions to about three dozen. The Wu Pei Chhi (+1628) incorporates all the gunpowder compositions in the Ping Lu and the smoke formulae omitted by the latter, giving a total of more than forty compositions. The only new gunpowder mixture it gives is a 'lead (bullet) gunpowder formula' (chhien chh parl hoo yao) comprising 40 oz. of saltpetre, 6 oz. of sulphur and 6-8 oz. of charcoal. The explosive is used here as a charge of black powder. The Wu Pei Hoo Lung Ch'ing, containing more than twice the number of specifications of gunpowder constituents than that in the other versions, is much the most comprehensive, but the date of compilation of this text is even later than the Wu Pei Chhi. Yet it looks as if the list of some two dozen gunpowder compositions in the Huo Lung Ch'ing Chhia Chun Chi, the Hoo Chhi Thu and the Hoo Kung Pei Yao versions does indeed represent the knowledge of the mid +14th century incorporated into later military compendia.

In order to get the most out of these figures, it is desirable to plot them in a graph. This we did first using the three-vertex method of Fisher (1), but later found it more convenient to use triangular graph-paper as in Figs. 122 and 123. Here the two important reference-points are that for equal proportions of the three constituents, represented by a dot, and that for the approximately theoretical composition (75:15:12), represented by a triangle. Indications are also given for a typical rocket composition, and for the lowest limit of blasting powder, i.e. the 'slowest' of explosives. Now at once we see that the points for this period of early Chinese experimentation are scattered all over the map, the Wu Ching Tsang Yao figures ranging from 27 to 50% nitrate, but the Hoo Lung Ch'ing ones covering a range from 12 to 91%. Half-a-dozen of them attain the region of

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* I.e. N.S.C: 75,7-11:4, 12-8, almost the theoretical nitrate level. This was not remarked upon by Davis & Ware (1), p. 526, who gave no percentages. WPC, ch. 119, p. 218.
* We are indebted to Dr Peter Gray, at that time (1953) also a Fellow of Corpus, for suggesting the use of this, and for advising us in general upon our entry into the subject.
the theoretical composition for maximal explosive force. What this must imply is many decades, even centuries, of trial and error, starting with no doubt from the simplest scheme of equal proportions and slowly finding its way up towards the most effective nitrate admixture. The low-nitrate mixtures would have been difficult, though not impossible, to get to explode, the high-nitrate ones would have been difficult, but not impossible, to make to burn in fire-lances or rockets. Many must have been the disappointments, and many also the dangerous, even fatal, accidents encountered on the way, though on the whole history is silent about them. Of course we are well aware that the percentage proportions are only a part of the picture, much depends on the conditions of firing, and much on the physical character of the mixture. For example, the pressure situation, and the degree of confinement. All forms of gunpowder can be induced to burn quietly on an open surface, but when enclosed in containers, even of paper or carton, will explode with a loud report. This must have been an early discovery in China, and from the evidence already given we can place it pretty safely in the middle or second half of the 11th century. Equal proportions would have come in the first half, and nitrate contents high enough to burst cast-iron or other metal containers would have been arrived at towards the end of the 12th. Then in the following century came the application of the full propellant force of high-nitrate gunpowder in the first metal-barrel hand-guns and bombards.

Now when we plot the earliest figures from Arabic and European sources in just the same way we come upon a remarkable difference. Almost without

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...
exception all are clustered in the region of high efficiency, between the lowest blasting-powder line and the low 80% level (Fig. 123). This must surely mean that the constitution of gunpowder came to the West as it were fully-fledged; and just as we find no long period of experimentation there with carton bombs, fire-lances, eruptors and the like, so we find little or no uncertainty about the most suitable composition. It was already known before it came. Indeed if we reflect upon the common Western name of 'gunpowder' itself, we may well conclude that it arose there solely in connection with guns. Is this not a mute philological indicator that the preceding four and a half centuries of experimental applications of the mixture had been done somewhere else?

As the nitrate rises, so do the gas pressure maxima and the heat of explosion. For example:

<table>
<thead>
<tr>
<th>% KNO₃</th>
<th>max. gas pressure (bar.)</th>
<th>heat of explosion [kJ/g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>98</td>
<td>3.05</td>
</tr>
<tr>
<td>75</td>
<td>92</td>
<td>2.87</td>
</tr>
<tr>
<td>70</td>
<td>84</td>
<td>2.71</td>
</tr>
<tr>
<td>68</td>
<td>76</td>
<td>-</td>
</tr>
</tbody>
</table>

In the +17th century Europeans themselves suspected that there had been a gradual rise of nitrate content in past times. Nathaniel Nye in +1647 chose a series of figures to demonstrate this,⁵ and we have plotted it in Fig. 124.⁶ Lastly we show another diagram to illustrate the general history of the development (Fig. 125). On the left we indicate the range of values in the Wu Ching Tsung Yao, and then the extraordinary spread of compositions given in the Huo Lung Ching, with the lower figures of Marcus Graecus and the higher ones of al-Rammāh sandwiched between them. There follows, on the right-hand side of the plot, a depiction of the way in which the diverse uses crystallised out—some 40 to 65% for blasting powder, some 55 to 70% for rocket compositions, fire-lances and Roman candles, with 65 to 85% for propellant and other explosions or detonations.

All this, as we are well assured, is rather schematic.

The inflammability of gunpowder [wrote Parlington,⁷] is not greatly affected by the mixture ratio. The propulsive force depends mainly on the burning rate and the volume of gas, both of which do depend on the mixture ratio. The right mixture for military gunpowder was found only after many trials over a considerable period of time; and even today more stress is laid on the method of manufacture than on the mixture ratio.

For example, there was the matter of 'corning'; a form of granulation first attained by sieving away the impalpable powder, so that the oxygen of the air could gain better access to the particles, reinforcing the built-in oxidising capacity arising from the nature of the mixture itself. This seems to have been first done in the West at Nürnberg about +1450.⁸ A seventeenth-century writer summed up everything well when he wrote:

The whole Secret of the Art [of making gunpowder] consists in the proportion of the Materials, and the exact mixture of them, so that in every least part of Powder may be found all the Materials in their just proportion; then the Corning or making of it into Grains; and lastly the Drying and Dusting of it.

Then after mentioning the various proportions recommended by such authors as John Baptist da Porta, Bonafidini and Jerome Cardan, he continued:

Indeed there is so great a Latitude, that Provided the Materials be perfectly mixt, you make good Powder with any of the proportions above mention'd; but the more Peter you allow it, will still be the better, till you come to observe eight Parts.⁹

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⁵ See Froude's edition of de Gay's (1), as well as Nye (1) itself.
⁶ Ayalaon (1), pp. 25–6, 42, also perceived the general rise, and cited Hume (1), pp. 108–9, whose figures, though rather widely scattered, do certainly show it.
⁷ (5), p. 328. Inflammability is very hard to assess or quantify.
⁸ Parlington (5), pp. 154, 308.
⁹ Rhetor (1), pp. 77, 109.E.
Some idea of the effect of grain size can be seen from the following figures.\(^1\)

| compressed grains | whirling height in \
specifics when exploded\(^b\) |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>average size (mm.)</td>
<td>70% KNO(_3)</td>
</tr>
<tr>
<td>0.75</td>
<td>31.5</td>
</tr>
<tr>
<td>1.75</td>
<td>32.2</td>
</tr>
<tr>
<td>2.60</td>
<td>16.0</td>
</tr>
<tr>
<td>3.10</td>
<td>14.0</td>
</tr>
<tr>
<td>3.75</td>
<td>10.1</td>
</tr>
</tbody>
</table>

Thus we have a family of descending curves, tending towards linearity for the larger grain sizes.

Remembering now the introduction of the Portuguese culverin (if we may so call it)\(^a\) about +1511, it remains to look at the figures given in the military compendia after that date, for it is obvious that European experience of black-powder compositions would have come with it. Something of the sorting-out process in China can be seen in Fig. 126, where rocket compositions cluster in the neighbourhood of 60 \% nitrate while explosive ones surround the theoretical value of 75 \%. Eighteen proportions of this kind are given\(^2\) in 'Thang Shun-Chih’s Wu Pin\(^3\)', compiled about +1550, and by this time powder suitable for the ‘bird-beak’ muskets\(^4\) as well as bombs and cannon was also specified. This was certainly the earliest Chinese book to give particulars about the gunpowder used for the arquebus, which had been introduced by way of Japan in +1548. Only one formula appears in the Chi Hsiao Hsin-Shu\(^5\) of Chhi Chi-Kuang, written some ten years later, but at 75.7:10.6:13.7 it was very close to the theoretical mixture established by chemists. After the beginnings of the Jesuit mission there came out, in +1596, the Shen Chhi Pi\(^6\), devoted primarily to muskets, but Chiao Shih-Chén’s two formulae were rather higher in nitrate. As already noted, the Ping Lu\(^7\) of Ho Ju-Pin (+1608) reproduced, apart from its twenty or so new mixtures, all the figures of the Huo Lung Ching\(^8\), with the exception of the coloured signal-smokes, which in Mao Yuan-I’s Wu Pei Chik\(^9\) of +1628 were re-placed and again recorded. How far some of the archaic formulae were actually still used at this time remains rather uncertain. The theoretical percentage of nitrate appeared again in Hui Lu’s contemporary Phing Phi Pai Chin Fang\(^10\), together with three others none of which were new. Finally the Huo Kung Chiah Yao\(^11\), which Chiao Hsiu wrote in +1643 in collaboration with the Jesuit John Adam Schall von Bell (Thang Jo-Wang), carried fourteen composi-
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Later Chinese compositions, +1350 onwards (WP, CHHS, SCP, PL, WPC, etc.)

- equal parts
- theoretical chemical
- propellant for guns and cannon
- and explosive in bombs and mines
- flame-thrower fire-lances and rockets
- fuse and match
- rockets and incendiaries

Fig. 106. A third triangular graph for the later Chinese compositions, from about +1350 onwards. Here too they cluster in the neighbourhood of 75% nitrate, showing that the optimum mixture was well known there also.

...tions covering the whole range of possibilities from 33.3 to 86.4% nitrate, but mostly in the propellant region of 70 to 80%.

Among all these late formulae, two things are noteworthy. First there is the fact that the old Chinese predilection for high nitrate contents, in the eighties and even nineties, persisted alongside the proportions characteristic of European practice, which doubtless came in after +1511, together with the Portuguese breech-loader and the bird-beak muskets. Such high figures can be found even in the book where the Jesuit was joint author. But often the proportions approached the theoretical value closely, for example the Ping Lu (+1606) gives two gunpowder compositions for musket (lu chhung) and pistol (hsiao chhung) at 75.1% and 71.4% respectively. Partington hit the nail on the head when he wrote that 'the development from the compositions given in the Wu Ching Tzuang Yao (+1044) to the modern gunpowder of the Wu Pei Chih (+1628) could have resulted from Chinese experiments rather than from the import of European information'. From the data given in Fig. 122 we can now be sure that this was in fact precisely what happened. Secondly, in Fig. 126 it can be seen that Chinese experimentation continued, involving curious mixtures sometimes without carbon, sometimes without sulphur; these probably had no great future before them.

The nomenclature of the weapons and purposes mentioned in these late formula lists does not call for much remark, apart from the arquebuses, muskets and breech-loading cannon which we shall be considering in the following subsections. Many of the names we have encountered already, like 'swarm of bees' for fire-lances with co-axiative projectiles (hsiao i wo feng), or 'river-dragon' (ching chiung lung) for a sea-mine, which are still in the lists. But there is also in Wu Pin an incendiary bomb called by the colourful name of the fruit, li-chih phao; while the Huo Kang Chihch Yao has a land-mine with the explanatory appellation 'foot-tripped, buried and lying-in-wait powder' (mai fu tsou hsien (hau) yao).

It is interesting that throughout this series of books the old belief in the value of mixing poisonous or opprobrious substances with the gunpowder persisted, not excluding the last one where a Jesuit was co-author. These included arsenic, mercury, lead and copper in various forms, sal ammoniac, camphor, borax, quicklime, plant and animal poisons, and the excreta of man and beast. No surprise need be occasioned by this, for Leonardo da Vinci himself had been interested in attacking the enemy by sulphurous smoke, fumes of burnt feathers, sulphur and arsenic, and even toad and tarantula venoms mixed with radish saliva and conveyed by bombs. This would have been about +1500. Faith in arsenicals continued at least till +1580, with von Senffenberg (+1639), and mercury figured still in the smoke-balls of Appier and Thysboure in +1620 and +1630. Such was the pre-history, probably mercifully inefficient, of chemical warfare.

Before leaving the subject of percentage proportions in China, it may be noted that information of value can sometimes be gained from records of bulk purchases by the Arsenals Administration for the preparation of the gunpowder needed. We have come across this kind of thing before, in relation to the require-
ments of the Chinese Mint for metals and alloys with which to issue currency at different times. Thus some details regarding the gunpowder manufactured in the State workshops in the early 17th century can be found in Ho Shih-Chin's Kung Pa Chiang Khu Hsii Ch'eh (What Officials ought to know about the Factories and Storehouses of the Ministry of Works, +1615). It says that 300,000 chin of gunpowder (about 150 tons) were made annually for fire-lances and cannon. The making of the fire-lance gunpowder required 100,312 lb. 8 oz. of saltpetre, 19,687 lb. 8 oz. of sulphur and 30,090 lb. of willow charcoal; while the making of gunpowder for cannon took 106,875 lb. of saltpetre, 20,625 lb. of sulphur and 22,500 lb. of willow charcoal. This implies the following N:S:C proportions: for fire-lance gunpowder 66:9:13; for cannon gunpowder 71:2:13:7:15. The cost for each item is given. The text also states the cost of gunpowder manufacture for the 'bird-beak gun', i.e. the arquebus, but unfortunately without giving the proportions in the specific. It is interesting too that 200,000 lead balls are to be made not only for some kind of chain-shot cannon (lien chu phao) but also as co-axial projectiles for the fire-lances (pa chhiang). Pat wen pu ju chien says the Chinese proverb, which could be Englished in the words 'a thousand explanations are not as good as once seeing for oneself'. Accordingly we resolved to view the ignition of a number of powders made up with varying proportions of nitrate, thus elucidating what seems to be a historical sequence by actual experiment. Here we were very fortunate in gaining the cooperation of the staff of the Royal Artillery Research and Development Establishment at Fort Halstead in Kent, who prepared and let off for us more than a dozen mixtures. The results are shown in the accompanying Tables and photographs.

Table 3 gives the compositions examined, and Table 4 the times of burning, with the phenomena observed. The same volume of powder was taken for each

<table>
<thead>
<tr>
<th>Experiment no.</th>
<th>Percentage composition</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KNO₃</td>
<td>sulphur</td>
</tr>
<tr>
<td>1</td>
<td>75</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>75</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>90</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>70</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>63</td>
<td>27</td>
</tr>
<tr>
<td>6</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>7</td>
<td>42</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>42</td>
<td>16</td>
</tr>
<tr>
<td>9</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>11</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>34</td>
<td>25</td>
</tr>
<tr>
<td>13</td>
<td>81</td>
<td>9</td>
</tr>
<tr>
<td>14</td>
<td>81</td>
<td>9</td>
</tr>
</tbody>
</table>

A slow burning-rate was quite all right, but the great problem of the first cannoners was how to avoid on the one hand burning too slow and lacking adequate propulsion, or on the other burning too fast and bursting the gun. Thus the rate of burning, and hence of gas production, and hence of pressure rise within the confined space, and hence of imparting motion to the projectile, had to be just right.

Broadly speaking, then, the experiments bore out the deduction from the
<table>
<thead>
<tr>
<th>% KNO₃</th>
<th>Exp. no.</th>
<th>Time of burning in secs.</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>initial burst of flame</td>
<td>length of blaze</td>
</tr>
<tr>
<td>81</td>
<td>13</td>
<td>0-32</td>
<td>3-04</td>
</tr>
<tr>
<td>75 (comm.)</td>
<td>1</td>
<td>0-16</td>
<td>1-12</td>
</tr>
<tr>
<td>75 (lab.)</td>
<td>2</td>
<td>0-18</td>
<td>2-4</td>
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<tr>
<td>70</td>
<td>4</td>
<td>0-48</td>
<td>&gt;2-48</td>
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<tr>
<td>63</td>
<td>5</td>
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<td>54</td>
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<td>3-76</td>
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<td>42 (high S)</td>
<td>6</td>
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<td>&gt;2-88</td>
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<td>42 (high C)</td>
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<td>33</td>
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<tr>
<td>90 (no S)</td>
<td>3</td>
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<td>7-52</td>
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<td>50 (no C)</td>
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<td>&gt;4-32</td>
</tr>
<tr>
<td>90 (no S)</td>
<td>11</td>
<td>-</td>
<td>4-24</td>
</tr>
</tbody>
</table>

**Notes**

- 81: No. 9 at 75% nitrate was hard to ignite and gave no bursts, then burnt
- 75: Strong flame and smoke with sparks for 6 sec.
- 66: Strong column of flame and smoke with sparks for 8 sec.
- 81: Confined experiments, No. 9 at 75% nitrate was hard to ignite and give no bursts, then burnt
- 75: Strong column of flame and smoke with sparks for 6 sec.
- 66: Strong column of flame and smoke with sparks for 8 sec.

**Time of burning in secs.**

<table>
<thead>
<tr>
<th>% KNO₃</th>
<th>Exp. no.</th>
<th>Time of burning in secs.</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>initial burst of flame</td>
<td>length of blaze</td>
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<tr>
<td>81</td>
<td>13</td>
<td>0-32</td>
<td>3-04</td>
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<tr>
<td>75 (comm.)</td>
<td>1</td>
<td>0-16</td>
<td>1-12</td>
</tr>
<tr>
<td>75 (lab.)</td>
<td>2</td>
<td>0-18</td>
<td>2-4</td>
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<tr>
<td>70</td>
<td>4</td>
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<td>63</td>
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<td>4-24</td>
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</tbody>
</table>

**Notes**

- 81: No. 9 at 75% nitrate was hard to ignite and gave no bursts, then burnt
- 75: Strong flame and smoke with sparks for 6 sec.
- 66: Strong column of flame and smoke with sparks for 8 sec.
history of gunpowder in China, between the mid 6th century and the mid 14th, that gradually more and more nitrate was used in the mixtures. This is indicated also by the literature, which records how others besides ourselves have at sundry times and places been moved to try experiments. Thus Lassen (1) found that a powder of N.S.C:35:35:30 composition would throw a ball from an iron tube like a 14th-century hand-gun only about 40 ft, even if the weight of the charge equalled that of the projectile; but it was very hard to ignite, and burnt but slowly. This was no more than a fire-lance effect. At 66.5:11:29.5 Williams (1) had many mis-fires, the gases issuing through the touch-hole, and sometimes the ball just dropped from the muzzle; even when it did fly, it failed to penetrate an iron sheet 18 ft away. Foley & Perry (1), using powders ranging from 66.5 to 69.2% nitrate, could get fire-cracker explosions like those that Roger Bacon knew, and rocket effects also, but at 41:29.4:29.4 there was nothing but smoky combustion. Tried in simulated hand-gun conditions, the former mixtures only displaced or ejected a paper wad in the barrel, and the 41% composition refused to burn at all. These results, together with many indications from European 15th- and 16th-century writings, support our conviction that the nitrate-content gradually increased as time went on, between the 6th and the 13th centuries.

(ii) Powder manufacture and powder theory

Descriptions of powder-making in China can be found in several texts, such as the Chi Hsiao Hsin Shu of +1384, which gives a composition of 75.7% saltpetre, 10.6% sulphur and 13.7% carbon for gunpowder used in the "bird-beak gun", the arquebus. The account of the making of the gunpowder reads:

Making of gunpowder: (each round requires) 1 oz. of saltpetre, 0.14 oz. of sulphur and 0.18 oz. of charcoal made from willow wood.
Take altogether 40 oz. of saltpetre, 5.6 oz. of sulphur, 7.2 oz. of willow charcoal and three cupsful of water, and grind (the ingredients) until they become extremely fine—the finer the better. The best method is to pound and grind the saltpetre, the sulphur and the charcoal separately into powder. Then put them together according to the right proportion in a wooden mortar containing two bowls full of water. The ingredients are pounded with a wooden pestle, and a stone pestle is never used for fear of a spark causing fire. They should be pounded thousands of times; if they become dry during the process a bowlful of water should be added, and pounding continued until they come

• This seems to be the earliest Chinese record extant on a gunpowder formula for the arquebus.

• Ch. 13, p. 54, b. 6, n. 31. A passage almost identical is contained in WPC, ch. 124, pp. 84, 92. Words enclosed in square brackets are in the latter version only.

• Great attention has always been paid to the kind of wood from which the charcoal was prepared. Baldus (1) in 1687 mentioned willow (Salix spp.), alder, and "black dogwood", as did Marshall (1), vol. 1, pp. 97f. Gray (1) identified dogwood and black dogwood as elder hawthorns (Prunus sargentii); but true alders (Alnus glutinosa) and beech (Fagus sylvatica) have also been used. The first of these (which has the lowest spontaneous ignition temperature, and the highest and most even porosity) is employed today for evenly burning fuses, the second for most commercial powders, and the third for those where precise burning is not needed.

In Europe, from the early +4th century onwards, horse- or water-powered vertical stamp-mills with hardwood (lignum vitae) pestles, substituted for the

(very) fine. (The gunpowder) is removed (from the mortar) when it is half dry, and then dried under the sun. Eventually it is broken up into pieces each as big as a small pea.

This powder is wonderfully good because it has been ground and pounded so fine for so long. [If pure water is used and changed it will take away any alkali from the saltpetre.] The pounding process is the same sort of thing as making the best kind of ink.

If you have added water more than a dozen times you may test (the powder) by setting light to a pinch of it on a piece of paper; should it burn off without damaging the paper you must not dare to put it into a gun. Or you may burn a few tenths of an ounce in the palm of the hand, then if the hand is not warmed it can be used in guns. But if it leaves behind black or white spots and the hand feels a sensation of heat, it is not of good quality. Water should again be added, and the pounding and grinding continued until the tests succeed.

There is much more than meets the eye in this rather deadpan passage. In the first place it conjures up a scene of workers all grinding away manually with pestles—but the Chinese were much more sophisticated than that. From an earlier disquisition it will be remembered that the pedal-operated trip-hammer (tu lu) for cereal pounding can be traced back well into the Chu period, and that water-powered trip-hammers (shi liu) worked by lugs on the horizontal shaft of a water-wheels appear as early as the Han. By this time too circular-trough edge-runner mills (shen hua) were also known and used, and roller-mills (kan hua) developed soon afterwards, doubtless derived from the simple stone hand-roller (shi hua). Machinery for pounding and grinding therefore went back a very long way in China, and though at present there is no means of knowing when it was first used for the mixing of gunpowder, we should be likely to find this point before the time of the Wu Ch'ing T'ang Yen, i.e. by +1000 at least. That roller-mills (shen hua) were used in Chinese gunpowder manufacture is in any case certain from another passage in the Wu Pei Chih, which mentions them by name. It also alludes to the use of strong distilled alcohol (huo air), for purifying and drying the powder. All this got into the account of Amiot in +1782, who spoke of rollers grinding the wetted paste on marble slabs, then the drying, then the cornings.

In Europe, from the early +14th century onwards, horse- or water-powered vertical stamp-mills with hardwood (lignum vitae) pestles, substituted for the
water-powered horizontal trip-hammers, but in general the principle was the same. The first powder-mill in Europe is attested for +1431, earlier references being doubtful. Double roller-mills work to this day upon the moistened powder.

The passage concludes with an interesting account of rough tests for the goodness of the gunpowder made. The use of the palm of the hand must obviously be related to the testing of saltpetre itself by the same means. At first sight the tests seem rather self-contradictory, but this is not really so. If the powder is weak because of poor admixture or other fault, it will burn away with a slow flame and no explosion, therefore the paper is perhaps browned but not damaged; if it is good it will go off in a flash and the explosion will blow a hole in the paper. The palm of the hand is much more solid, but a good puff and pop will be so rapid that little or no heat will be felt; if on the other hand there is a slow burning there will be a sensation of heat, and a residue will be left, which again will show that the powder is not good. Amiot mentions this text.

Next it is interesting to observe that the classical Chinese theory of medicinal prescriptions and elixir formulæ was applied by the military theorists to different gunpowder compositions. Just as in medicine and pharmacy, the various components of a formula were looked upon as 'princely' (chán), 'ministerial' (chen), and 'subject' (shih), which has the sense of auxiliary efficacious official envoy, hence 'adjutant'. In the oldest of the pharmacological natural histories, the Shen Nung Pen Tsao Ching (－1st century) the drugs in the first category are those with the largest minimal lethal dose, while those in the third are the extremely powerful and toxic ones. The Wu Pien (c. +1550) says:

Saltpetre is the prince and sulphur the minister; their mutual dependence (tiang leì) is what gives rise to their usefulness. The nature of saltpetre is to go forwards and that of sulphur to spread out sideways, so that the two can act together without contradicting each other. 'Ash' (charcoal) is their adjutant, being able to follow (substances of the same category (tiang leì).1

Again, the Ping Lu (+1606) gives a theory of the substances that went to compose gunpowder.

The nature of the chemicals used in attack by fire is as follows. Among the principal substances saltpetre and sulphur are the princeonly ones, charcoal is the ministerial one, the various poisons are adjutants (tiang), and those constituents that produce chì is are the envoys (Shān). One must know the suitability of the ingredients before one can master the wonderful (effects) of attacks on incendiaries and explosives. Now the nature of saltpetre is to be linear (chì), the nature of sulphur is to radiate (hēng), and the nature of charcoal is to take fire (yao). That which is straight by nature governs impact at a great distance, so for propulsion we take nine parts of saltpetre to one part of sulphur. That which goes sideways by nature governs explosion, so for detonation we take seven parts of saltpetre to three parts of sulphur. Charcoal from green willow is most sharp in nature, charcoal from dried fir is slow, while that from the leaves of the white mountain bamboo (yao) is particularly fiery.

The chì of realgar is high, causing the flame to rise; the chì of arsenic (pī) is placed, but its fire is toxic. If iron pellets and sharp porcelain fragments previously prepared by roasting with urine (chì), and its sediment (jīn hú) and sal ammoniac, hit one of the enemy, they will cause his flesh to rot until the bone shows. Wild aconit (zhao shao), croton oil (pa luo), and parts of the thunder-god vine (lì thing), roasted together with a small quantity of (dried) sea-horse (shì ma), can be used on dragon-lances as a poison, which if it draws blood.1


Köhler (2), vol. 1, p. 37; Partington (5), p. 278.

A contemporary example with ten-ton wheels is shown in Davis (17), p. 49, fig. 20. Today black powder is used almost wholly in fireworks.

Apparatus for more exact quantitative measurement of its properties arose later, and we shall briefly consider some of the types of it below (p. 548) in connection with the idea of gunpowder engines.

Cf. pp. 105-6 above.

Cf. Davis (17), p. 47.

This trial was widely used in the West too; cf. Marshall (1), vol. 1, p. 57.

Perhaps the oldest European text that is in the Fourteen Books of c. +1437, on which see Hassenzien (1), p. 64 and Partington (5), p. 155.


Ch. 5, p. 61, tr. aut.; (1) on this concept, see Vol. 5, pt. 4, pp. 305ff., 316ff., and Needham (83), 84, Ho Ping-Yü & Needham (2).

1 See Vol. 6, pt. 1, p. 243.

Ch. 5, p. 61, tr. aut.; (1) on this concept, see Vol. 5, pt. 4, pp. 305ff., 316ff., and Needham (83), 84, Ho Ping-Yü & Needham (2).

1 See Vol. 6, pt. 1, p. 243.

Ch. 5, p. 61, tr. aut.; (1) on this concept, see Vol. 5, pt. 4, pp. 305ff., 316ff., and Needham (83), 84, Ho Ping-Yü & Needham (2).
that this was derived from the classical theory of the nature of thunder, which went back far into antiquity, at least as early as the beginning of the Han. Here our Chinese authors came close to a conception much agitated in the Europe of the +16th and +17th centuries, that of the 'aerial nitre.' Giving rise to a large literature, it had more to do with the explanation of thunderstorms, and ultimately with the discovery of oxygen, than with the chemistry of saltpetre, but it played a considerable part in the thought of the time.

Actually, the men of the Revolutionary Science had been anticipated by Chu Hsi, writing in the latter half of the +12th century. As Huang Jen-Yü noticed, he regarded thunder as due to the sudden expansion of intolerably compressed chhi, and analanised it explicitly with gunpowder explosions. His words were: 'Thunder is just like our present day fire-crackers (pao chang)'; most probably (the chhi) is densely compressed, and when this attains its climax, then it bursts forth and dissipates, scattering in all directions.' As we have seen so often, the word 'thunder' was applied to so many gunpowder weapons from the end of the +10th century onwards, that it is not surprising that the 'aerial nitre' should appear in Neo-Confucian dress.

What is rather extraordinary is that a text of closely similar wording to that in the P'ing Lu can be found in the Hau Kung Chhih Yao of +1643, written by Chiao Hsü and Adam Schall von Bell. The section bears the title 'Huo-Kung Chu Yao Hsing Chhing Li-Yung Hsü-Chih.' (What one ought to know about the Practical Use of the Natures and Relationships of the various Chemicals used in Attacks by Fire). The exposition follows the P'ing Lu passage closely, with much of the commentary incorporated into the text, all the ideas being essentially the same. We hear of realgar, croton oil, soap-bean powder, the wolf-dung, the dolphin and the sea-horse, the petrol and even the nine-tailed fish. These are among the many adjutant (te) ingredients. This is the book, we remember, in which Thang Jo-Wang's Jesuit is described as the transmitter or instructor (lan), Chiao Hsü as the compiler (tsuan), and Chiao Chung as the editor (ting). From this it has been concluded by some that the Jesuit was the responsible writer, with the others just taking down what he said. But if this were so one would hardly expect to find passages of such highly traditional ideology. Presumably Schall von Bell found nothing to object to in them. The bringing of modern science into China was necessarily a slow business, and the Jesuits only partly effected it. We prefer our usual course of regarding von Bell's title as partly an honorific one; Chiao Hsü must have been a true collaborator, and not someone writing to dictation. Hence the medieval account of the nature of gunpowder's constituents.

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30. THE GUNPOWDER EPIC

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At this point mention may be made of an interesting piece by Mao Yuan-I, the famous author of the Wu Pei Chih which we so often quote. It is entitled Huo Yao Fu (Poetical Dissertation on Gunpowder) and would be well worth a translation in full, epitomising as it does the traditional thinking about the mechan- ism of the explosive mixture. The nature of saltpetre is to expand vertically (shash), while sulphur expands horizontally; saltpetre is the prince, with sulphur and charcoal as the ministers, and even poisonous substances are brought in as adjuvants. It could show very clearly how Chinese technologists thought of explosive phenomena in the early years of the 17th century.a

It remains only to say a few words about the time of the Opium Wars, when the Chinese were busy catching up with the gunnery developments, modern for that day, which had been made by the European nations. Thus in 1843 Chhen Chieh-Phing, Admiral of Fukien, memorialised that the remaining gunpowder-mills (nien) worked by man-power should be done away with, and animal-power or water-power, seven times more effective, universally substituted.b He also had something to say on the preparation and purification of saltpetre (cf. p. 94 above), recommending oxide glue for the clearing. Rondot (2) knew this text when he visited some Chinese arsenals in 1849; there he found that the nitrate percentage of the powder made was equivalent to that of the best French product (75-5%). Ting Kung-Chhen, who was one of the leading gun- ner and powder experts of the time, observed this too.c Rondot found, rather to his surprise, a large Chinese chemical laboratory and works organised and equipped by Phan Shih-Chhêng, where saltpetre was prepared and recrystallised in bulk, and alcohol and nitric acid distilled. Some of this was used for making silver fulminate detonator caps, which had been produced in China since 1842.d

perhaps the nearest Western parallel to Mao Yuan-I's essay would be the pages which Sir Thomas Browne consecrated to the nature of gunpowder in his Pseudodoxia Epidemica (commonly called 'Vulgar Errors') of + 1641. They occur in bk. 2, ch. 5, para. 5 (Sawrey ed., vol. 1, pp. 271 ff.). Now all these (constituents) are seen in Chinese, although they bear a share in the discharge, yet they have distinct intentions, and different offices in the composition. From Brimstone proceeds the piercing and powerful firing.... From Small-coal ensures the black colour and quick ascension.... From Salt-petre proceeds the force and the report; For Sulphur and Small-coal mixed will not take fire with noise; or explosion; and Powder which is made of impure and greasie Petre hath but a weak emission, and giveth a faint report. And therefore in the three sorts of Powder under the strongest contain most Salt-petre....

The memorial he submitted is to be found in Hsü Ko Chu Chih, ch. 91, pp. 88-114. He appears in European accounts as Ching Ki-Pimn. He also recommended the use of vine charcoal instead of that made from pine or fir.

The memorials are submitted to be found in Hai Kao Wu Chih, ch. 91, pp. 111-154. On him, see Chien Chhi-Thien (1); Huang Thien-chu, Tshai Chhing-Chhi & Liao Yuan-Chhân (1). e

Pwarz See-Ching (or Tingka) to Europeans, cf. Chhen Chhi-Thien (1), pp. 96 E, p. 40 G, 56 E, (2), pp. 8-9, and p. 205 above, where we discussed the attention he gave to seas and mines, and his employment of an American expert to assist in their construction.

See Davis (17), pp. 400 E, 405 C. Silver fulminate had first been prepared by Berthollet in + 1788, but on account of its excessive sensitivity it was soon replaced for military purposes by mercuric fulminate. One of us (J. N.) always remembers the nervousness which accompanied a visit he made to a Chinese fulminate factory during the second world war in his capacity as Adviser to the Arsenal's Administration. Cf. p. 56 above.

The memorials are submitted to be found in Hai Kao Wu Chih, ch. 91, pp. 111-154. On him, see Chien Chhi-Thien (1), p. 115. He appears in European accounts as Ching Ki-Pimn. He recommended the use of vine charcoal instead of that made from pine or fir.

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There has been much disagreement about the date when breech-loading artillery appeared in Europe. Reid may not be far off the mark when he concludes that the evidence points to a time some time not long before 1372. Räthgen said +1380 or +1398, and Köhler chose +1397, but these were all German datings, and the Burgundians seem to have had the device as early as +1394. England comes in with a picture of +1485 referring to 'port-pieces' of +1417, and Portugal with 'versos' (heresus) in +1410. The design lasted for several centuries, but it could never be made satisfactorily airtight, and the serious loss of gas resulting naturally decreased the propellant force. Only in 1609 was the problem solved when S. J. Paulin invented the cartridge, first of many varieties to come.

When, early in the +16th century, the breech-loader entered China, it got the name of fo-lang-chi, the 'Frankish culverin'. But although we occasionally use this translation ourselves, culverin is not the right word, yet unfortunately there is no satisfactory or well-recognized one. In +15th- and +16th-century English

According to Runciman (5), pp. 66-7, 108, 116-7, 119, 146, the Turks, in the whole, took artillery a good deal more seriously than did the Byzantines. In the city they had few cannon, and if fired from the walls the recoil shook and damaged them, moreover there was a saltpetre shortage (p. 94). The Turkish bombardment continued for six weeks, but in circumstances difficult for the gunners, since their cannon lacked proper mountings (pp. 97-8). However, Sultan Mehmed II was advised from +1453 onwards by a Jewish physician Jacopo of Gueirts, who knew something about guns; and in the following year they were joined by Urban, a cannon of Genoa, who manufactured at least one monster some 27 ft long (pp. 77-8). It is particularly found that he manufactured at least one monster some 27 ft long, pp. 77-8. It is particularly found that he manufactured at least one monster some 27 ft long, pp. 77-8. It is particularly found that he manufactured at least one monster some 27 ft long, pp. 77-8. It is particularly

For those who would like to pursue the matter further, the best collection of texts, translated and annotated, is that of Pernot (1). (1) A Swiss artilleryman, originally a wagon-maker, b. +1766. See Reid (1), p. 188; Blackmore (1), p. 66. (2) Its worst feature was that it was generally used to imply muzzle-loading cannon.
Fig. 132. Example of the fo-lang-chi. A 'sling' or 'base' (loosely called 'culverin' or 'caliver') from a Spanish warship, c. +1475. Photo, Metropolitan Museum of Art, New York City, where it is numbered 17-199 (courtesy of Helmut Nickel). This piece was dredged up near Seville; it has its chamber in position, and a swivel fitted under trunnions. The barrel is of four cast-iron staves welded together and surrounded by hoops. Length 3'11''; barrel length 1'10'', bore at muzzle 11.7 cm., at breech 6.3 cm., wt. c. 50 kg.

a Portuguese sling; its chamber is missing but it retains its long tiller. These are the types of weapon which were called fo-lang-chi.

(i) The fo-lang-chi

'In +1523 the Chinese captured two Western ships in which they found Portuguese culverins. These weapons were presented to the emperor and given the name fo-lang-chi, following the Chinese appellation for these foreigners; then in +1529 these guns were copied in China. So runs the conventional wisdom, but the story is a good deal more complicated, as Pelliot showed in a remarkable monograph (53) on the Hoja and the Said Husain of Ming texts. Actually, the standard statement is the gist of the account in the Ming Shih, which adds that Wang Hung was the one who presented the cannon at court.

The official historians were basing their account on two books, the Shu Yu Chou Tzu Ia (Record of Despatches concerning the different Countries) of Yen

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* Tower of London Armouries, Blackmore (2), p. 170, no. 295. Barrel length 5 ft 2 in. Other breech-loaders in the Tower will be found in Blackmore (2), p. 50, no. 6, pl. 59 C (Dutch of +1670) which keeps an original chamber; p. 151, no. 196, pl. 59 A (Portuguese c. +1525) with a hoop ed barrel 6 ft 10 in. long, very like Fig. 132; and p. 166, no. 234 (Malay or Filipino).

* Mendel Peterson (1) describes an expedition of nautical archaeology made by Edward Tucker and Edwin Link of Hamilton Harbour, Bermuda, in 1935-6, which recovered half-a-dozen Spanish or Portuguese culverins of this kind.

* He was really trying to identify these characters, and cleared up the breech-loader problem on the way. There was at some point a Chinese-speaking envoy named Hsao- Chê-Ya-Sun, evidently of Muslim origin, probably a Malay, possibly Hoja Hasan, or Khija Hasan (i.e. Master Hasan). He was either an ambassador from Malacca, or one of the interpreters of the unfortunate Tomé Pires (cf. Vol. 4, pt. 3, pp. 294-5); whoever he was, he was executed at Canton in +1523. The other Muslim mystery-was was Hsieh-I Hu-Hsiao (Said Husain), a Uighur prince from Hami in Sinkiang; he was in good odour in +1488, but fell from grace and was executed in Peking in +1522. See also Lin Wen-Chao & Kuo Yung-Fang (1).

* Ch. 325, pp. 193-194; Ch. 74, p. 114; L., nos. +1520 and +1521.

* He had in fact been the naval commander off Kuantung who defeated the Portuguese squadron under Martim Afonso in +1522; cf. Chang Thien-Tsê (1), pp. 56 ff., 60-1.
Fig. 133. Portuguese breech-loader of c. +1520 bearing the national arms. The chamber and the iron tiller are missing. Overall length 8' 2". Photo. Tower of London Armouries. Blackmore (2) catalogue, p. 139, no. 178.

Fig. 134. An African copy of a Portuguese breech-loader, date uncertain. The chamber is missing but the iron tiller is intact. Photo. Tower of London Armouries. Blackmore (2) catalogue, p. 139, no. 239.
372. The gunpowder epic

Tshung-Chien (1517), and the Huang Ming Shih Fa Lu (Ming Political Encyclopedia) of Chih Jen-Hsi (1530); but both of these say that it was a lower War Ministry official, Ho Ju, who got hold of the guns in 1522, and that later on copies were cast at the capital by two Westernised Chinese, Yang San (Pedro) and Tai Ming. However, when in 1519 the famous philosopher Wang Yang-Ming (d. 1529), then Governor of Chiangsi, was putting down the revolt of a prince named Chu Chih-Hsien, he used, or intended to use, fo-lang-chi cannon. In his collected works there is a piece in which he says that his friend Lin Chün, army commander against the prince, had his bronze-founders cast fo-lang-chi chuang at this time—consequently the weapon was known in China, at least in Fukien and Chiangsi, before 1522. Moreover, there had been another rebellion in the same province twelve years earlier, when Huang Kuan was prefect, and it had been put down largely by a volunteer officer named Wei Sheng, who attacked the brigands with more than a hundred fo-lang-chi, and destroyed them. Therefore the Frankish breech-loaders were a fairly familiar weapon in the south as early as 1510.†

If this is the case, it cannot have reached China directly from the Portuguese, because Malacca did not fall until 1511. Peliot thought it most probable that the guns came up from Malaya before Chinese people had ever met anyone from Portugal, in which case the word chi† really meant 'machine' from the first, i.e. 'the engine of the Farangi, or Franks', and then the syllable stayed on in the transliteration of the name for the people. As Peliot put it: 'on avait connu les canons fo-lang-chi avant les étrangers Fo-lang-chi'. At all events there was a per-}
Fig. 155. The first Chinese illustration of a 'Frankish culverin' (fe-hsi-chih-shang), from CHTP, ch. 13, p. 335. One chamber or culasse is also shown. This book came out in +1367, but the relevant quotation came from a report of +1253 or so. The small cannon is mounted with its trunnions supported on a swivelling pivot.

Fig. 156. Another illustration from the same work (ch. 13, p. 334). The mounting is more elaborate but the same principle of swivelling trunnions pertains.
finding its target, will smash the hull and send the enemy to the bottom. With this arm one can sail about at will on the high seas, and no other country’s ships can match it.\(^a\)

When a cannon of this type, and its gunpowder formula, was submitted (to the throne) by an officer from the campaign against the sea-pirates, the gun was tested on a parade-ground, and its range was found to be only about 100 paces.\(^b\) But it was admitted an effective weapon on shipboard, and it could also be used in the defence of city walls. However, it was not much good for carting about on open battlefields.

Later on, when Wang Chhêng-Chai\(^1\) (i.e. Wang Hung) became Minister of War, he sought permission to cast more than a thousand of such cannon for issue to (defence posts on) the three frontiers. One type was mounted on a wooden stand, so that it could be lowered and raised, or turned to the left and to the right (for accurate aiming). This method of mounting guns was originally developed in China, and did not come in with the Portuguese.

Each (breech-loading) cannon weighs about 200 catties,\(^c\) and its three chambers weigh about 30 catties each. The single lead shot which each one contains weighs about 10 ounces.\(^d\)

The passage then concludes with a few lines which to some extent repeat what has already been said, extolling the universal mounting and recommending it for rampart defence, if not for attack. Although the smaller guns at sea let the force of the fire partly escape when they go off, and fill the vessel with thunderous noise, there is no wooden ship that can withstand a direct hit. They can also be mounted on rafts for coastal defence.

(ii) Field-guns, siege guns, and garrison artillery

After this, illustrations and descriptions of breech-loading cannon are not rare in the Chinese military literature. A cannon with a bulbous belly and replaceable chambers like the \(\text{fo-lang-chi}\) and called the ‘flying-over-the-mountains magically (effective) gun’ (\(\text{fei shen shen phao}\)) is illustrated by the great general Chhi Chi-Kuang\(^2\) in his \(\text{Lien Ping Shih Chi}\) of +1568. There is no text to accompany the drawing (Fig. 137) but the caption says that the cannon measures 2 ft 7 in. long and weighs 280 catties. The \(\text{fo-lang-chi}\) itself, with nine replaceable

\(^a\) On p. 32 of the same chapter, Chêng Jo-Tsêng was not quite so optimistic. ‘Although the large Kuang-tung warships use cannon,’ he said, ‘yet as they rise and fall in the troughs of the waves they are dashed about, and they cannot be sure of hitting the pirate ships, even if they do, they cannot hit many.’ The \(\text{fo-lang-chi}\) breech-loader itself may not hit the mark—but I must say if it does there is no ship which will not be pulverised by it.’ Tr. aut., adjuv. Mills (6).

\(^b\) If this was the usual 5 ft double-pace, it would mean about 500 ft, but Ming Shih (ch. 92, p. 118) says more than 1000 ft.

\(^c\) Ming Shih later on (ch. 92, p. 118) says from 150 to 1800 catties.

\(^d\) This material was often paraphrased subsequently, as by Ling Yang-Tsao in his \(\text{Li Shao Phu}\) of +1799, ch. 40 (p. 649).

\(^1\) Chih Chi-Kuang in \(\text{LPSC}\) (TC), ch. 5, p. 258, a work of +1568. The piece is short and stumpy but one culasse is clearly shown, so it was a breech-loader. Note the double trunnions (cf. Fig. 94). \(\text{WPC}\), ch. 83, pp. 64, 74, has it mounted on a wheelbarrow (Fig. 139). cf. pp. 375, 379.
chambers, also appears in this work. Another artillery piece rather smaller than the fe-lang-chi but faster to fire was called the 'cannon-rivalling gun' (sai kung chuang) and is described in the Ping Lu of +1606 with a diagrammatic illustration. Before long the breech-loading principle was extended to quite heavy guns, like the 'invincible general' (zu ta ta ching chun) illustrated and described by Chi Chi-Kuang (Figs. 140, 141). This weighed 1950 catties, and was carried into position on a kind of barrow. Here a good new term was at last found for the chambers, tzu chung. The range for grape-shot was over 200 ft.

Cannon of this name we have already come across (p. 338), but like all the largest ones they were muzzle-loading. Let us look at another one in the Chlien Hai Thu Pien, that called the 'bronze outburst cannon' (thang fu kung). Fig. 142. Chêng Jo-Tsêng says:7

Each of these weighs 900 catties or thereabouts, and fires 100 lead shot, each weighing about 3 catties. It is a powerful weapon for assaulting city-walls, as also for attacking the enemy when tens of thousands of them are gathered in massed formations. The stone cannon-balls are as large as a small peck measure, and any object struck by them must inevitably disintegrate. Walls will be penetrated, houses in their path will crumble, trees hit by them will fall, and from any men or animals that get in the way blood will flow in streams. If fired at a mountain-side, the balls will bury themselves several feet deep. Not only are the cannon-balls not to be withstood, but objects which are struck by them will ricochet and strike other objects—even parts of the human body like limbs and trunks thrown about in this way will also cause damage.

Not only are the cannon-balls so powerful and frightening, but after the priming-powder (7) is ignited, the gas (chi)2 coming from (the explosion) is poisonous. the blast can blow people to death, and even the earthquake-like noise can kill. Hence before letting off a bronze outburst cannon it is necessary to dig a trench in which the gunner can take cover before lighting the fuse. Then, as the fire, the gas, and the roar all go upwards, he is protected from injury and death.

Of course it is always necessary to guard the gun with a detachment of brave soldiers so as to prevent the misfortune of the enemy capturing it. But if you are not attacking strong defensive works, nor getting out of a dangerous situation, you do not need to use this (great siege cannon).

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7 Tzu Chi, ch. 5, pp. 163, 172, with two pages of description following. Fig. 138.
8 Ch. 19, p. 844. 7
9 Tzu Chi, ch. 5, pp. 153-162.
10 The caption of the illustration has bang without the fire radical, but properly bang meant any great piece of ordnance.
11 Ch. 19, pp. 348-350. tr. exact. The same picture appears in HIC, pl. 2, ch. 2, p. 24, with text on pp. 28, 32.
12 One remains having come across this curious procedure before, and in fact it is (derivatively) in the Then Kung Khâng Wû (+1657), ch. 15, p. 73 (Sun & Sun tr. p. 271, Li Chhiau-Phéng tr. p. 395, both misunderstanding in different ways). One wonders whether it is not a relic of the ever-present danger of these early big guns burning, and killing the gunners.
And the text goes on to say that this weapon could also be used on board ships at sea, if the vessels were large, and a part of a fleet; it was also good for defending the gates of cities or encampments. The design was derived from the countries of the Western-ocean barbarians (Hsi-Yang Fan Kuo') in the Chia-Ching reign-period (+1522 to +1566).

The passage further adds that just as the first bronze outburst cannons were developed from foreign examples, so Chinese ingenuity (chhiao ssu') produced a smaller version of the fo-lang-chi breech-loaders, and called it the 'lead-and-tin gun' (chhien hsi chhung'), presumably because of the shot it fired. One of these is in the Tower of London (Figs. 143a, b); it has a swivel mounting though hardly larger than a musket.

By +1605, when Ho Ju-Pin was writing his Ping Lu, even the terminology for cannon was reflecting Western usage, as we can see in Table 5, where 'serpent-

tine', 'falconet' and 'saker' had their counterparts in Chinese. Illustrations too, now often show clear influence from the West, e.g. the field-gun with its trun-
nions (chhuan chh'ung'), the heavy garrison piece (hsiao chh'ung'), and the siege gun ornamented in very European style (kung chh'ung'), Fig. 145. Variations in elevation are shown by the pictures in Figs. 146, 147, with the quadrant and plumb-bob at the cannon’s mouth, set in the howitzer case at 60°, as the inscription says. The carriage here resembles closely those of late +16th-century can-
non in the West. Finally, the 'tiger-cat mortar' (fei piao chhung') is illustrated (Fig. 148) in the act of bombarding a city, which with its church towers and crenelated walls seems likely to have come out of some Western gunnery book.

Fig. 139. One of Chi Chi-Kuang’s vase- or bottle-shaped breech-loaders (cf. Fig. 137) mounted at the front of an assault wheelbarrow (WPC, ch. 83, pp. 63, 76) accompanied by four spears. The text says that there were three such cannon, one large and two small, but only a single one is shown.

Fig. 140. The culasse breech-loader applied to larger cannon; the ‘invincible general’ (see it in chhang-chhia) on its two-wheel carriage. LPSC (TC), ch. 5, p. 144, b.
Fig. 141. Three chambers or culasses for the same (LPSC (TC), ch. 5, p. 138).

Fig. 142. A large artillery piece of the 16th century, the "branze outbust cannon" (shuang fa tong), muzzleloading. From CHTP, ch. 13, p. 339. CP, WPC, ch. 102, p. 48.
<table>
<thead>
<tr>
<th>Field-guns</th>
<th>Siege-guns</th>
<th>Defence-guns</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>weight in catties</td>
<td>range in paces</td>
</tr>
<tr>
<td></td>
<td>projectile</td>
<td>powder charge</td>
</tr>
<tr>
<td>Field-guns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>large serpentine</td>
<td>18–25</td>
<td>eq.</td>
</tr>
<tr>
<td>extra-large serpentine</td>
<td>26–40</td>
<td>eq.</td>
</tr>
<tr>
<td>small Frankish sling</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>large Frankish sling</td>
<td>6-12</td>
<td></td>
</tr>
<tr>
<td>Siege-guns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>flying tiger-cat mortar</td>
<td>60–100</td>
<td>60</td>
</tr>
<tr>
<td>Falconet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ying shun chuang</td>
<td>9–13</td>
<td>2/3 wt</td>
</tr>
<tr>
<td>pouncing-owl cannon</td>
<td>14–18</td>
<td>2/3 wt</td>
</tr>
<tr>
<td>pansaker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pan chun chuang</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>large saker</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>extra-large saker</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>roaring-tiger cannon</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Defence-guns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>demi-running-hog cannon</td>
<td>6–12</td>
<td></td>
</tr>
<tr>
<td>large running-hog cannon</td>
<td>12–18</td>
<td></td>
</tr>
<tr>
<td>extra-large running-hog cannon</td>
<td>19–25</td>
<td></td>
</tr>
<tr>
<td>leaping-tiger cannon</td>
<td>26–30</td>
<td></td>
</tr>
</tbody>
</table>

* This name for a small cannon should not be confused with the similar name for the lever in arquebuses that brought the slow-match to the touch-hole; cf. pp. 455 ff. below.
* The word 'saker' originally meant a kind of hawk; here it is the serpent-eagle or poison-falcon, Spilornis cheela (RJ 17; Ch'eng Tso-Hsun (x), vol. 2, p. 104), so the translation seems appropriate.
* Here there seems to be many printing errors.
* Said in the text to be of Western origin.
Fig. 145. Muzzle-loading siege gun ornamented in very European style, with swabs and other impediments.
PL, ch. 13, p. 138

Fig. 146. European-type field-gun at low elevation, from PL, ch. 13, p. 138 (+1666).
Fig. 147. European-type field-gun at high elevation, from PL, ch. 13, p. 2a.

Fig. 148. The "flying tiger-cat mortar" (fei hiao ohong), no doubt copied from some Western gunnery book, since it is in the act of bombarding a town with church towers and crenellated walls. PL, ch. 13, p. 114. And indeed the heading of the following page says "Details of the Western Methods of casting large and small Canon". Note the quadrant, protractor and plumb-bob at the muzzles of the cannon in all these three pictures.
Nevertheless, Chinese artillery continued to impress Westerners quite favourably. In +1596 Jan van Linschoten wrote:

All the Townes in that Countrie are walled about with stone Walles, and have Ditches of water round about them for their Security; they use no Fortresse nor Castles, but only upon every Gate of the Towne they have strong Towers, wherein they place their Ordinance for the defence of ye Towne. They use all kindes of arms, as Calivers, etc.

It was rather acute for an observer at this time to realise that there were no castles in China since for centuries there had been no military feudal aristocracy, but only centres of population and administration held for the king. After the passage from Juan de Mendoza (+1585) quoted on p. 54, he goes on to say that Friar Gerrardo saw some 'ill-wrought' pieces of artillery, but it was given them to understand that in other provinces of the kingdom there be that bee very curiously wrought and faire, which may bee of such that the Captain Artreda did see; who in a letter which he wrote unto King Phillip, giving him to understand of the secrets of this Countrie, amongst which he saide: 'the Chinese doe use all armour as wee doe, and the artillerie which they have is excellent good'. I am of that opinion, for that I have seen vessels there of huge greatness, and better made than ours, and more stronger.

Three hundred years later, after that long a period of capitalist enterprise and production, the disparity between Western and Chinese artillery became considerably greater.

Mention of the quadrant and plumb-bob at the mouth of the cannon in Fig. 146 leads us on to say something about the beginnings of external ballistics. As is generally known, the earliest Western speculations about the path of a projectile supposed it to move in a straight line for a while, before succumbing finally to the influence of gravity and then falling downwards in an equally straight line, not unlike the course of the mortar shell seen in Fig. 148. This was the conception in the days of Nicolo Tartaglia (+1537, +1546). But Galileo (+1638) and Torricelli (+1644) proposed a parabolic trajectory, and this eventually became more like a hyperbola when the resistance of the air was fully taken into account, as by Newton (+1674) and later mathematicians.

In East Asia ballistics was pursued more in Japan than in China, but the connections were close. The famous Inatomi family of gunsmiths left many MS books still extant on the theory and practice of gunnery, notably one of +1607 to +1610 in twenty-nine large volumes. The most outstanding member of the family, Inatomi Naosie, recorded a tradition that Sasaki Shiyō-huziroyo had first learnt the art in China, and then transmitted it to his grandfather Inatomi

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30. THE GUNPOWDER EPIC

Sagami-no-kami Naotoki; this would take us back to +1500 or earlier, certainly before the arrival of either the Turkish or the Portuguese musket (cf. pp. 440 ff. below) in China and Japan, and would suggest that the Chinese hand-guns of the +15th century, probably with serpentines, had begun the affair. By +1618 trajectories were being studied by Shimizu Hidemasa, who visualised a slow rise followed by a slow fall. Then from +1659 onwards the parabolic trajectory was proposed, first in the Kaisen-ki (1) (Book of Improved Mathematics) by Yamada Shigemasa, then in the remarkable work of Nozawa Sadanaga, the San Kyōki (Mathematics in Nine Chapters) of +1677. This book, which accompanied the illustration of the curve with complicated quadratic equations, was the first Japanese treatise to explain physical phenomena using mathematical formulae. There may have been some Jesuit or other Western influence here, but Nozawa's view of the world was at last as much Chinese, based on the Yin-Yang theory, decimal metrology, and the standard pitch-pipe dimensions. The Suon Fa Thung T'ung (Systematic Treatise on Arithmetic) of Chhêng Ta-Wei (+1592) had been translated into Japanese only two years before Nozawa's own writing, and he was probably strongly influenced by it. Lastly there was the extension of Yamada's work by Mochinaga Toyotugu & Ōhashi Takusui, the Kaisen-ki Komoku, which continued to speak of gunshot parabolas. After the rangaku (Dutch learning) period had opened, Shizuki Tadao produced in +1795 the Kuki Happō-den (On the Firing of Guns and Cannon) translated from the relevant parts of J. Keil's Inleidinge tot de Waere Natuur- en Sterrekunde. This continued the parabolic interpretation. But gradually more advanced ideas became prevalent, as in the Kikai Kawa-ren (1) (Survey of the Ocean of Pneuma) by Aoji Rinsō (1825), the first work on modern science in Japanese, including besides physics much astronomy, meteorology and ballistics.

There was an extension of this in +1851 by Kawanomoto Kōmin (1), entitled Kikai Kawa-ren Kōki (1), and the theory of projectile motion in this was studied by Mikami Yoshio (25). But we need not pursue the story into the modern period further, and must return to the +17th century.

(1) vol. 3, p. 150-1. The passage was largely a borrowing from Mendoza (1), p. 342 (Halkett Soc. ed., vol. 2, p. 388, whose translator said attributes or 'hargabushet').

(2) Letter, p. 150 ff., ch. 15 of bk. 3.


(7) Inatomi & Inatomi (1), p. 83.
European cannon, in the era of nascent capitalism, were indeed now making all the running. In +1600 or soon after, late in the Wan-Li reign-period, Chinese artillerymen obtained a cast-iron cannon larger than any hitherto known, from some European ship. The Ming Shihs says:6

At this time, a ship arriving from the West (Ta Hsi-Yang) brought an enormous cannon, which got the name of the ‘red (haired) barbarian gun’ (hung i phan). It measured over 20 ft long, and weighed as much as 3,000 catties. It could demolish any stone city-walls, and its earthquake-like roar could be heard for several dozen li around.

During the Thien-Chhi reign-period (+1621 to 7) the (old) name of ‘great general’ (ta chiang-chian) was given to it, and officials were sent to pay honour to it.

During the Chhung-Chen reign-period (+1628 to 43) the grand secretary (ta kaiieh shih) Hsi Kung-Chhi requested the emperor to issue an edict commissioning Westerners to fabricate weapons of this kind.

It will be remembered that Hsi Kung-Chhi was a great friend of the Jesuits,7 so this text immediately plunges us into the strange story of the apostles of Christianity engaging in gun-founding for the Chinese governments of the day.

It began in a relatively small way, with the Jesuits marginally involved,5 because from +1620 onwards the danger of Manchu incursions and border frights8 caused the Peking government, urged by Hsi Kung-Chhi and other officials, to look with favour on the idea of importing Portuguese artillery detachments north from Macao to oppose the Manchus.6 The first group of these gunners set out, with some cannon, in +1621, but failed to get through; the second, consisting of gunnery instructors, arrived in Peking in the spring of the following year.6 Urgent invitations, however, continued, and the colourful Jesuit Joao Rodrigues (Lu Jo-Han)9 went with others to Kungchow early in +1628 to arrange for a larger detachment, then accompanied it himself as interpreter. It was commanded by an artillery captain, Goncalvo Teixeira-Correa (Kung-Sha Ti-Hsi-

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5 Ch. 92, p. 116; tr. auct. Often afterwards quoted, as by Ling Yang Tso in his Li Shu Phien of +1799, ch. 40 (p. 650).
6 In Taoist folk-religion any device or machine of almost miraculous potency was something which should receive veneration; analogous perhaps to Indian jatai addressed to roots and instruments. This went against the grain of Confucian orthodox, but they generally played along with popular feeling.
7 We have often discussed him and his work, cf. Vol. 1, p. 149; Vol. 3, pp. 52, 110, 447; and Vol. 4, pp. 2, passim. The Jesuits called him ‘Doctor Paul’. According to Matteo Ricci’s account and Hsi’s biography in Ming Shi, ch. 451, p. 158, they discussed together not only astronomy, mathematics and calendrical science, but also the modern firearms of the West.
8 A good brief account is that of Cooper (1), pp. 334 ff.
9 We shall see something of this as closer range from the gunnery point of view in a few moments (pp. 398 ff. and Figs. 152 to 155 below).
10 Already in +1557 a force of Portuguese gunners and musketeers had helped the Governor of Kuangchow to suppress an uprising of pirates and disaffected soldiers (Cooper (1), p. 355; Vidaire-Pires (1), p. 698 ff.).
11 Unfortunately, one of the artillerymen, Joao Correa, lost his life, together with two Chinese gunners, when one of the cannons blew up in +1604.
12 He was always known as Rodrigues Tetszuz, or Interpreter Rodrigues, partly because of his exceptional linguistic ability, and partly to distinguish him from other Jesuits of the same name. Tetszuz comes from Jap. tajii = tang shih. He was really a long-standing member of the Japan Mission, but had been exiled to Macao.
13 This was partly because of growing bureaucratic nervousness at having so many armed Westerners around (in this connection cf. Vol. 4, pt. 3, p. 534), and partly because of the commercial interests of the Kuangchow merchants, who profited greatly by the Portuguese trade and wanted no weakening of the city of Macao, already subject to attacks by the Dutch. They actually paid the return travel expenses of the force.
14 Cooper (1), p. 335 (add.).
15 This work is now extremely rare, if extant at all; on it see Pelliot (45). It may be no coincidence that the two Chinese Christian officials who were sent down to Macao twice (+1631 and +1632) to expedite the Portuguese artillery detachments were named Michael Chang and Paul Sun respectively. They may well have been the authors concerned. See Cooper (1), pp. 355-6 and Pfister (1), p. 107 (add.).
16 Kajda Pekhon, ch. 3, pp. 652 ff. For the probable nature of these weapons, cf. pp. 424, 480 below.
17 On all these episodes see Boxer (12).
18 We can be brief in this relation because we discussed the matter fairly fully in Vol. 5, pt. 3, pp. 249+1. The facts can be followed further in Pfister (1), p. 165; Borset (1, 2, 3); Vratislav (1), pp. 111 ff.; 370; and Duh (1), pp. 60 ff. Occasionally references occur, for example, in Remusat (12), vol. 2, p. 250.
19 See above, p. 239, and Vol. 3, pp. 447 ff.
20 Schall von Bell (1), pp. 34, 90.
expostulations this was what he had to do. The arms desired were like sakers and all he could do was to get their size reduced from 75-pounders to 40-pounders; of these twenty were cast that year, and 500 smaller ones in the year following. It was at this time that he collaborated with Chiao Hsi in producing the book "Huo Kung Chihtieh Yao" (Essentials of Gunnery), an admirable work, which we quote from time to time. Schall von Bell survived both the end of the Ming, and a wave of severe persecution also, not dying till +1666, at which time he handed over his astronomical position to another Jesuit, the Belgian, Ferdinand Verbiest (Nam Huai-Jen).

It must not be supposed that the Ming metal-workers were incapable of designing and casting good cannon themselves. In 1525 when in Shenyang, I visited the home of a former warlord, Thang Yu-Lin, and found outside two big guns, the larger one about 12 ft long and of 5 in. bore. It had on it the following inscription, which I copied:


That was +1642, and the day cannot have been so fortunate, only for two years later the Manchus captured Peking, and the cannon was probably used by them during the ensuing century.

What happened to Schall von Bell happened also to Verbiest—a decade later, the identical play was acted over again. Wu San-Kuei, the powerful general who had joined his army with the Manchu troops of Dorgon in +1644 to capture the capital from the Ming, and then served the Chihhung loyalty for nearly thirty years, especially by his successful campaigns against the remnants of the Southern Ming in Yunnan and Burma, became in the end disaffected, and set up a standard of revolt in Kweichow and Hunan in +1673. He pro-

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claimed himself emperor of a new dynasty, the Chou, in +1678, but died of dysentery that same year. It was therefore perhaps not surprising that Verbiest, who had been re-equipping the Peking Observatory with splendid bronze instruments from +1669 to +1675, should receive a summons in +1675 to set up another cannon-foundry, this time for the Manchus.

Let us listen to the elegant account of another Jesuit, Louis Lecomte (Li Ming) written twenty years or so later.

After the Emperor had tried many several ways to no purpo, he faw plainly that it was impossible to force them [i.e. the troops of Wu San-Kuei] from the places where they had entrenched without using his great Artillery; but the Cannon which he had were Iron, and so heavy that they dared not carry them over such steep Rocks, as they must do to come to him. He thought Father Verbiest might be affiant to him in this matter; he commanded the Father therefore to give directions for casting some Cannon after the European manner. The Father prefently excused himself, saying that he had lived his whole life far from the noise of War, that he was therefore little instructed in those affairs. He added also that being a Religious, and wholly employed in the concerns of another World, he would pray for his Majesty's good successes; but that he humbly begged that his Majesty would be pleased to give him leave not to concern himself with the warfare of this World.

The Fathers Enemies (for a Missionary is never without fome) thought that now they had an opportunity to undermine him. They perfused the Emperor that what he commanded the Father to do, was no ways opposit to the will or intention of the Gofpel: and

Fig. 149. Southern Ming cannon cast in +1650, dredged up from Kaitak Bay in 1956, and now standing beside the Central Government Offices in Hongkong. See Lo Hsiung-Lin (6). Photo: John Cranmer-Byng.
that it was no more inconvenient to him to cast Cannon than to cast Machines and Mathematical Instruments, especially when the good and safety of the Empire were concerned: that therefore without doubt the reason of the Fathers refusal was because he kept Correspondence with the Enemy, or at least because he had no respect for the Emperor. So that at last the Emperor gave the Father to understand, that he expected obedience to his last Order, not only upon pain of losing his own Life, but also of having his Religion utterly rooted out.

This was to touch him in the most sensible part, and he was indeed too wise to stand out for a nicety or a scruple at the hazard of losing all that was valuable. I have already assured your Majesty [he said] that I have very little understanding in casting Cannon; but since you command me I will endeavour to make your Workmen understand what our Books direct in this Affair. He took therefore upon himself the Care of this Work, and the Cannon was proved before the Emperor, and found to be extraordinary good. The Emperor was so well pleased with the Work, that he pulled off his Mantle, and in the presence of the whole Court gave it to Father Verbiest for a token of his Afection.

All the Pieces of Cannon were made very light and small, but strengthened with a lock of Wood from the mouth to the breech, and gilt with several bands or Iron; so that the Cannons were strong enough to bear the Force of Powder, and light enough to be carried thro' any, even the worst, Roads. This new Artillery did every way answer what they proposed from it. The Enemy were obliged to leave their Intrenchments in disorder, and soon after to Capitulate; for they did not think it possible to hold out against those any longer, who could destroy them without coming themselves into reach.

It seems that the Manchu artillery had about 150 cannon, but (as Lecomte says) many were too heavy for a mountain campaign, so Verbiest was called upon to cast a lot of smaller ones. Having duly organised the foundry he cast twenty in the first month, then 320 during the rest of the year. On a previous occasion we could not help commenting adversely on the Christian ceremonies that Schall von Bell carried out in his foundry, but now Verbiest did not hesitate to bless the guns liturgically with asperses and incense, giving to each one the name of a saint, and inscribing it accordingly. He was awarded the title of Deputy Minister of Public Works (Kung Pu Shih Lang), for his pains. By an extraordinary coincidence, two of his guns are still preserved in the Tower of London, having been captured at the Taku Forts in 1860 (Fig. 150). One has a legible inscription, which runs as follows:

General of Holy Authority. Cast in the 28th year of the Kbang-Hsi reign-period [1689]. It takes 1 catty, 12 liang, of powder as charge, and fires an iron ball weighing 3 catties, 8 liang. Height of the sight 6 shen, 3 li. Official in charge, Nan Huai-Jen.

* See Romains (2, 4) and Pfister (1), pp. 347 ff. What is interesting here, as Dr Clayton Bredt points out, is that Verbiest seems simply to have made improvements on the long-established Chinese tradition of producing remarkably light-weight cast-iron ordnance, rather than introducing imported Western types. All the Hau Lung Ching and Chi-lu Hsi Tha Pan weapons weighed very much less than Western guns of comparable calibre. These Chinese 'minions' continued in use right into the nineteenth century, as late as 1875 (cf. Bellew, 1).

Verbiest's chief modification seems to have been the lengthening of the barrel.


* See Blackmore (2), pp. 133-4, no. 203, pl. 42 a, b. Another of these cannon bears the date of 4.1689.

Since this was the year after Verbiest's death, his foundry must have gone on producing a whole series of cannon designed by him. Each has a solid trail fitted with a hinged traversing lever and elevating screw. Here we cannot refrain from reproducing an imaginative drawing of Ferdinand Verbiest aiming and firing one of his guns (Fig. 151) under the admiring gaze of assorted mandarins and artillerymen. Verbiest too seems to have written a treatise in Chinese on cannon and cannon-founding, but the title is not known and the text seems to have perished.

Leaving now the exploits of the Jesuits as cannon-founders, we must retrace our steps a little to look at some quite remarkable drawings which have come down to us portraying the state of artillery in China in the second decade of the +17th century. They are battle pictures contained in the Thai T'u Shih Li Thu² (Veritable Records of the Great Ancestor of the Chhing Dynasty) with Illustrations, first written in +1635. This was Nurhachi², who fought the Ming from +1609 onwards, especially after +1616 when he proclaimed himself emperor of a Later Chin (Hou Chin³) dynasty, recalling that the Manchus traced their descent in part from the Jurchen Chin Tartars. His first invasion of China was in +1618, and he continued at war until he died in +1626.

When one studies the pictures in the book it is clear at once that the Manchus are generally drawn as mounted archers wielding bow and sword, with the guns all on the side of the Ming; but towards the end the Manchus are using firearms too. A characteristic study of the field-guns is that of Fig. 152, which shows Nurhachi's cavalry taking a Ming battery from the rear. The eleven guns shown are mounted on two-wheeled barrows, the handles of which form the trails, and in front of each there is a shield, presumably of metal. Three are

* These may have been later additions. Another of Verbiest's guns is preserved in the Hakozaki Shrine on Kyushu in Japan. ² It is the frontispiece of the second volume of the popular book of Gaillot (1), published in 1818. ³ Du Halde (1), vol. 2, p. 49; van Hée (2); Pelliot (55), p. 192; Plüster (1), p. 359. It was not known to Cordier (8), but Du Hui T'ai-Fung tells us (priv. comm.) that its title was Shên Huí T'zu Shâu¹ and its date in +1608. ⁴ The text is in Chinese, but the pictures have Manchu captions also. No writers are known by name, but they must have been official historians living very near the dates of the events described. The bibliography is complicated (see Hummel (1), pp. 598–9), and there are several versions of the text, while some sets of pictures were re-drawn by Mên Ying-Chiao⁵ in +1781. We use the MS. of +1740, reproduced in facsimile by the North-east University at Mukden in 1950. How exactly faithful the illustrations in this are to the MS. of +1635, one cannot know, but they have no flavour of the late +17th or +18th centuries.

⁵ The name Chhing¹ was not adopted till +1618. ⁶ Something should perhaps be allowed for Manchu self-congratulation in that they felt they had conquered troops better armed than themselves. But from Chihien Wen-Shih (2) we learn that the first 'modern' cannon was cast by the Manchus until +1621, i.e. after the death of Nurhachi. CL. Li Shuo P'ien, ch. 40 (p. 650).

² One of the Four Princes (Beile) is shown in the right-hand bottom corner with his staff. The caption says that the artillery belonged to the forces of Kung Nien-Suí, one of the Ming generals.

⁷ We shall say something more of shields on pp. 414 ff. below. Here they are generally painted with lion-muzzles, suns, etc.

Fig. 151. An imaginative reconstruction of Ferdinand Verbiest, in his Jesuit robes, aiming and firing one of the field-guns cast for the Chhing dynasty under his directions. Manchu officials look on. From Gaillot (1), the frontispiece of vol. 2 (1818).
partly or wholly overturned, and the gunners are dead or fleeing. Between each gun there are double-barrelled bird-beak muskets with prongs\(^a\) at the front end as supports;\(^b\) six of these can be seen, but none in use. One gets the general impression that the Chinese artillery was good when emplaced, but rather lacking in mobility.

Another picture (Fig. 153) shows a frontal attack on a Ming battery\(^c\) by Manchu archers, both mounted and on foot, with Nurhachi himself commanding in the right-hand bottom corner. Again there are the field-guns and the shields to protect the gunners,\(^d\) but besides these one can see five more guns simply resting on the parapet of the entrenchment, with a bombardier just about to fire one off at the bottom on the left.\(^e\) The priming-pans of the cannon are carefully drawn in, and twelve of the bird-beak muskets may be noted, this time single-barrelled.\(^f\) Double-barrelled muskets appear again, however, in Fig. 154, where the front line of Khang Ying-Chih\(^g\)\(^h\) men is firing six of them, while he himself is indicated commanding behind.\(^i\) The musketeers have quilted armour, but not the swordsmen with round shields.

The two-wheeled barrow-carriage was not the only way in which field-guns were mounted at this time, for Fig. 155 shows another frontal attack on a battery by the Manchu cavalry,\(^j\) and here the guns are all attached to what we can only call ‘carpenter’s bench trolleys’. These trestles seem at first sight to have wheels at the end of each of their splayed legs, but a more careful look suggests that they were simply round flat feet, in which case the mobility was very poor.\(^k\) Two of these trestles have overturned in the combat.\(^l\) This curious type of carriage appears again in other illustrations, such as that depicting Nurhachi’s siege of Liaoyang, which fell in +1621. Here they are all mounted on the flat ground between the city-wall and the moat, and in several cases the gunners can be seen applying their match (Fig. 157).\(^m\) One could hardly get a better insight into

\(^{a}\) Anyone wishing to see a photograph of such prongs in contemporary use may find it in Stone (1), p. 465, fig. 528, who calls them ‘A-shaped rest’. The example comes from the Lamut, a Tungusic people in Siberia. And the Chinese army still had them on its muskets in 1860 (Fig. 156).

\(^{b}\) On muskets see the following sub-section, pp. 429 E.

\(^{c}\) Under the general Phan Tsung-Yen\(^n\), who can be seen in person in the left-hand top corner. Nurhachi’s men are opposed by a few Ming archers, who do not seem to be doing anything however.

\(^{d}\) One gun-carriage is already overturned.

\(^{e}\) This lack of any form of carriage or mounting appears also in another drawing, which depicts the death of the Ming general Liu Shing\(^o\) in +1619. On the whole campaign of this year see the paper of Huang Jen-Yü (f).

\(^{f}\) Two of them can be seen firing, in the top right-hand corner of the picture.

\(^{g}\) Besides these, there are thirteen bird-beak muskets to be seen.

\(^{h}\) The Chinese were here commanded by a general named Ma Lin\(^p\), and this may well be part of the battle of +1619 in which he was killed.

\(^{i}\) De Bredt, however, is sure that they were wheels, and that most, if not all, of these field-guns were leather-wrapped.

\(^{j}\) Besides the field-guns, nine bird-beak muskets, some double-barrelled, are to be seen.

\(^{k}\) As in most of the other drawings, the field-guns are all breech-loaders, though no spare chambers ever appear.

\(^{l}\) 唐應乾 \(^m\) 鄭宗顯 \(^n\) 劉綱 \(^o\) 立林
Fig. 153. Another drawing from the same work. TPSLT (nos. 4 & 6). Manchu archers, both mounted and on foot, are attacking frontally a Ming battery commanded by the general Phan Tsung-Yen, who is himself seen in the top left corner, while Nurhachi is depicted opposite at the bottom on the right. Besides the field-guns with their shields and the pronged muskets, several guns are simply resting on the parapet of the entrenchment, with an artilleryman about to fire one off with a brand in the left bottom corner.

Fig. 154. A group of Ming musketeers firing off their guns, while their commander, Kiang Ying-Chhien, is to be seen behind them on the right. At the top there are more lightly armoured swordsmen with round shields.

From TPSLT (no. 6).
Fig. 155. Another mounting for field-guns in early 17th-century China; they are carried upon 'carpenter's bench' supports (cf. Figs. 82, 83, 106). These may have had wheels, but it is more likely that the legs simply ended in round flat feet, so that the mobility was very limited. In this picture (TTSLT, no. 3), the Manchu cavalry is overrunning a Ming battery commanded by Ma Lin, and it may be the very battle of 1619 in which he was killed. In this illustration the pronged muskets are again visible, and a couple of the trestle mountings have been overturned in the mêlée.

Fig. 156. Prongs still in use on muskets in 1860, a drawing from Hutchings' California Magazine for June of that year, p. 555. Ref. courtesy of Michael Rosen. The prongs are shown erroneously, however; they were evidently intended to help aiming when firing over a parapet or on the ground, and should therefore curve in the same direction as the butt (cf. the TTSLT illustrations). The present artist was not the only one who fell into this mistake, for it was also made in the illustration of Allom & Wright (1), vol. 1, opp. p. 87 in 1843, depicting a military guard-station at Thung-chang-fu on the Grand Canal. Cf. Vol. 4, pt. 3, Fig. 718 above.
the artillery of China in the early +17th century than from these drawings.\textsuperscript{a} The world of learning has perhaps been unduly dazzled by the cannon of the Jesuits, so that the real achievements of the indigenous artillery have been somewhat overlooked.

All through the +16th and +17th centuries artillery was very prominent in the Chinese culture-area. One can see this from the many memoirs of adventures and narrow escapes in those troubled times, especially when the Manchus were fighting the remnants of the Ming, and both were in arms against the popular leader Li Tzu-Chhêng\textsuperscript{4} and the tyrant of Szechuan Chang Hsien-Chung\textsuperscript{5}. They constitute a whole genre of literature. For example, Shen Hsin-Wei\textsuperscript{6} went with his father to Szechuan in +1642 at the age of five, then later his father was martyred by the tyrant, and he spent the rest of his youth escaping from manifold dangers, as he tells in his \textit{Shu Nan Hsî Lüeh}\textsuperscript{7} (Records of the Difficulties of Szechuan), by which he meant something equivalent to our own +17th-century phrase: 'battle, murder, sudden death and other inconveniences'. In this book there are many references to gunpowder, gunfire and cannonades.\textsuperscript{8} Another writer, Huang Hsiang-Chien\textsuperscript{9}, who described a decade of peregrinations escaping from combat zones (+1641 to 51), speaks in his \textit{Huang Hsiao Tzu Wan Li Chi Chhêng}\textsuperscript{10} of 'hearing the noise of cannon, and seeing the distant fire and smoke'.\textsuperscript{11} In another place, he says that 'the sound of gunfire was like thunder, shaking the very mountains and valleys'.\textsuperscript{12} Similar descriptions come in Pien Ta-Shou's\textsuperscript{13} \textit{Hu Houa Yi Sheng Chi}\textsuperscript{14} (Life Regained out of the Tiger's Mouth) of +1645, a book so called because after having devastated the tombs of Li Tzu-Chhêng's ancestors in order to stop his conquests, he actually fell into the hands of one of his commanders, but managed to escape therefrom.\textsuperscript{15}

Nor was the age lacking for inventors, such as Ong Wân-Ta\textsuperscript{16}, who presented improved firearms in +1546,\textsuperscript{17} while in the same year Chang To\textsuperscript{18} offered prototypes of four-barrel and ten-barrel guns made of bronze, and capable of a range up to 700 paces.\textsuperscript{19} In +1596 the judge Hua Kuang-Ta\textsuperscript{20} presented further gunpowder-weapon inventions made by his father.\textsuperscript{21} There were also great artillery generals such as Chi-hen Lin\textsuperscript{22}, who was prominent during the second conquest of Korea by the Japanese in +1597, and fought some decisive naval battles.

\textsuperscript{a} Further information on the early Manchu use of artillery can be obtained from Tanaka Katsumi (1). He fixes the first use in +1668, and says that it was very prominent in +1644/5, but much less so in the war against Koninga (Chhêng Chhêng-Kung\textsuperscript{23}), who apparently made little use of field-guns. Tanaka noted that the artillery arsenals were always under the Eight Chinese Banners.

\textsuperscript{4} Cf. Struve (1), pp. 346, 362.
\textsuperscript{5} E.g. pp. 46, b, 35, h, 39b.
\textsuperscript{6} P. 4b. \textit{Fu Chuan}, p. 3b. \textit{Ibid.} P. 6b.
\textsuperscript{7} Cf. Hummel (1), p. 74.
\textsuperscript{8} Ming Shih, ch. 97, p. 1:4b.
\textsuperscript{9} \textit{Ibid.} \textit{Ibid.}

\textsuperscript{10} 李自成 \textsuperscript{11} 沈起龍 \textsuperscript{12} 顯嘉 \textsuperscript{13} 黃向察 \textsuperscript{14} 蘇龍 \textsuperscript{15} 莊元 \textsuperscript{16} 黃時 \textsuperscript{17} 黃顯 \textsuperscript{18} 黃少 \textsuperscript{19} 黃氏 \textsuperscript{20} 黃氏 \textsuperscript{21} 黃氏
\textsuperscript{22} \textsuperscript{23}
during their withdrawal. A typical Fukien warship of this time (parallel those that fought the Spanish Armada at the other end of the Old World) carried one heavy cannon (a kung), one mortar (huo tuih pho), six large culverins (fo-lang-chiu), three falconets (wan khou chhung), and sixty fire-lances (phin thuang), doubtless to repel boarders or set fire to the enemy’s sails and rigging, and finally a number of shen chii chien, probably arrows shot from guns. Another Chinese gunner officer who distinguished himself in these campaigns was Lo Shih, who successfully defended Chiang-hua against the Japanese, and repulsed an attack by 500 of their ships upon the port-town of Phu-khou using shore-based artillery.

The following century also produced some notable inventors. We may give the life-story of just one, Tai Tzu. His biography runs as follows:

Tai Tzu, whose other name was Tai Wen-Khia, was a Chihien-thang man from Chekiang. His remarkable ingenuity appeared even while he was still young. He himself made a gunpowder weapon which could hit a target at more than a hundred paces away.

In the beginning of the Kiang-Hsi reign-period (+1673) Keng Chung-Chung rebelled in Chekiang, and Prince Gyi Chieh (Chieh-Shu) led a government army south to overcome the uprising. Tai Tzu as a simple commoner or private joined this army, and presented a design for a rapid-fire machine-gun (liyen hou huo chhung). Its shape was like that of a balloon-guitar (phi-pho). The gunpowder and lead balls (kau hau, chhien wou) were all contained within the back of the gun, which was opened and closed by the hand. There were also two parts fitting into each other like male and female. If one lever was pulled the gunpowder and lead bullets fell automatically into the barrel, whereupon the other mechanism followed suit and moved all together (sui chih pung tang). The flint was struck, the spark came out, and the gun fired off accordingly. After twenty-eight rounds, the magazine had to be refilled with bullets. The design was in principle similar to that of the guns of the Westerners (chian kuan chiang). But the weapon was not at that time widely used, and the prototype was kept at Tai’s home. This was still in existence during the Chihien-Lung reign-period (+1736 to 95).

When some Westerners presented ‘coiled intestine (helical screw) bird guns’ (phaen kung-fung), Tai Tzu copied a number of these at the request of the emperor. Ten of his make were presented to the Western officials.

Tai was also commissioned to design and make a ‘mother-and-son’ cannon (tsu mu pho). It fired a projectile which burst and sent forth other projectiles that all fell down upon the enemy (mu tung to erh erh li). It was rather like a Western morter (tsa pho). The emperor, accompanied by all his ministers, watched a demonstration of it, and honoured the device with the name ‘Awe-inspiring Far-reaching General’ (Wei Yuan Chiang-Chin). The name and title of the inventor and maker was inscribed on the back of the cannon. When later the emperor personally commanded in the campaign against Galdan, this weapon was among those used to defeat the enemy.

Because of (his part in the expeditionary force of Gyi Chieh against Keng), when national authority was restored over the territory, Tai Tzu was given the title of ‘Acting Circuit Governor’ (T’ai Yuen Ta Fu Shih). Returning (to the capital) he had an interview with the Kiang-Hsi emperor, who recognised his literary ability and examined him on the poem ‘Dawn Audience in Springtime’. So he was given a post in the Han-Lin Academy as Expositor (Shih Chiang), and (then), together with Kao Shih-Chi, was seconded to the Nan Shu Fang (as one of the emperor’s secretaries), and later to the Yang Hsin Tien. *Tai was expert in astronomy and mathematics, but when the Lü Lu Chiang (Collected Principles of Acoustics and Music) was being edited, his views were not in agreement with those of Nan Huai-Jen (Ferdinand Verbiest) and the other Westerners. So everybody envied him, and was at the same time jealous of him.

Unfortunately there was a person named Chhen Hung-Hsien, who had been a foster-son of Chang Hien-Chung, but switched his allegiance and became an official under the Ching. This man accused (Tai) falsely, and it came to blows, so the matter was taken to court, giving Tai the opportunity of avenging himself; thus he lost his office, and was exiled to Kuan-tung. Later he was pardoned and went home, where he stayed at Thieh-ling for the rest of his life.

Thus was a remarkable talent wasted. How striking it was that when the Kiang-Hsi emperor saw that he was literate, and called him into his direct service, all he could think of was to examine him in poetry. His scientific and technical ability was evidently considered quite secondary, and even so it got
him into trouble in due course. One is very much reminded of the story of Ma Chün, the 17th-century engineer and inventor, which we told earlier on. Even in our own time and in the Western world, four centuries after the Scientific Revolution, the only avenue of promotion in technical services is all too often from ‘blue-collar’ practice to ‘white-collar’ paper-work. If we look at Tai’s inventions in order, we see that the first must have been some kind of quick-firing machine-gun. It was at a time when people everywhere were trying to make devices of this kind—for example, in Samuel Pepys’ Diary for 3 July 1662 we read that the attention of the Royal Society was drawn to a ‘rare mechanician’ who claimed to be able ‘to make a pistol shooting as fast as it could be presented, and yet to be stopped at pleasure, and wherein the motion of the fire and bullet within was made to charge the piece with powder and bullet, to prime it, and to bend the cock’. But the problem was not practically resolved till 1718, when James Puckle developed his breech-loading gun with a revolving set of chambers which could fire sixty-three shots in seven minutes. Thereafter the line led straight to the multi-barrel ‘pepper-box’ pistols and revolving ‘coffee-mill’ guns of Ethan Allen (1837) and others, whence to the Gatling gun of the American Civil War (1861) and the Maxim gun of 1889. Chinese antecedents for Tai Tsu’s efforts are easy to find, for we have already described (pt. 6, 2, iv) the magazine crossbow, widespread in the 17th-century Ming use, as also (pp. 269–77) the magazine eruptor, which may well have been common considerably earlier, indeed back to +1410 or even +1350. All the same, we should very much like to have further details about Tai Tsu’s guitar-shaped machine-gun. 

The second of his exploits is more difficult to pin down, but it could have been some kind of screw-chamber breech-loader. If it was a variety of musket, as one might at first sight suspect from the name ‘bird-gun’, a screw of one sort or another was evidently involved. Here rifling would not come altogether amiss.

The rotational stabilisation of a projectile’s flight by endowing it with a spin, due to spiral grooves contrived inside the barrel, may go back to Leonardo, and in any case began to be fairly frequently used by gunsmiths from about +1500 onwards. A number of examples have survived from the second half of the +16th, and from the following, century. These however were sporting guns, and general military use did not come in until the American War of Independence, from the late +18th century onwards. Still, it is not at all impossible that rifling was what interested Tai Tsu at this point, the text says ‘bird’, not ‘bird-beak’, so it might well refer to the use, rather than to the shape of the cock or butt, hence perhaps the presentations to the ambassadors or officials, to please them in their fowling.

The third and last of his designs was fairly clearly a shell-firing cannon, for the projectile burst and released other projectiles, falling down like the shower of sparks from a firework rocket. Shells had been known in Europe since the +15th-century, Feuerwerk, probably of +1437, and they are also described in Valturio’s De Re Militari of +1450. Moreover, we met with them already in China in connection with eruptors (p. 264, cf. p. 317), which would take them back to the +15th, if not the +14th; and it was only a logical development from the ‘thunder-crash’ bombs with iron casings (p. 170 above), which were older still. It was only to be expected therefore that people in China should by this time (+17th century) have been experimenting with shells. They finally came into their own in a memorandum addressed to the emperor Lin Tse-Hsi¹ in 1846, entitled Chu Pha Fa. But it is interesting (and certainly not generally known) that shells or shrapnel of some kind were used by Khang-Hai’s artillery in the war against the Eleuths at the end of the seventeenth century. 

 Mention of the period of the Opium Wars reminds us that an important gun-founding invention was made at this time by a pioneering Chinese engineer, Kung Chen-Lin, some thirty years before its adoption in the West. This was
the casting of iron cannon in cast-iron moulds (1845), as described in his Thieh Mu Thu Shaw the following year. Rather earlier, about 1830, a Japanese metalurgist named Sakamoto Shunji had described cannon-founding in his Taihô Chūzôhô, with illustrations in traditional style, showing tatara bellows and the boring of the barrels, but his moulds were still of sand.

Kung Chen-Lin's invention was all the more piquant in that cast-iron moulds for making iron tools had been known and used in China anciently, as the 4th-century finds from Hsing-lung in Jehol bear witness. Such moulds are in wide use still today, since they have the advantage of producing a chill casting with increased hardness and resistance to wear. To avoid any risk of adherence of the casting to the mould, a dressing of plumago or lamp-black is usually applied, but this is probably not essential as long as the volume ratio of mould to cast metal is sufficient to avoid undue mould heating and damage. This was an astonishingly high development of metallurgical technology for the Warring States period, and it was remarkable that it should have appeared again at the other end of history. Afterwards the same process was announced in 1873 by three inventors simultaneously, Lavrov in St Petersburg, Uchiatius at Vienna, and Rosset at Turin. Of course, cast-iron moulds or 'coquilles' had been used for casting iron cannon-balls in Europe from +1514 onwards, a practice seemingly introduced by François Gilbert of Dijon. The rapid cooling of the surface layers gave the skin a white (ferric carbide) quality, hardening it and increasing its efficiency of fragmentation. But this was a much simpler matter than the casting of cannon themselves.

There is one last brilliant innovation which calls for description here, and that is the use of telescopic sights with artillery, or perhaps it would be better to call them spotting telescopes. Knowledge of this arose when we discovered in the Wu Hsien Chih (Local History and Geography of Suchow) a remarkable account of two 'optick artists' of that city—Po Yu (active between +1628 and +1644) and Sun Yün-Chhiu (active between +1650 and +1660). Of Po Yu it is said that in the Chhung-chên reign-period (+1628 to +1643), when the rebels invaded An-Ching [i.e. Anhui province] the Provincial Governor Chang Kuo-Wei commissioned Po Yu to cast bronze cannon. This had a range of 30 li, and whenever they were shot off they did great execution, because the gunners had telescopes (chhien ti chhêng), which showed just where the enemy had concentrated his forces.

These rebels must have been the revolutionary peasant armies under Li Tzu-Chhêng, which eventually succeeded in overthrowing the effete government of the last Ming emperor, and capturing Peking; only to be defeated in their turn by the general Wu San-Kuei who opened the gates to the Manchus from the north with the intention that they should help him to recover the country for the Ming. As history so well knows, they took over the empire for themselves.

Po Yu had other connections with military technology, for he made explosive mines (ti lei) and spring-trap guns (ti nu), both said to be very effective. As for the younger man, Sun Yün-Chhiu, he was also a maker of telescopes, as the Wu Hsien Chih records, but there is no reference to his use of them in a military context. However, he wrote a book on optical instruments with the title Ching Shih, though it seems never to have got into print.

Po Yu may actually have been one of the several inventors of the telescope, but in any case he deserves much credit for applying it to gunnery, and that must have happened about +1635. This seems to precede by some time any similar application in Europe, though Galileo in +1590 was already aware of the possible use of the telescope in naval warfare, as he demonstrated in a famous incident to the high officials of the Signoria in Venice. Later in the same century optical sights were proposed by the Jesuit Francesco de Lana, in his Magisterium Naturae et Artis of +1644; and the application of a four-lens telescope to a gun was described in the Ocularis Artificialis Teleopicus of Johann Zahn in +1702. After that, telescopic sights figure throughout the 18th century, and Frederick the Great in his diary recorded trying one at a Schützenfest in +1737. By the mid-nineteenth century they were commonplace. But the first date after Galileo's forecast of what the telescope could do in war remains the time when Po Yu introduced his optical equipment for artillery in China, +1635. It was certainly a memorable day.

Of the skill and gallantry of Chinese gunners through the ages nothing has been said, and perhaps a history of technology is not the place for it. But we cannot forbear from quoting a couple of statements from Lt. Ouchterlony, a Scottish soldier who wrote an account of what he saw during the Opium Wars. For example:

In the earlier period of the war in +1840, Her Majesty's brig Algerine, commanded by Lt Mason, was on her way to the mouth of the Yang-tse-kiang, in company with the Connay frigate, and paid a flying visit to the port of Chapoo, upon which occasion a fire was opened upon her from some works near the town, which was well sustained for some time, during which the coolness and steadiness of the Chinese gunners excited much applause from the officers and crew of the brig. But the Algerine, having anchored with
her broadside bearing on the battery which annoyed her, shortly silenced its fire, and having fulfilled the object of examining the sea defences of the place, made sail for her point of rendezvous.

And again, with reference to the bombardment of the batteries of 'Ko-lang-soo':

The engagement was a fine spectacle, but beyond thepicturesqueness of the scene afforded no point worthy of comment, save that it furnished strong evidence of the excellence of the Chinese batteries, upon which the fire of the seventy-fours, though maintained for fully two hours, produced no effect whatever, not a gun being found disabled, and but few of the enemy killed in them when our troops entered. The principle of their construction was such as to render them almost impervious to the effects of horizontal fire, even from the 32-pounders of the seventy-fours, as, in addition to the solid mass of masonry, of which the parapets were formed, a bank of earth bound with sods had been constructed on the outer face, leaving to view only the narrow mark of the embrasure.

(iii) Shields, 'battle-carts' and mobile crenellations

In Figs. 150 and 153, taken from the Thai Tia Shih Lu Thu, we have already seen pictures of the shields, presumably of iron, which protected the men who worked the field-guns, mostly on the Ming side, during the first quarter of the +17th century. But shields adapted to the uses of fire-weapons did not begin with guns and light cannon, they began with fire-lances (cf. pp. 236 ff. above).

This we know from an item called the 'mysteriously-moving-planx-breaking fierce-flame sword-shield' (shen hang hong chen ming hau tao phai)—a rather enigmatic description the meaning of which will in a moment be clear. In the Hwo Lung Ching we read:9

The apparently automatic fierce-flame-spouting' shield for use with cutlass-wielding soldiers to destroy enemy formations, is covered with fresh ox-hide. In it are concealed thirty-six (fire-lance) tubes, containing magical gunpowder, poisonous gunpowder,

1. The* broadside bearing on the battery which annoyed her, shortly silenced its fire, and having fulfilled the object of examining the sea defences of the place, made sail for her point of rendezvous.

2. The engagement was a fine spectacle, but beyond the picturesqueness of the scene afforded no point worthy of comment, save that it furnished strong evidence of the excellence of the Chinese batteries, upon which the fire of the seventy-fours, though maintained for fully two hours, produced no effect whatever, not a gun being found disabled, and but few of the enemy killed in them when our troops entered. The principle of their construction was such as to render them almost impervious to the effects of horizontal fire, even from the 32-pounders of the seventy-fours, as, in addition to the solid mass of masonry, of which the parapets were formed, a bank of earth bound with sods had been constructed on the outer face, leaving to view only the narrow mark of the embrasure.

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5. **On these forms of gunpowder see p. 110 above.

6. The passage (Sing Shih, ch. 98, pp. 153, 164) is given in translation by Elbeck (44), pp. 255-6, who, as a Greek himself, was inspired by the resemblance to the Hiongkung of the Hsiuhsan (pp. 379-81); cf. p. 421 below. Unfortunately, he translated phai as 'pique', presumably 'dartillerie', instead of trebuchet. However, the main thrust of his paper was against true guns or cannon at that time.

7. Chih Shih, ch. 57, p. 34, Yang Hsung (1), pp. 92-3, and Bootheil (45), pp. 2, 6, translating from a source supposedly Thang. The name obviously derived from the fact that all sides bristled with defences when the vessels formed a circle or a square.

8. Tae chi seng, ch. 6, pp. 86, 90.
before at least as early as +1350 and probably used long before that. It is the 'mysteriously moving phalanx-breaking fierce-flame sword-shield' (wén hóng jī fān yǐng hòng lòu lùn shí). The fire-lances are stated to contain the usual rocket-composition (low-nitrate) gunpowder, but the title suggests a Greek Fire flame-thrower behind the shield. This last must have been mounted on wheels, and was certainly accompanied by swordsmen on either side.
drawn by mules, and carried screens which could be folded out to a length of 15 ft, thus forming a continuous battlement, only the hinged ends of each allowing for the ingress or egress of defending soldiers whether on foot or mounted. Twenty men were assigned to each battle-cart, ten of them manoeuvring it into place and firing the muskets or breech-loading fo-lang-chi culverins which it carried, the other ten forming an assault team with close-combat weapons.

* In many of the pictures which we reproduce it can be seen how the trail of a field-gun developed from the shafts of the two-wheel barrow on which it was originally borne.

A closer view of one of these battle-carts is given (Fig. 160) in a slightly later book, the Ch'ih Chhiung Thu¹ (Illustrated Account of Muskets, Field Artillery and Mobile Shields) dating from about +1385. In Fig. 161 we see a breech-loader, the barrow on which it was carried, and three of the chambers (here called t'ai-pan²) for the charges and projectiles. Finally, Fig. 162 shows two of the screens, with some men ready to shoot off their muskets, while others get ready to fight.

¹ Ch'ih Chhiung Thu
² t'ai-pan
with swords.1 We have already seen one or two illustrations from Chao Shih-Chén’s2 book, in Fig. 56 above, for fire-lances were still in use in his time, contemporaneously with the siege of Malta. The book by Chhen Phé3 must belong to this same date, as one can see from its title Huo Chhí Chen Thu Shao4 (Illustrated Account of the Formations in which Mobile Shields can be used with Guns and Cannon).5

A rather different tank-prototype can be seen in some of the illustrations in the Thai Tzu Shih Lu Thu of +1633, namely mobile ramparts borne on two wheels and pushed by two men using four poles, with a platform on which a couple of musketeers could fire through crenellations (Fig. 163). This picture shows the defeat of the troops of Tung Chung-Kuei6 by Nurhachi’s men, but the former are not visible, and the platforms are in the act of being overtaken by the Manchu cavalry and mounted archers. By now the Manchus too are using muskets.7

Lastly a word must be said about the ‘rapid thunder gun’ (túnh chih lung8) described in the Shen Chhi Phu9 of +1598, also due to Chao Shih-Chén. Five barrels were fixed through a round shield, with a rotating stock in their midst which would bring the serpentine into five separate positions for touching off each barrel in turn (Fig. 164).10 This ribaudequin itself is seen in an accompanying picture (Fig. 165). While firing, this multiple matchlock musket rested on the handle of an axe fixed in the ground, and the end of the stock took the form of a pointed spear, so that the soldier could defend himself with these weapons if the worst came to the worst. The barrels were only about 2 ft long, and each one was provided with its own fore-sight and back-sight. A model reconstruction is seen in Fig. 166.11 This arrangement is very reminiscent of the discoidal pistol-shields used by Henry VIII’s bodyguard and now in the Tower of London Armouries (Fig. 167), each shield having only one matchlock barrel at the centre.12

This discussion of shields has taken us into the territory of small arms such as muskets, as well as that of field-guns and artillery. We must now turn our attention briefly to the former subject in particular.

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1 The laager tactics of the +16th-century Chinese armies are irresistibly reminiscent of the methods of the great Hussite general Jan Ziska in Bohemia and Germany during the first half of the +15th. The ‘battle-wagons’ which carried cannon as well as folding ramparts of oak, and linked up to form a defensive square, circle or triangle upon the word of command, brought the Hussites and Taborites great success for many years; cf. Oman (1), vol. 2, pp. 361 ff.; Delbrück (1), vol. 3, pp. 497 ff. Denis (1). But the inspiration for the Wageningen seems to have come from Russia, where the gelagteg or movable city had been known and used long before. If this was so, could it not have been originally Mongolian? Perhaps further research will show that both Ziska and Chi-ki-Chuang had both the same root.

2 Half (2) says that the M3 of the ‘Anonymous Hussite’ dates not from +1439 as usually thought, but consists of two parts, dating from +1470 and +1490 respectively, therefore after Tacosco and Fontana. But this does not affect the present argument.

3 In Wang Ming-Huo’s Hsiao Kung Wén Tsu of +1458 too, much is also said of gun-carriages and mobile shields forming laagers (pp. 306 ff.).

4 Another illustration in ch. 6 also shows these platforms, depicting the defeat of the Ming troops of Chhen Tsyu13.

5 P. 128. 6 By Mr S. Vido of Brisbane, Australia. 7 Reid (1), p. 107; Blackmore (4), p. 14.
Fig. 163. Mobile crenellated rampart platforms used by the Manchu troops (musketeers now as well as archers) in their defeat of the Ming brigade under Tung Chung-Ku, c. +1620. From TTSLT, (no. 8).

Fig. 164. The 'rapid-fire thunder gun' (hsin lei chhung), a five-barrelled ribaudequin fired by a Ming gunner protected by a shield. From Shen Chhi Phu, p. 22b (+1598).
(18) **Later Developments in Hand-Guns; the Arquebus and the Musket**

(i) *Matchlocks, wheel-locks and flintlocks*

Before taking a brief view of the later history of portable fire-arms in China it is well to be clear about what happened in Europe, between the simple hand-guns of the +14th and +15th centuries, and the era of the cartridge and percussion-cap from the end of the +18th century onwards. This was the period of the arquebus and the musket. The simplest hand-guns, which go back in China, as we have seen (p. 294) into the last decades of the +13th century, consisted of nothing but the muzzle-loaded barrel, the touch-hole for the slow-match, and a socket with a wooden handle (the tiller) fixed into it. They must have been exceedingly difficult to hold, aim, and ignite effectively, all at the same time; so that from about +1400 a Z- or S-shaped lever (the serpentine) was pivoted in the stock (which now began to be shaped to fit the shoulder) in such a way as to bring the burning slow-match (which it held in its jaws) near to the touch-hole (or priming-pan, filled with gunpowder, just above it). The oldest depiction of this dates from +1411. All the technical terms are a little vague, partly because

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*a* See Blackmore (1), p. 9; Reid (1), pp. 58–9. This was the origin of all triggers.

*b* Hence the idiomatic expression 'a flash in the pan'—just that and nothing more.
their contemporary use fluctuated like that of all pre-modern terms, and partly because of the variable uses of modern gun historians; but 'arquebus' belongs somewhere here, though in fact the name arose, with all its variants (such as hackbut, hargabush, etc.) from the German Hakenbüchse, i.e. a hand-gun with a hook-like projection or lug on its under surface, useful for steadying it against battlements or other objects when firing.a

a) It thus had nothing to do with Latin arcus or arbalistes, as some 17th-century etymologists thought.

Although the match was thus held in a holder, and moved to ignite the charge at will, the true matchlockb had not yet been born. The ingenuity of the locksmiths was still needed to fashion it, and this they effected from about 1475 onwards. The smouldering match was now held by some kind of vice at the head of a curved lever called the cockc (which could face either forwards or backwards according to the design), and which was connected with the trigger by a series of

b) See Blackmore (I), pp. 10 ff., 12 ff.; Reid (I), pp. 60-1, 132, 134-5; Pollard (I), pp. 6 ff.

c) On the locksmith’s art see Vol. 4, pt. 2, pp. 265 ff. Hall (5), p. 354 well emphasized the close relation of gun-locks to door- and coffer-locks, with their frame-plates, springs, levers and fixing-pins. One would like to know more about the social relations of musketeers and locksmiths at that time.

d) Hence the idiomatic expression ‘going off at half-cock’, for forcible–feeble actions.
detents, working in many different ways, but generally including springs, ear levers, tumblers, notches, lugs and the like. By about 1575 a trigger-guard was often added. The earlier form was known as a snap-matchlock because the cock was forced down on to the priming-powder by a spring; the later, sauerform, or sear-matchlock, had a spring which held the cock back until the trigger was pulled and a catch dislodged. In the 16th century matchlock muskets were heavy, weighing up to 20 lb., and had to be fired from a rest, i.e. a wooden pole with a Y-shaped piece of iron at its upper end.

The matchlock system lasted on a very long time, as we shall see, but it was deeply unsatisfactory if only because of the problem of keeping the slow-match (generally a hempen rope saturated with saltpetre) glowing in damp or wet weather. This was therefore thrown aside in favour of striking a spark each time from flint and steel. Two systems came into existence almost but not quite contemporaneously, first the wheel-lock from about 1550 onwards, and then the flintlock from about 1550 onwards. In the wheel-lock the V-shaped spring was connected by a chain to the spindle of a wheel, which, on being released, rotated very like that in a modern cigarette-lighter, and struck sparks from a piece of steel pyrites held in the jaws of the cock. Since there was no small danger that one would lose the key for winding the mechanism up again, a rack-and-pinion device was presently developed to give a self-spanned wheel-lock. But the wheel-lock system was always rather costly, sometimes including as many as fifty separate components.

As for the flint-lock musket, it did away with the wheel, and arranged for the cock to hold a flint (in its screw-jaws) which came down upon a piece of steel, and ignited the powder in the priming-pan by the sparks so struck off. We can now use the word 'musket' without hesitation because it came into use first about 1550, and lasted on into the nineteenth century. The piece of steel (also called hammer, battery or frizzen) was therefore developed to give a self-spanned wheel-lock. But the wheel-lock system was always rather costly, sometimes including as many as fifty separate components.

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of the wheel-lock, were a considerable help against rain or mist, and as the flintlock was a good infantry weapon, it completely displaced the matchlock by 1725 or so. In a similar way, the wheel-lock had been the limiting factor for cavalry pistols and carbines, as was seen in the English Civil War of the mid-seventeenth century.

Of course all the weapons we have been discussing were muzzle-loaded, and the application of the breech-loading principle to portable firearms came about only slowly. True, Leonardo had sketched an arquebus with a screw-on chamber in the Codex Atlanticus, but the idea was not very practical, and the first breech-loaders were wheel-lock guns of about 1650. In these the barrel was unscrewed, hence the name 'turn-off' muskets. Only in China, so far as we know, were chambers like those of the fo-lang-chi culverins applied to portable guns (p. 380 and Figs. 143, 144). All this meant that the matchlock and even the two spark-producing types were very slow in firing, one round in 5 to 15 minutes depending on the skill or clumsiness of the musketeer. Of course this could be compensated by having large numbers of them, like the 10,000 at the Battle of Nagashino in Japan in +1575.

(ii) The musket in China and Japan

What happened with artillery now happened with portable firearms too; the improved devices of the Western world were transmitted, and in more ways than one, to the Chinese culture-area. The usual view has been that matchlock muskets of Portuguese origin were acquired by the Chinese military from Japanese pirates (see kow) on their coasts about +1548. Indeed, Chi-Hi-Kuang says so clearly. These raids were very severe throughout the fortes and fifties of the century; in +1546 and +1552 much of Chekiang was devastated, in +1555 Suchow and Nanking were besieged, and in +1562 there was much fighting in Fukien. Evidently we need to take a close look at how the Japanese themselves had acquired these muskets.

It seems historically established that in the year +1453 two Portuguese adventurers were shipwrecked on the island of Tanegashima, just south of the southernmost tip of the Japanese mainlands. We can identify the name of one of

* A sort of sear implies locks and bolts, from OF seer, serrer.
* Allegedly +1575, but however this may be, Leonardo da Vinci was making drawings of flint-and-steel gunlocks as well as tinder-lighters by about +1520. Of course the idea took time to spread. See Blair (1).
* By a screw-tightened vice, interesting because it was the second principle of fire-arms. The first had been the screw-in breech (p. 438). A third seems to have appeared in China (cf. p. 410 above).
* The rack-and-pinion appears again, also in a different context (p. 446 below).
* As Blackmore (4), p. 61 has pointed out, the French word for any gun, fusil, comes from the Ital. fusill, meaning a piece of steel for striking sparks from flint, cognate with L fusill.
* The name originated from Ital. mastichetta (sparrow-hawk), a word alluded to mosquito, from Lat. musca, a fly.
* They were still being made in Napoleonic times, e.g. 1810 (Reid (1), pp. 168 ff.), and for tripod spring-guns even later (ibid. p. 168).
* From Dutch snaaphaak, Ger. Schnapphahn, the action of a pecking hen, so similar to the motion of the cock as it descended.

+ A sort of kow implies locks and bolts, from OF kować, serrer.
+ Allegedly +1575, but however this may be, Leonardo da Vinci was making drawings of flint-and-steel gunlocks as well as tinder-lighters by about +1520. Of course the idea took time to spread. See Blair (1).
+ Liu Ping Shih Ch' (Tue Ch), ch. 5, p. 243 (p. 239). This was in +1668 CE Huang Jen-Yu (2), p. 165, 250. Lang Ying, in Chi Hsin Li Kao, ch. 45 (p. 660) makes the same statement, perhaps rather earlier, say +1585.
+ Cordier (1), vol. 4, pp. 60-1.
+ The best account is that of Arima (1), p. 67 ff. CE. Boxer (2), p. 96 ff.; Perrin (1), p. x. The earliest Portuguese version, that of Fernão Mendes Pinto in +1514 (see Vol. 4, pt. 3, p. 335) is considered to be partly fictional.

1 長崎 2 善政 3 棒子島
them, Kirishitadamōta, as Christopher da Mota, the name of the other remains only in Japanese, Murashukusha. The matchlocks which they carried, explained and demonstrated, interested greatly the lord of the island, Tokitaka, and largely through his efforts only a few years passed before the Japanese smiths were able to make such matchlocks themselves. At first they were called by the name of the island, but soon the expression 'ippō (thief phao)' became universal. All this information comes to us partly from an almost contemporary source, the Tippe'ki (Record of Iron Guns) written by a monk, Nampo Bunshi, in +1606 though not printed till +1649. Exactly a hundred years earlier than this last date the great unifier Oda Nobunaga had ordered 500 matchlocks for his army, and in +1560 at the siege of Marune a Japanese general had been killed by a matchlock bullet. The weapon was thus by this time well established in the country.

The two Portuguese had earned a certain immortality, but one should not assume that their guns were the first which the Japanese had ever seen or known. There is some evidence that hand-guns in small numbers reached Japan from China during the +15th century, and a well-authenticated case is the presentation of a 'thief phao' to a feudal lord in +1510 by a Buddhist priest recently returned from China. By this time a hand-gun would be far more likely than a cast-iron bomb. It is interesting that the lord in question was Hōjō Ujitsuna, a doughty warrior and general but also a great proponent and establisher of peace throughout his extensive domains.

But how sure is it that the muskets of the Chinese were derived from Japan?

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30. THE GUNPOWDER EPIC

Quite a lot of information is available about the events of +1548, and Chén Jung, who was in a position to know, wrote only a dozen years later that they came direct from the Western barbarians (Hsi Fan) rather than the Japanese ones (Wo F'ê). In the year in question the Governor of Chekiang and Fukien was the Censor Chu Wan (+1494 to +1550), and under him he had an energetic young military commander, Lu Thang (+1530 to c. +1570). At a certain point this brigadier attacked a pirate lair at Shuang-hsû-kang near Tinghai, and reduced it, capturing many persons, including eleven Portuguese who had good muskets. They were merchants, but not above a bit of smuggling when convenient. Chu thereupon ordered the volunteer officers Ma Hsien to get the smiths to copy these guns, and Li Huan to have the proper powder for them made, in which matter they succeeded well, so that the new weapons were even superior to the foreign ones. Yet it is also recorded that in the same year there came an official Japanese embassy or tribute mission led by the Buddhist cleric Sakugen Shuryo (+1501 to +1579) and Chu Wan gave them very hospitable treatment. So the question can hardly be settled, though we suspect that Chén Jung knew what he was talking about.

There is another passage of Chén Jung which may be worthy of more notice than it has yet received. In his work of +1566 the Chiang-Nun Ch'ing-lüeh (Military Strategies South of the River) he wrote:

Our first emperor Thai Tsu (Chu Yuan-Chang), because of his remarkable military accomplishments, gained control of the whole Middle Kingdom. He possessed every sort of fire-weapon in existence from past to present, and kept them in his armories. Every year when the Magically effective Weapons Brigade (Shen Chi Ying) held its exercises, the names and appearance of most of the (weapons on display) were quite unfamiliar to the onlookers. And yet they were only several hundred types (out of what were stored in the armories). People nowadays all say that the fu-lang-chi cannon and the bird-beaked musket both came from foreign ships (i.e. from the Portuguese adventurers and the Japanese pirates respectively). But I once heard the Adjutant-Commander (Tsin Chiang) Chi Chi-Ch'üan say that when formerly he held a garrison post in Shantung he excavated a pit and found a fu-lang-chi cannon. The date could be checked from the inscription (on the barrel) showing the year and month when it was cast and kept (in the armory) of the Yang-Lu emperor Ch'üng Tsu (r. +1493 to 241). Again, he also found (some) bird-beaked muskets in the garrison armoury. So these things must have been already possessed by the Middle Kingdom before the time of the Japanese pirates.

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2. The Dominican Gaspar da Cruz gave an extended account of the incident, translated in Bosqy (1), pp. 193 ff., but says nothing about muskets. Law and administration seem to have interested him more than arms.

3. The mission was quite seizable, in four ships with more than 400 men.

4. It was noted by Wang Ling (1), p. 179, but without reference.

5. Ch. 8, p. 86, tr. 44, p. 390 above.

6. Ch. 6, p. 56, tr. 37, p. 399 above.
This is a rather precious relic of a conversation between the great geographer and the great general. There is no reason for doubting that Chhi Chi-Kuang found an old disused cannon in Shantung, and as we know from Table 1, there are plenty of inscribed artillery pieces from the Yung-Lo emperor's time still extant today; but Cheng Jo-Tseng must have understood him wrongly in supposing it to have been a breech-loader. On the other hand, although matchlock muskets could hardly have existed in the Yung-Lo reign-period, there is a suggestion here that in fact they were known in China before the Japanese-Portuguese contact, and indeed this will shortly appear.

From the first coming of the musket into southern China, it was dubbed the 'bird-gun' (niao chhung) or 'bird-beak gun' (niao tsui chhung). Sometimes the word chhung was reserved for guns with the shorter barrels, and those with longer ones were called chhiang. The term bird-beak must have been derived, one would think, from the pecking action of the cock that held the match, paralleling the term 'snaphance' which developed in the West (cf. p. 428 above). But there is some authority for the view that the reference to birds arose because of the use of muskets as fowling-pieces. It has also been supposed that the stocks, which tended in China to be short like pistol-grips (cf. Fig. 168), might have been likened to bird-beaks—but the cock derivation is probably the right one.

The first illustrations and descriptions appeared in two books printed in the same year (+1562), Cheng Jo-Tseng's Chhou Hai Thu Pien and Chhi Chi-Kuang's Chi Hsiao Hsin Shu. Fig. 168, taken from the former, shows the general view, and Fig. 169 the lock, of the bird-beak gun. The stock is called mu cha*, the spring and trigger kwei chhing, while the forward-falling cock is a 'dragon-head' (lung hou)† with the spring acting on its other end (lung wei)‡ after release from a sear lever (kou). Figs. 170 and 171 give further details. The touch-hole is called huo men§ and the fence or pan-guard huo men kai∥, while the ramrod is the chha

* As by Song Ying-Hsing in Tho Kang Khi Wu, p. 458 below.
† Davis & Ware (1), p. 536, got this right. Mayers (6), p. 98 had supposed that the name referred to the flared mouths of blunderbusts.
‡ See Chhi Chi-Kuang in Lien Ping Shih Chi (Tse Ch'i), ch. 5, p. 218, and Mao Yuan-I in Wu Pei Chih, ch. 124, p. 68. The latter book has a detailed description of the cock.
§ Ch. 15, pp. 36a ff. Similar illustrations with a different text are in WPC, ch. 124, pp. 24 ff. Cheng quotes Chhi at one place (p. 364) because the latter had been writing a couple of years earlier.
∥ Ch. 15, pp. 94 ff., with rather clear illustrations.

Note: This usage arose from the old Neo-Confucian identification of kou (anciently 'devil') with all forms of compression and contraction (cf. Vol. 5, p. 490). Shou (anciently 'spirit') comprised all forms of dispersion and relaxation.

This is the term later adopted in Chinese for a water-tap. One would have expected 'bird-beak' rather than 'dragon-head'.

From the diagrams in Figs. 169 and 170 it looks as though these locks were of the type known as snap matchlocks. Here the trigger is quite separate from the cock, and pulls back a horizontal sear which has previously retained its toe (or tail). The long-armed U-shaped spring which then drives the cock down can be well seen in both diagrams, though the artists did not draw the whole mechanism very clearly.

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Fig. 168. The 'bird-beak musket' (niao tsui chhung), an illustration of +1562, from CHTP, ch. 15, p. 368.
Fig. 169. The lock of the bird-beak matchlock muskets, with its system of springs, from CHTP, ch. 13, p. 37a.

Fig. 170. Another drawing of the same (CHTP, ch. 13, p. 37a). For explanation see text.
shuo chang.¹ The most curious feature is the screw, or ‘turning coiled silk-thread’ (lo sú chaun²) used for plugging the breech (hou men³). The illustration is similar to that in the Sun Tshi Thu Hui⁴ encyclopaedia (+1609) which we gave at an earlier stage, but pre-dates it by almost half a century. It is important because the screw was one of the rare mechanical devices not indigenous to Chinese civilisation, and its appearance here shows the careful way in which the musket was being copied. In flintlocks it found still another use, but the question of flintlocks in East Asia must be postponed for a few pages.⁵

Old Chinese matchlock muskets are rare in Western collections, but we can show one (Fig. 172 a, b) which is in the Maidstone Museum in England. In +1637 Sung Ying-Hsing gave an intelligent layman’s account of matchlock muskets and their making. He said:⁶

The bird-gun (niao chang⁷) is about three feet long, an iron pipe containing gunpowder, and inset in a wooden holder so that it can be conveniently grasped by the hands. To make the bird-gun tube, an iron rod of the size of a chopstick is used as the cold core, and three strips of extremely red-hot iron are forged and welded together around it longitudinally. Then the interior of the barrel wall is highly smoothed by drilling with a four-edged steel reamer of the diameter of a chopstick, so that frictional resistance to the discharge is minimised. The bore at the back end is larger than that at the muzzle, so that it can hold the gunpowder.

Each bird-gun is loaded with about 0·12 oz. of gunpowder⁸ and 0·2 oz. of lead or iron bullets. No fuse is used to ignite the gunpowder. (Comm. Except in South China sometimes but instead a ‘choking hole’ (kung hau chang ne⁹) is filled with gunpowder, and a slow-match made of ramie or hemp (chu hua)¹⁰ is employed for the ignition. The musketeer holds the bird-gun in his left hand, and points it at the enemy, then with his right

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¹ The fore and back sights above the barrel were chhiau kung¹¹ and lou kung;¹²
² See CHHS, ch. 15, p. 116, and even more explicitly WPC, ch. 172, p. 2. Cf. Blackmore (4), p. 9. It is curious because the Japanese gunsmiths consistently avoided using screws (Blackmore, p. 17); and this might be an argument for direct acquisition from the Portuguese. It is also curious because the screw-thread shown is left-handed, and you turned it to the right, not the left (as our common usage is), to screw it out.
³ Vol. 4, p. 2, Fig. 416.
⁴ Tangent-plane helical structures were, however, known and much used. Cf. Vol. 4, p. 2, pp. 118 ff.
⁵ Apart from the screw-plug of the breech, and the screws which held the tang or tangs of the barrel in place on the stock, the screw came in again as a vice to keep the fit tight in the jaws of the cock. Cf. Blackmore (1), pp. 17, 42 (4), p. 23.
⁶ See p. 453 below.
⁸ We cannot accept the term ‘bird-pistol’ used by Sun & Sun, nor the ‘flox-piece or spotting-gun’ proposed by Li Chhiao-Ping. Enemy soldiers are distinctly mentioned; furthermore, the illustration (Fig. 172 a, b) shows them.
⁹ Sun & Sun interpreted this as three sections of tube welded together end on, but this cannot be right.
¹⁰ One wonders whether it meant to say that the wall was made thicker at that point, as it had been in the earliest vase-shaped cannon (cf. p. 487 above), thus strengthening the explosion chamber.
¹¹ The word actually used here is hiau¹², nitre, saltpetre, but probably Sung was only using it in order to avoid saying gunpowder at all, according to the ‘principle of elegant variation’.
¹² One wonders whether this means that a serpentine was employed in the south at times, or even a free match rather than the developed matchlock.
hand he pulls the iron trigger (fa thiek chi) (of the gun-lock), thus bringing the glowing hemp to the top of the (touch-hole filled with) gunpowder. The gun then fires.

Sparrows and other birds when struck by the bullets within a distance of 30 paces are shattered all to fragments; but those more than 50 paces away are killed without being destroyed. At a distance of some 100 paces the force of the bird-gun is almost exhausted.

The long bird-gun (niao-chhiang) has a further range, about 200 paces. It is constructed in the same manner as the shorter bird-gun, but its barrel is of greater length, and it needs about double the amount of gunpowder.

More professional, one might say, were the comments of the general Chhi Chi-Kuang, who remarked that the only sound way to make musket barrels was to

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30. THE GUNPOWDER EPIC

Fig. 173. The bird-beak matchlock musket in use, a picture from TKWW, ch. 5 (ch. 15), p. 35b (Ming ed.). The Beiping enemy are probably Miao tribesmen.
forge together two pieces of wrought iron so as to make a tube with a very small bore. A steel reamer must then be used to drill the hole, working slowly and carefully so that only about an inch was drilled each day. The drilling should continue for a month until the whole bore was completed. Unfortunately, the supervising officials too often yielded to the complaints of the smiths (who were probably on piece-work wages), and let them make guns by rolling iron sheet into tubes. The resulting barrels were of uneven bore, and could only accommodate a lead bullet or bullets weighing 0·3 to 0·4 oz. All kinds of dire consequences would follow from this unevenness of the bore. The gun could even explode when fired. Moreover, the officials issued bullets of quite different sizes, some too big, even able to melt and block the bore, some too small, so that the explosive propellant force leaked past them, greatly reducing the range, and some so small that they would just drop out from the muzzle after loading. All in all, Chhi was very discontented with the work of the arsenals administration in his time.*

Next comes an unexpected turn—perhaps the first muskets to reach China were neither Portuguese nor Japanese, but Turkish? This possibility arises from the accounts of Chao Shih-Chên1 in his Shen Chhi Phu2 (Handbook of the Magically Efficient Tools, i.e. Muskets) finished in +1598. The background story takes us from the South-east to the far North-west of China, and it starts at the beginning of the +16th century. The people of eastern Sinkiang were Uighurs, mostly Muslims, of Turkic speech, and naturally had relations with the Islamic culture-area that reached as far West as the European Balkans, including old Byzantium, now Istanbul. In +1505 the Ming emperor conferred a title on Bayaji3, the Emir of Hami, but in +1513 he revolted against Chinese rule, in alliance with Mansûr4, Sultan of Turfan.5 In +1517 they occupied Shachow (Tunhuang), but after +1524 they were driven back across the Gobi Desert, and though the Chinese armies could not reduce the two city-states themselves, a stable agreement was made whereby Hami was recognised as subject to Turfan, but both princesoms paid tribute to the emperor, an arrangement which lasted till the end of the century.6 In the meantime, during the period immediately following these proceedings, there were a number of Ottoman Turkish missions to the imperial court, especially in the years +1524, 1526, 1543, 1544, 1548 (a fateful year, as we have just seen), and 1554.4

* This was a recurring failure of the bureaucracy, met with already in Sung times, as we may remember from p. 173 above.

1 Actually Turfan had annexed Hami, but the two rulers were as one against the Chinese. This was the context of the trouble about Sa'd Husain, and his execution (cf. p. 369 above). The Chinese court must have considered him a spy for Mansûr.

2 On all this see Cordier (1), vol. 4, pp. 48–50; Goodrich & Fang Chiao-Ying (1), vol. 2, pp. 1073–8.

3 Ming Shi, ch. 332, pp. 294, 302. They all came from Rûm (New Rome, Lu-Mi), i.e. Istanbul. Sinologists seem to have written remarkably little on these tribute-bearing embassies.

4 This cannot have been the famous Chên Yin, an officer of the same name, and Commander of the Embroidered-Uniform Guards, because he died in +1540.

5 Just under 100 yards. * This must have been about +1538.

6 This was probably Chên Chiu-Chou4.

7 Lu-Mi6 in RFC, ch. 124, pp. 94ff.

8 This would take us back to +1568 at least.

9 Turfan was constantly sending presents of lions to the imperial court, so the Pa family were more probably Sinkiang Uighurs rather than Asia Minor Turks.

10 Both Pa and To were characters that had long been used for translating Mongolian, Jurchen and Hsi-Hsia names; here they would apply to Chinese families of Turkish or Uighur origin.

In the Shen Chhi Phu1, Chao Shih-Chên says:4

During the 24th year of the Wan-Li reign-period (+1556) Chên Yin, a Regional Commander (Yu Chi Chiang-Chên)6 who happened to be in the capital, showed me a bird-gun (ning chuang) of the Western (Portuguese) foreigners. This was slightly longer than the Japanese (matchlock) musket, but its cock also went down after the trigger was pulled, and rose up again after firing. It used 0·1 oz. of gunpowder (and fired) a lead bullet 0·8 oz. in weight. The weapon was light and convenient, while compared to the Japanese musket its range was greater by 50 or 60 paces.5

I remember that it was during the days when my grandfather Chao Hsing-Lu7 was a Deputy Judge (Su Fu)8 in the Grand Court of Appeals (Ta Li Ssu), that the Japanese pirates (pipi ho)9 first trespassed upon the coast of Chikiang province, but they did not at that time possess any bird-beak guns; it was only six or seven years later that they had such weapons. My grandfather once spoke to me as follows: ‘I heard’, he said, ‘that during previous reigns the Turfan princeedom (Thu-Lu-fan)9 annexed its neighbour Hami (Ha-mi). The Middle Kingdom then appointed someone as Commander of an Expeditionary Force (Ching-Lieh Ta-Chên),15 who enlisted tens of thousands of soldiers, and went to the aid (of Hami) from several different directions. But because the Turfan troops were equipped with efficacious firearms from Rûm (Lu-Mi)12 our soldiers could not rescue (Hami), which ultimately fell into their hands. Now Rûm is near the Western Ocean regions (i.e. Europe) by sea. Could it be that this weapon was transmitted from there to the Western Ocean people, who in turn brought it to the Japanese?’

(What my grandfather said to me has been in my mind for thirty-year-olds.5 Last year I had an archery contest with (two friends of mine), the brothers Pa Chên12 and Pa Chung18. I only then came to know that their father Pa Pu-Li17 was a man of Lu-Mi himself, and had originally come to the capital to offer a lion as tribute, whereupon the Emperor let him stay (in China) without sending him back.18 I asked them about the bird-beak guns, and (Pa) Chên and (Pa) Chung (both) said that their adopted uncle To Sa-Ma18 had been an officer-in-command of firearms in that country, and that I could find things out just by paying him a visit. So I went one day with (Pa) Pu-Li to (To) Sa-Ma’s home.19 To gladly showed me a bird-beak musket which he had brought along from his country. I found that its mechanism was more convenient than that of the Japanese gun. Upon testing it, I observed that it had a longer range, and was several times more destructive than the Japanese musket, which made me very happy, for I said to myself that with this weapon the Japanese gun would find itself superseded. (To)
30. MILITARY TECHNOLOGY

Ssu-Ma also said: 'I have received great favour by being looked after all through three reigns and I have often worried that I could see no way to express my gratitude. I should be delighted if I could get an opportunity to spread the design (of this weapon), so as to add to the military power of the Imperial Court.' He then explained to me the technique of making (the Turkish musket).

After this I disbursed funds and employed smiths to manufacture this weapon. I showed the product to (To) Ssu-Ma and it met with his approval. During my younger days I often observed musketeers in combat not being able to recharge their powder and shot in time, and as a result being taken advantage of by the enemy. I therefore deliberated over something between the Western musket and the fo-lang-chi cannon, and so made the 'gripped-lightening musket' (châte tien chung).\(^5\) Similarly, as an intermediate between the musket and the 'three-eye gun' (san yen chung),\(^6\) I made the 'fast thunder gun' (hsin lei chung).\(^7\) I think that on the battlefield, besides the larger firearms like the 'third general' (san chao-ch'ün), the fo-lang-chi (breech-loading) cannon, and the 'thousand-li thunder' (chhien li let), among the small firearms nothing has a greater range and does more destruction than the Rüm (Turkish) musket, and next to it is the Western (Portuguese) musket.

All this requires a little commentary. We have often come across Byzantium before, under its early medieval Chinese name of Fu-Lin,\(^8\) transublating From and Hrom, the names that Eastern Rome had acquired in passing further east across the Old World.\(^9\) In the Tang it replaced the earlier name Ta-Chhin,\(^10\) which the Han people had used for Roman Syria.\(^11\) Then after the Arab conquests got under way, and Asia Minor as well as the Great City (after +1453) had become Rüm, the transubliteration changed again, becoming Lu-Mi,\(^12\) as in the passage just given. Many masters in Islam were from Rüm; one thinks at once of Ssu-Ma T'ung, a little a Turk, who cast a howitzer of enormous size for the Ming emperor Hsüan-Yün in India in +1458 (again that fateful year).\(^13\)

The surmise of Chao Shih-Chên's grandfather that the Turkish culture was the origin of all muskets, though at first sight bizarre, is not to be lightly dis-

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\(^4\) This would mean the Lung-Ching and Chia-Chen reign-periods as well as Wan-Li, therefore taking us back as far as +1552.

\(^5\) Clearly this was a breech loader with a number of replaceable chambers, cf. p. 380ff. Fig. 143.

\(^6\) Often used as a signal-gun, cf. p. 331 above, and Fig. 112. It was a triple-barrel gun used on horseback in northern China.

\(^7\) We have come across this before (p. 421, Fig. 158) in connection with shields for infantrymen and gunners.

\(^8\) Vol. 1, p. 116, 205. Among the many Byzantine embassies there was one in +1372 led by Nicholas Kamarios (Nichos-Ko-Lu) who was accompanied back some part of the way by a Chinese ambassador named Phu Lu. We have often wondered whether part of his mission did not concern the know-how of gunpowder weapons (by then real cannons) which might be acquired from the Chinese. See Ming Shih, ch. 398, p. 718, and Vol. 1, p. 806.


\(^10\) Born at Baflk, but his ancestors must have been from Rüm.


\(^12\) 薩其氏 / 三保郎 / 鄭若來 / 千里雲 / 沈賓

\(^13\) 这样会说早期使用火枪的国家只有土耳其，也可能是蒙古帝国。
before +1548. It was a remarkable chance that Chao should have known the Pa and To families of sinified Turks by the end of the century, and that he should have been able to learn from them at first hand the details of the Turkish musket. Perhaps the most likely conclusion is that there were two introductions of the matchlock to China, first from Turkey by way of the Muslims of Sinkiang, forming a tradition known only to restricted circles in the north and north-west; and secondly, in the south and south-east, a little later, either from the Japanese pirates or directly from the Portuguese merchant-adventurers.

The Shen Chi Phu also gives a picture of the Turkish match-lock and describes how it was operated by the musketeer. Of this Rum musket (Lu-mi chhung) it says:

The musket weighs about 7 or 8 lb., or (sometimes) 6 lb., and is about 6 to 7 feet long. The holding mechanism of the cock (lung tho) is situated inside the stock. On pressing (the trigger), the cock falls, and after ignition it rises again. A steel knife is attached to the end of the stock, so that (the musket) can be used as a lance if the enemy should get too near. Or it can be used for defence against cavalry. At the time of firing, one hand should hold the grip in front, and the end of the stock should rest against the arm-pit. When firing one should only squeeze (the trigger), not pull it, and the body and hands should be still. (In the Rum musket) the touch-hole is slightly further away from the place where the eye takes aim (than in the case of the Japanese bird-beak gun), and hence the smoke and flame developed when the musket is fired affects the eye and startles the musketeer less. This is one way in which (the Rum musket) is superior to the Japanese bird-beak gun. It uses 0.4 oz. of powder and a lead shot weighing 0.3 oz.

The illustration of the Turkish musket (Fig. 174) also shows the match, made up of four strands of cord; and two sorts of copper dispensers containing the gunpowder. The larger one (yaou kuang) carried the propellant charge, the smaller one (ja yao kuang) provided the priming powder. Each bottle had an elongated neck, and that of the larger one was pierced by a sliding copper diaphragm, or "cut-out", so that it dispensed just the right amount. The dispenser was first to remove the wooden stopper with the teeth, then to place a finger over the opening of the container and turn it upside down. When the powder filled the neck the diaphragm was set so as to prevent further flow, and then the charge was poured into the barrel down the muzzle. As for the priming, it was just shaken until the pan was full.

Other diagrams in the Shen Chi Phu explain the various component parts of the Turkish musket in detail. Of the sights the caption says:

* Such a transmission inevitably calls to mind another, which occurred in the opposite direction, and about the same time, namely the gift of the technique of inoculation against smallpox (variation), from the Chinese to the Ottoman Turks through Central Asiatic intermediaries. This must have happened in the +16th or +17th century, because the technique was passed on further West by the celebrated Lady Mary Wortley Montagu early in the +18th. On this whole subject see Needham (8b). It is rather a poignant fact that the West provided the Chinese with instruments of death in the shape of a more effective war weapon, while they for their part presented the West with a life-giving technique in the form of an extremely beneficial medical invention. And these transmissions must have been approximately contemporaneous.

* P. 114, tr. auct. This translation is taken from the main right-hand caption of Fig. 174. A representation of the Lu-mi chhung, with a brief description, is also found in HLC, p. 9, ch. 9, pp. 133, 144.

This is the first mention so far of a bayonet. The name is said to derive from the town of Bayonne in southwestern France, where they would have first been made, but it was not much before the last quarter of the +17th century. Thus this Turkish arrangement was rather advanced. See Reit (1), p. 124; Blackmore (1), p. 36, (4), p. 19.

* P. 129, tr. auct. The back-sight was a small plate with a hole, the fore-sight a pin.
The back-sight (chao men) and the fore-sight (chao hsiung) are essential for the musket, since accurate aiming depends entirely on them. In the Japanese gun a U-shaped sight is employed, but that is nothing worth compared with these. The sights are fixed on by horseshoe-shaped clamps.

Of the stock (chihng chihng) we are told that the best wood is mulberry, and the second-best is from the tamarisk tree (ho liu), while in the south they generally use chiou mu.  The ramrod (chiou chang), used for pressing down the charge and the bullet, is carried in a long tube in the stock under the barrel; after action it is wrapped round with a cloth soaked in boiling water and becomes a swab to clean out the barrel. It can be of wood for most of its length, but its forked head, just fitting the bore, must be of iron. Another illustration shows the barrel, and the screw-in breech-plug.  The bore must of course be absolutely uniform, otherwise the gun is useless. A third gives details of the touch-hole (kung men) and its pivoted copper fence (kung yen kai).  It is recommended that the priming-pan (sheng yao chih') should be rather deep, but the touch-hole itself small, so as not to dissipate the propellant energy (chihi).  And as near the breech as possible, so as to minimise recoil (kung tsoi).  The same page also illustrates the V-shaped spring of the lock (hsii an chi), which must be made neither of copper nor iron but of unquenched steel.

The Turkish musket that Chao Shih-Chen described in 1598 was of course a matchlock. But when the same firearm was described in the Wu Fei Chih of 1628 the cock was replaced by a rack-and-pinion mechanism.  A cursory glance might put this down as a wheel-lock, but the function of the wheel here was not to produce a spark, but to move the match forward to the touch-hole. In Fig. 175 the drawing on the right simply shows this, with its fence, but that on the left shows the trigger mechanism. When the trigger is pulled for firing, the rack on the right is pushed back, compressing a brass spring (ping tsu), and rotating the wheel in a clockwise direction so that the other rack, bearing the match, goes forward and ignites the powder. On the release of the trigger the two racks (hsia kuei) and shang kuei) return automatically to their original positions. We are not aware of any similar mechanism in European or other Asian matchlock muskets.

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* Tamara Abies (R 286).
* This wood is rather difficult to identify, but it may be the sweet oak, Quercus ilex (R 644; Chih Jung (3). p. 293).
* P. 118 Octagonal exteriorly.
* As in Fig. 171 above, for the Japanese bird-beak matchlock musket.
* P. 119a.
* One limb is called kuei and the other one j'a kuei.
* Ch. 224, p. 114.
One of the illustrations in the *Shen Chi Phu* shows a Turkic musketeer with a turban firing his gun. The text reads:

After inserting the match firmly (in the cock), kneel down on the right knee, and hold the musket by the peg (*tho shaw*) projecting from the stock in the left hand, with the elbow resting on the left knee. The back of the stock (*hou wek*) is firmly held under the right armpit. Close the left eye, and take aim with the right eye by looking through the backsight at the fore-sight. Keep one's mouth shut, hold one's breath, aim at the enemy and squeeze the trigger.

Fig. 176 shows a Muslim soldier following these instructions. The same book also describes the Western (Portuguese) musket (*Hsi-yang chhung*), which was similar to the Turkish one but slightly shorter, with the back end of the stock bent almost like a hook, as in Fig. 177. A drawing of a European firing a musket, one of the miscellaneous foreigners of the Western Ocean countries, as the caption says, also appears in the *Shen Chi Phu*; see Fig. 178. It is followed by a picture showing how the Chinese musketeers improved the firing position when using Western guns (*kai fang hsi-yang chhung*). As the illustration in Fig. 179 shows, it was a matter of using the fork-clamp rest-peg with the left hand and kneeling like the Turk, while holding the musket and raising it to the right eye.

During the 16th century, the breech-loading principle was applied to these muskets, as we see from the *Shen Chi Phu* (Fig. 181). The 'gripped-lightning musket' (*chhe tien chhung*) had several six-inch-long chambers (*tsu chung*) into which the lead bullets and powder charges were pre-loaded, and they easily fitted into a slot at the breech end of the gun. A small touch-hole in the chamber then came under the cock with its match, permitting ignition on the pressing of the trigger; there was no priming pan. Each chamber took a bullet 0.2 oz. in weight, and 0.25 oz. of gunpowder. The musketeer carried his gun ready loaded with one chamber, while four more were borne in a leather bag of suitable size.

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*a* P. 19a, tr. aur.
*b* This is said to be three inches long and made of wood. It clamped on to the stock (Fig. 177). Its presence suggests that the barrels were considerably lighter than European models. Something similar is used today in modern target shooting by the 'off-hand' system, using a palm-rest which transmits the weight of the barrel down through the elbow to the hip, in the standing position. See Trench (1), p. 292.
*c* P. 13a. d P. 13b gives details of the barrel and the stock.
*d* P. 21a. e P. 21b
*e* We have not come across any Chinese illustrations of the stocks with Y-shaped heads that Western musketeers used for supporting and steadying their guns (p. 448 above). But in *WPC* (ch. 123, pp. 28–33) there is a picture (Fig. 186) of a musketeer aiming his gun and firing through an iron ring attached to a slanting wooden staff with an iron ferrule held by a second soldier. This is called the 'successive rotation detachment musket system' (*tsu-hau huan huan phat*), and it is explained that while one man is finding the required elevation with the sights and firing accurately with this aid, four or five more are loading and awaiting their turn.

A version of the picture was given by Mayer (6), p. 97, but he misunderstood the purport of the entry's title.

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Fig. 176. A turbaned Muslim soldier kneeling and firing his gun (*SCP*, p. 194). His left hand holds the peg, a downward-pointing handle which was clipped on to the barrel and stock; this is shown separately in the next illustration.

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Fig. 177. The Hsingyang or European muskets (SCP, p. 134). At the left on the top the spring system of the trigger is seen, then in its right the touch-hole and fence, finally below the barrel to the right, the clamp-peg.

Fig. 178. A European firing his musket from the standing position (SCP, p. 214). The caption reads: "A foreigner from one of the miscellaneous Western-Ocean sea countries letting off his gun."
Fig. 179. A Chinese musketeer combining the kneeling position of the Turk, with the fork-clamp rest-peg, while using a Western musket (SCP, p. 219).

Fig. 180. The ring-rest for muskets (from WPC, ch. 123, p. 28).
and shape slung round him. The lock, the two powder-dispensers and the ramrod were all the same as those of the Turkish musket, but the peg-vest for the left hand was as in the modified European musket. On the other hand, a bronze or copper trigger guard (hu chhiao) was now provided.

Another breech-loading musket was the 'sons-and-mother gun' (tsu mu chhung) described in the Ping Lu of +1606 (Fig. 182). The barrel (the 'mother') was 4 ft 2 in. long, while the chamber (the 'son') was but 7 in. long. The bore of the two was carefully made identical, and then one 'son' after another could be inserted at the breech and fired off. The number of chambers carried by each musketeer was the same as in the previous case. Since, as we saw on p. 442, Chao Shih-Chên claimed to have invented breech-loading muskets himself, this one of Ho Ju-Pin's would seem to be derivative—but of course there may well have been many such inventors.

So much for matchlocks. But what about the hither side, as it were, of the history of the matchlock musket? Nothing has yet been said about the simple serpentine in China, the pivoted S-shaped lever which brought the glowing match to the touch-hole (cf. p. 425 above). Now the late Ming military compendiums preserve a family of archaic hand-guns, both single-barrelled and multi-barrelled, which in some cases show what appears to be a serpentine. We have something to say about these first, and then we must turn to what one might call the further side, and consider the flintlock musket in East Asia.

The Wa Pe Chih describes a long hand-gun with a barrel weighing 18 catties, and 4 ft 4 in. long, attached to a handle 1 ft 9 in. long and bent in scroll-shaped curves. This is called the 'large blowing-away-the-enemy lance-gun' (ta chhia chhing). It had sights and was operated by two soldiers using a tripod support; with a blunderbuss muzzle it would fire a lead ball weighing 0.65 oz. with a range of more than 200 paces. No serpentine is shown in the illustration (Fig. 184), but it probably had one because an alternative name is given: 'match-holding lance-gun' (chhia huo-shing chhing).

The rest of the series consisted in multiplying the number of barrels. Thus the 'triple-victory magically effective contraption' (san chhieh shen chih) had three barrels rotating on a central shaft so that they could be fired off in turn. Each one had a fore-sight, but there was only a single back-sight, fitted on the handle itself, which ended in a curve as before. But now for the first time we see what
Fig. 182. Another breech-loading musket, from PL, ch. 12, p. 12b. One of the chambers is seen below on the right, and a bayonet for fixing in the muzzle is to the right above.

Fig. 183a. Above, a breech-loading arquebus of Henry VIII's time; below, a breech-loading carbine of about the same date. Photo. Tower of London Armouries. Note in both cases the peg or palm-rest for the left hand, analogous to the Chinese examples just seen (Figs. 176, 177, 179).

Fig. 183b. The breech-loading arquebus of the previous picture with the space for the culasse. Photo. Tower of London Armouries.

Fig. 183c. The same breech-loading arquebus, showing the culasse extracted. Photo. Tower of London Armouries. All these three illustrations by courtesy of Howard Blackmore.
looks extremely like a serpentine, so arranged as to bring the match down to the touch-hole of each of the three barrels one after the other (Fig. 185).\(^5\) The principle was then extended to five barrels, and these came in two forms, the rotary,\(^6\) and a set arranged in a row.\(^7\) The 'five thunder-claps magically effective contraption' (\(\text{wu lei shen chi}\)) was quite similar to the three-barrel gun just described. The barrels (now called \(\text{chih}\)) were all 1 ft 5 in. long, and the whole apparatus weighed 3 catties. The sights were arranged in the same way, and it is explained that the gun should be held in the left hand for aiming, whereupon the forefinger of the right hand should bring down the serpentine upon the touch-hole of each barrel in turn.\(^8\) One can see the slow-match (\(\text{huo sheng}\)) held in a copper tube at the business end of the serpentine (Fig. 186), through which it must have been fed as it burned away, and a whole length of it is shown dangling.

Just how practical any of these devices were remains a little uncertain, but the principle was extended to seven and ten barrels. The 'seven stars gun' (\(\text{chi hsing chih}\)) consisted of six barrels 1 ft 5 in. long turning around a longer and larger barrel of pure iron, and all attached to a wooden handle 5 ft long. The barrels were bound with iron straps, and the whole set-up mounted on two wheels 1 ft 5 in. in diameter, approximating it to a small held-gun (Fig. 104). No serpentine is shown, but perhaps we may deduce it from the other weapons in the series.

What is important here, however, is that this design goes back not only to the \(\text{Wu Pei Chih, but to the Hau Lung Ching, and to the earliest stratum of that too,}\)\(^9\) so that we are dealing with a firearm of the mid-14th century, certainly well before +1400. Finally, the 'sons-and-mothers hundred-bullets gun' (\(\text{tzu mu pai tan chih}\)) consisted of ten wrought-iron barrels each 5 in. long, surrounding a larger barrel 1 ft 5 in. long, all attached to a wooden handle. Each barrel fired several dozen small lead bullets, and we are told that it takes a strong man to wield it (Fig. 188).\(^7\) Again the serpentine is not shown, but there must have been some way of igniting the barrels one after the other.

Could the serpentine have been in fact a Chinese invention? As we know from p. 425, it would have to have reached Europe by +1410, and that probably means the last quarter of the previous century. When we look at the possible

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\(^1\) The same device appears in a weapon called the 'sword lance-gun' (\(\text{chih hsiang}\)) in HPC, ch. 138, p. 82. This had but one barrel, but was provided with a close-combat blade at the stock end.

\(^2\) HPC, ch. 135, p. 142.

\(^3\) This was the 'bow-off-five lance-gun' (\(\text{tzu shu hsiang}\)) in HPC, ch. 135, pp. 155, 164 (Fig. 187). Each barrel, said to be of pure iron, fired 4 or 5 lead bullets. No serpentine is shown. We encountered similar arrangements in the fire-lance period, cf. p. 243 above.

\(^4\) The explanation is clear, but it doesn't look as if the artist quite understood how the serpentine worked. On the deficiencies of the old Chinese technical illustrators cf. Vol. 4, pp. 2, p. 360 ff.


\(^6\) HPC, ch. 125, p. 142.

\(^7\) The explanation is clear, but it doesn't look as if the artist quite understood how the serpentine worked. On the deficiencies of the old Chinese technical illustrators cf. Vol. 4, pp. 2, p. 360 ff.


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Fig. 184. The origin of the serpentine. An archaic weapon in HPC, ch. 125, p. 38, the 'large blowing-away-the-enemy lance-gun' (\(\text{chih hsiang}\)). No serpentine is shown, but it probably had one because of its alternative name, the 'match-holding lance-gun' (\(\text{chih hsiang hsiang}\)).
Fig. 185. Gun with three barrels rotating on a central shaft so that each one could be fired in turn by a slow-match held in a serpentine. The 'triple-victory magically effective contraption' (san shih shen shi) from WPC, ch. 125, p. 154. The unexplained object on the left must have been some kind of holster for carrying the weapon.

Fig. 186. The five-barrelled version of the same arm (WPC, ch. 125, p. 144). Here the serpentine is quite clearly seen, with the slow-match (huo shen) dangling from it.
Fig. 187. Gun with the five barrels aligned in a row (WPC, ch. 125, p. 134).

Fig. 188. A ten-barrelled ribauldequin, the 'ten-mother-hundreds-bullets gun' (li san hua jiu bai jiu jiu gu), from HLC, pt. 2, ch. 2, p. 144, repeated in WPC, ch. 125, p. 134.
means of transmission we find some that are too early to fit the case, but others too late. But the voyages of the fleets under the admiralcy of Chêng Ho, which certainly brought a knowledge of the most up-to-date things the Chinese had to the attention of technicians and potentates in all the Indian and Arabic lands, would just qualify (+1405-33); and in +1409 the Timurid court of Shâh Rûkh at Samarqand, which was in touch with China, saw the arrival of the Spanish ambassador Ruy González de Clavijo, who picked up a lot of information there. Other Europeans, like the Bavarian Johann Schiltberger, were present in the Timurid service at the same time, and eventually got home safely too. Moreover, the embassy of Nicholas Comans from Byzantium to China in +1371 (cf. p. 442 (e) above) would not really have been too soon. More important perhaps than any of these is the remarkable but little-known fact that between +1350 and +1430 there was a slave-trade from Mongolia to Italy which brought many hundreds, even thousands, of "Tartar" servants from north-east Asia to Europe. We speculated long ago on the technology which some of them must have brought with them, whether in textiles or in firearms. We have also recognised 'clusters' of transmissions from China to Europe, in the +12th, +13th and +15th centuries, but especially the +14th century; and it may be that the serpentine lever belongs with these lists. After all, it was the simplest possible improvement on the original hand-gun, with its slow-moving flourish being about, and once the method of control (for that was essentially what it was) had passed to Europe, it would have been just like the locksmiths of the West to take the further step of inserting springs, levers, detents and tumblers, between the trigger and the touch-hole. Early Renaissance sophistication would thus have added valuable safety devices to a system which had had its origin at the other end of the Old World.

One important consideration touching the first appearance of the serpentine, which further suggests a Chinese origin, is the fact that the trigger as such, a lever...

downward-hanging as we know it, was so age-old in that country. As we saw (pt. 5 (e), 2, ii above), China of the Warring States period (+5th century) was almost certainly the home of the cross-bow, and by the time that became the standard weapon of the Han armies (+1st to +2nd centuries) it had acquired a bronze trigger-mechanism of beautiful and intricate construction (see K.P. Mayer, 1). The crossbow was introduced to the Western world probably twice, before the +5th century and again during the +1oth. Of course there were trigger-mechanisms of various kinds in the Greek and Roman proto-artillery of catapults, onagers, arcuballistae and the like, but they seem almost always to have relied on the bow-stringings from a holding-claw by a transverse lever working up or down, or around a pivot. This is true even of the hand-held gastrapetres. In other words, the triggers did not operate from below, through a stock in which they were pivoted, as the Chinese triggers did. Hence their relevance to the serpentine.

We now return to the later trans-matchlock territory, namely that of the flintlock musket. First coming into use about +1550, it displaced the matchlock slowly but steadily in the Western world, gaining complete dominance from about +1725 onwards; but it was destined to obscurise itself a century later when mercuric fulminate was successfully confined in percussion-caps and used to detonate the cartridges with the charges that propelled the bullets. This was the work primarily of Alexander Forsyth in the first decade of the nineteenth century, but the man with the best claim to be the inventor of the little top-hat-shaped copper cap was Joshua Shaw in +1822.

By and large there seems to have been no flintlock period either in China or Japan, the former because of military conservatism, the latter because of the Sakoku closure of the country to all outside influences between +1636 and 1853. As we have noted already (p. 37), very few military compendia were produced during the Ch'ing period, and it would therefore be difficult to say on what occasions flintlock weapons came to the attention of the Chinese; at any rate in +1841 Wei Yüan described and eloquently recommended them, telling how the flint (hua shih) was held in the screw-vice or 'jaws' of the cock. But...

• For example, the travels of the Franciscan friars in Mongolia and Cathay on the period from +1320 to +1360, which is too soon (cf. Vol. 1, pp. 189, 202, 224). Among the travellers Nicola Costi centres on +1390; Athanasius Kunitz +1468-74, and Hieronymo di Santo Stefano +1466 (Yale (2), vol. 1, p. 124; 172, Cordier (1), vol. 3, p. 94. The Portuguese voyages (+1415 to 98) are of course much too late; cf. Vol. 4, pt. 3, pp. 489 ff.)
• See Vol. 4, pt. 3, pp. 489 ff.
• The exchange of embassies between the Timurid dynasty and the Chinese emperor in +1414 and +1419 is only just too late; cf. Dunlop (10), Maidra (1).
• Yule (2), vol. 1, pp. 173-6, 204 ff.
• Ibid. p. 174.
• Of course we should like to know something about the musket in Byzantium before +1455, but all is silence.
• See Olschki (6).
• Vol. 1, p. 189.
• One may mention, besides gunpowder itself, the mechanical clock, the blast-furnace for cast iron, block-printing, segmental arch bridges and summit-canal lock-gates. The three-component assembly for the interconversion of rotary and longitudinal motion came in the +15th century. See Vol. 4, pt. 3, p. 383; and Needham (5a), pp. 61-2, 119 ff., 201.
• Or even of the Turki.
• This point was made by our friend Prof. Yoshida Mitsukuni during a symposium in Kyoto on 5 Oct. 1961. Cf. Allen (1), pp. 71 ff., 110.
• See our introduction, p. 429 ff.
• The oldest European illustrations of crossbow-triggers are in the Book of Ezekiel by Haimo of Auxerre (Bib. Nat. Lat. MS. 1320; Blackmore (3), p. 174, fig. 72a), a late +10th-century work; and in the Catalan version of The Four Riders of the Apocalypse, +1086 (Cathedral Library MS. Burgos de Osma; Blackmore (3), p. 175, fig. 72b).
• Among many accounts that of Blackmore (4), p. 124 ff. is one of the shortest and clearest. Flintlock mechanisms still lingered on for some decades after 1800. On the nature, history and use of the fulminate see Davis (17), pp. 400 ff.
• It was Forsyth who had the idea of using fulminate as priming, and Shaw devised the mass-produced metal caps.
• Hai Kuo Thu Chih, ch. 91, p. 14 ff.
• As Waley (40), p. 55 remarked, 'percussion-guns' were just coming in at this time, so it was rather late to recommend flintlocks, though the Westerners still used them to some extent.
• 箭矢
• 弓矢
• 火石
still in 1860, at the time of the Anglo-French war against China, matchlocks were in regular use on the side of the defenders (Fig. 156). As for Japan, there is evidence that the Dutch +1656 presented a dozen new flintlock pistols to the Shogun, and that certain provincial samurai tried out flintlock guns with satisfaction on board the Dutch ship Batavia in +1643—but the matter went no further, perhaps for a reason which we shall mention a few pages hence.

It is rather extraordinary that the flintlock musket did not catch on in China, for we have seen (pp. 198ff.) that flint-and-steel must have been known in China much earlier, quite probably as far back as steel itself, and that would mean the - 3rd century. Opinions about the beginning of this method of fire-making in the West have differed a good deal; it was certainly known to Pliny and the Romans of early Christian times, but some put it much earlier than that. There was therefore no reason at all why the advantages of flintlock muskets should not have been appreciated in East Asia. They just were not.

So one may say that the matchlock musket was superseded only by the percussion-cap and cartridge rifle in the second half of the nineteenth century. The first significant modernisation of Chinese armed forces is generally said to have been due to Li Hung-Chang, who in 1864 equipped his army with 15,000 foreign-made rifles. But the troops of the Taiping revolutionaries under Li Hung-Ching had acquired several thousand similar small-arms already two years before. At the same time Chêng Hsiêh-Chîn was organising foreign arms companies' (yang chiang tau) and in 1863 the cavalry of the Nien jef (Nien jef) was routed by machine-guns (tien huan chiang phao) of some kind or other. This was the time when China began to set up her own arsenals, among which the An-ching Ping Kung Chiang, founded by Tsêng Kuò-Fan and directed by the engineers Hsi Shou and Hua Hêng-Fang (1862) continued to make matchlock muskets, but also began the making of percussion-caps for rifles. The famous Kiangnan Arsenal (Chiang-Nan Chi-Chhi Chih-Tso Chi) was founded in 1864, but it did not produce satisfactory modern rifles until 1871. Ten years earlier one of the censors, Wei Mu-Thing, had memorialised his conviction that China ought to copy Western firearms without hesitation. He claimed that 'the vaunted European weapon technology was, after all, a legacy of China herself'. He asserted that 'it was the Mongols of the Yuan dynasty who had introduced gunpowder and firearms to Europe, though they had afterwards been greatly improved there by extraordinary skills multiplied in a hundred ways.' Many other scholars said the same, for example Wang Jen-Chün in his Ko Chih Ku Wei (Scientific Traces in Olden Times). How right they were; and even more right would they have been if they had ventured to claim the preceding dynasty, the late Sung, as the time of transmission.

Lastly we may take up a point touched on a couple of paragraphs ago, the failure of Japan to adopt flintlock muskets—it was because they almost abandoned muskets altogether. There was a period, the hundred years before the Sakoku closure of +1616, when fire-arms were very prominent in Japanese strategy and tactics, but after the turn of the century controls increasingly strict were brought in, and the activities of the gunsmiths diverted in other directions.

We mentioned already (p. 492) the ten thousand musketeers under Oda Nobunaga at the Battle of Nagashino in +1575 when he defeated Takeda Katsuyori; only a few years before (+1567) another lord of the same clan,
Takeda Harunobu\(^1\) had recommended the musket as the most important weapon of the future.\(^2\) Indeed it was much used in the Korean expeditions of Hideyoshi,\(^3\) but especially after the Chinese armies flooded in to support the Koreans, frantic letters were sent home by Japanese commanders asking for urgent reinforcements of muskets and musketeers.\(^4\) The last important engagement in which muskets were used was the siege of Hara\(^5\) in the Shimabara\(^6\) Rebellion of +1637, an uprising of Christian peasant-farmers and landless samurai.\(^7\)

Then came the period of firearm control and almost abolition. The first step was taken by Hideyoshi himself in +1586, when he announced that he needed as much iron as possible to make a giant Buddha image, and all farmers, samurai and monks had to "volunteer" to surrender their guns for this purpose.\(^8\) Then, after Ieyasu\(^9\) had won the Battle of Sekigahara\(^10\) and established the Tokugawa shogunate in +1603, came the licensing of the two great gunsmith centres, Nagahama\(^11\) on Lake Biwa and Sakai\(^12\) near Osaka.\(^13\) An office of a Commissioner of Guns (Teppō Bugyō\(^14\)) was set up, and he cleared no orders except those from the central-government, but the gunsmiths got an annual salary, whether they made any muskets or not. By +1625 the monopoly was complete, but the orders were reduced to a minimum.\(^15\) Export of guns was also forbidden.\(^16\) And so matters continued until the arrival of Commodore Perry in 1853 joined the Japanese shogunate into the modern world, and set the stage for the Meiji\(^17\) Restoration of +1867. The firearm suppression policy of Tokugawa times probably accounts for the fact that the Honcho Gunkikō\(^18\) (Investigation of the Military Weapons of the Present Dynasty), written by Arai Hakuseki\(^19\) (+1656 to +1725) and published in +1737, has only one brief chapter on guns and cannon.\(^20\)

Five reasons have been given for this singular story, all convincing enough.\(^21\)

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\(^{1}\) Brown (1), p. 239. The given name of Takeda Harunobu (+1521–1575) was by this time Takeda Shingen\(^2\), for he had changed it in +1551.

\(^{2}\) From +1590 to 1598. The translation by Pfumaier (197) of the Chōen Menagaeri, an account of these campaigns, though now very old, remains of much interest.


\(^{5}\) Murdoch (1), vol. 4, p. 369.

\(^{6}\) A graph showing the continuously decreasing production of firearms from Sakai during the +17th century will be found in Itakura (1), p. 145.

\(^{7}\) The best account of all this is in Arima (1), pp. 657 ff., 657 ff., 670–7.

\(^{8}\) Though Richard Wickham of the Hon. East India Co. managed to get out a few for Siam in +1617 (Pratt (1), vol. 1, pp. 243–4, 256).

\(^{9}\) Cf. Waterhouse (1), p. 95. But as time went on, there was considerable uneasiness about the policy. In +1868 the eminent rangaku scholar Satō Nobuhito\(^10\) (+1769 to +1850) published a book on the use of small-arms and even made some inventions himself, while in +1870 there were experiments with flintlock guns. Only the year before Perry a third scholar, Sakuma Shizens\(^11\) (+1811 to +1864) deplored the parlous condition of Japanese shore batteries. See Tsunoda Ryosaku (2), pp. 538, 615. There was also Murakami Sadaharu\(^12\) (+1808 to +1872) whose school of gunnery had, according to the study of Iwasaki Tetsumi\(^13\), considerable influence. And at the term of the century Honda Toshiaki had advocated the making of muskets; see Kerese (1), p. 182.

\(^{10}\) See Perrin (1), pp. 24 ff., 33 ff.

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\(^{1}\) 武田晴信

\(^{2}\) 原

\(^{3}\) 島原

\(^{4}\) 武田昌玄

\(^{5}\) 萬

\(^{6}\) 長瀨

\(^{7}\) 堤

\(^{8}\) 鐵砲奉行

\(^{9}\) 明治

\(^{10}\) 本朝軍器考

\(^{11}\) 新井白石

\(^{12}\) 佐藤宣親

\(^{13}\) 佐久間義山

\(^{14}\) 村上守平
First, muskets and gunnery interfered with the age-old feudal class-relationships of Japan. The lords (daimyōs), armed retainers (samurais), professional soldiers (bushis) and knights errant (ronins) were accustomed to look down on the local worthies (ji-samurais), yeomen (goshi), peasant-farmers (ashigaras) and the artisans and merchants (heimin). Putting weapons in the hands of the common people which would enable them to kill at a distance the finest lord or knight in the country, was an affront to all right-thinking feudal values. As the Governor of Izu, Matsudaira6, said at the time of the Shimabara Rebellion, 'firearms destroy the difference between soldiers and peasants.' Musketry also interfered with feudal knighthood customs such as the single combat of champions (cf. pt. 6, c. 2 above), and it had the effect of transferring skill from the field commander to the gunsmith and the arsenal mechanic. No wonder the Japanese military aristocrats, so different from the non-hereditary bureaucratic elite of China, which for the most part of two thousand years could successfully keep down the military in a subordinate place, intensely disliked both musketry and gunnery.

Secondly, there was a great mystique of swords in Japan, as opposed to firearms. The privilege of name and sword (myōji taiō) was forbidden to peasant-farmers and merchants. Sword-play, involving as it did elegant body-movement, was esteemed as an aspect of aesthetics. In contrast the musketeer's motions were uncouth and humdrum, and that remarkable MS. work, the Inatomi-ei Toppō Denshō,6 depicts the figures illustrated clad only in the familiar apron-loincloth, as if to emphasize their plebeian or ugly, unadorned and unaccounted, nature. Third, the warrior class was much more numerous relatively in Japan than in the Western world (perhaps eight per cent of the population as against 0.6 per cent in England), so the prejudice against firearms was more able to find a voice in public policy. This may go some way to explain why gunpowder successfully played its part in overthrowing occidental feudalism while it could not easily do so in Japan—apart from all other factors such as the city-state tradition of Europe, and the burghers and merchant-adventurers who had for centuries been waiting in the wings.4

5 Of course, such martial arts, with a strong aesthetic element, were practised in China too (cf. Lu Guoyi-pen & Needham (3), p. 305), often as part of Taoist self-cultivation, but somehow they never came into conflict with the artisan public business of suppressing rebellions, establishing new dynasties, or repelling invasions.
6 Of p. 305 above.
7 This work, which has 32 illustrations, was produced in 1595 for one of the Inatomi family, famous for gun-making. A copy of it is in the New York Public Library, Spencer Coll. MS. 55. Perrin (1) has reproduced several pages of it, pp. 45f.
8 Seventeenth-century group portraits such as the 'Honourable Company of the Merchants of Antwerp' (above) with their wine in conical glasses, are deeply symbolic here.

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Fourthly, there was a great wave of xenophobia in Japan after its first contacts with Westerners. As we know, Christianity was illegal after +1616. The English gave up their factory in +1623, the Spaniards were expelled in +1624, the Portuguese in +1638, and the Dutch were confined to Dejima Island from +1641 onwards. Obviously firearms were (and always had been) something essentially foreign. And fifth, the Japanese could close their country completely because they were, as a single political entity, more isolated geographically than any country on the Eurasian continent could be. Historically they had always been isolated too, far more so than England from Europe or Ceylon from India. In a brilliant and stimulating book, Noel Perrin (1) has used this history to demonstrate that over a period of time a certain people did succeed in putting back the clock of military technology, or at least in stopping its hands. He argues that this was a successful instance of the 'selective control of technology', and that it ought to inspire us with the conviction that the atomic arms race is not inevitable, nor the holocaust of nuclear warfare either, which no one can win. He claims that a 'no-growth' community is perfectly compatible with prosperous and civilised life, and that human beings are less the passive victims of their own knowledge and skills than most people in the modern world suppose. The history of Tokugawa Japan demonstrates, he feels, that men can give up a new and dreadful weapon. With much of this argument we deeply sympathise, but Japan was a very special case; the decision to abandon firearms was essentially a feudal and anti-democratic one, which could only work because it was possible to isolate the whole country indefinitely from the rest of the world.

Today no people is an 'Iland unto itselfe' (in John Donne's famous words); orbiting satellites keep watch on everybody, the trade nexus links all communities, telecommunications connect all parts of the globe, and for good or ill the world is one. Rather do we feel that the mastery of nuclear energy as well as atomic weapons, of laser beams, space flight and computerisation, is something that is set before the human race to achieve. What we know, we cannot unknow. Nor can we refuse new knowledge. But we can decline to use. At an earlier stage we quoted the words of the +8th-century Kuan Yin Tzu1 book, where the writer was talking about many wonders of Art and Nature—how to induce thunder in winter, how to restore the dead to life, how to make images speak, and how (strangely appropriate in the present context) to make exceedingly sharp swords. 'Only those who have the Tao', he said, 'can perform such actions—and better still, not perform them, though capable of performing

1 To whom we are indebted for much of the material of the preceding paragraphs.
2 Though this rather contradicts his enthusiasm for the technical progress of Tokugawa Japan, described in Tuge Hidemoto (1).
3 Cf. what Rosaz (1, 2) has had to say on the 'technological imperative'.
4 Vol. 2, p. 449. 'Probably Thien Thong-Huei.'
5 鍾伊子
6 蘭陽秀
them. Knowing but refraining, this is the lesson that humanity must at all costs learn, for the price is survival, continued existence, itself, no less.b

(19) Gunpowder as Propellant (II); the Development of the Rocket

Now at last we come to the problem of the rocket. It is a peculiarly difficult one for many reasons, not least because a device changed fundamentally while a name did not. 'Fire-arrow' (huo chien), as we have seen (pp. 11 ff.), was a term applied in Thang times and much earlier to the incendiary arrow; but in the days of the Mongolian dynasty, the Yuan, it had come to mean the rocket. Nobody noticed the change, and no-one gave a thought to the difficulties which in the course of centuries it would cause for historians of technology. Thus rockets were certainly in use in warfare by about +1280, but that is just the time when Hasan al-Rammāh was calling them 'arrows of China' (sahn al-Khadii), which implies that they had already been known and used there for some time previously (p. 41 above). Their presence in Marcus Graecus, at a roughly similar date, is rather less certain; his 'ignis volantis in aere' may have been rockets, but were much more probably fire-lances.4 At another point earlier on (pp. 153, 236) we were driven to the conclusion that the rocket is almost certainly not described in the Wu Ching Tsung Yao of +1044; the 'gunpowder whip-arrow' (huo yao pien chien) was rather an incendiary javelin projected by two men. Yet the rockets are present in full force by +1340, so it is somewhere in those three centuries that we have to look to find their origin. We believe that it is to be sought essentially in the 'ground-rat' or 'earth-rat' (ti lao shu), a firework first used for scaring troops and upsetting cavalry, then applied, with stick (the arrow shaft) and balance-weight, to long-distance trajectories.6 But exactly when?

Many things make this search difficult. For example, there was the secrecy generally surrounding arsenal and military supplies (cf. pp. 24, 93) and there happens to be a dearth of battle accounts between +1100 and +1300 which mention rockets or anything similar. They do not seem to have been used in the wars between the Sung and the Chin Tartars which culminated in the fall of Khai léng (+1126). Yet the fire-lance, as we have noted (p. 223) was already in use by +950, and over the centuries the strong backward pressure on the arms of the wielder, the recoil, must have become well known. Moreover, during fights a chance sword-cut which hacked off the haft of a fire-lance would have released its flame-throwing tube to fly swishing backwards, perhaps up into the air. And there is another close connection here, in that fire-lances were occasionally rocket-propelled (cf. p. 484 below). We shall suggest that the rocket originated, as it were, from the tube of the fire-lance filled with gunpowder, but detached from its handle, and therefore free to travel in whatever direction chance dictated.

In these circumstances the best plan will be to describe first the several types of rocket weapon at the time when they first come fully into the limelight, and then to look again at their history with a view to sketching out as far as we can their probable origin and development. Here it will be desirable to follow the most logical order of arrangement possible, and this we try to do in the following sub-sections. Such order cannot be found in the military compendia of the Yuan and Ming themselves, where the weapons are all jumbled up with juxtapositions which are sometimes quite confusing; each text and each illustration have to be studied carefully before one can decide to what genus and species the weapon in question belongs.c

(i) The ti lao shu (ground-rat or earth-rat) in military use

This contraption we met with at a much earlier period when speaking of civilian firework displays (p. 134), concluding that it was a tube of bamboo filled with low-nitrate gunpowder and having a hole in the septum at one end, then lit and allowed to rush violently about all over the floor or the ground, in a rudimentary form of rocket-propulsion. The thing could just as easily be made by floats to skate over the surface of water, when it was called shui shu5; and it took other

a We yu Tao chih shih ning uei chi, i uei uei uei erh pu uei chi! (Kien Yin Tsa, p. 204; We Shi Chen Ching, ch. 7, p. 14).

b To decide what to refrain from will of course necessitate great judgment. The Tokugawa Japanese knew, but refrained, in our view for the wrong reasons, and under conditions unrepeatable today. But Perrin's admiration for them was not wholly unjustified. Nor are we maintaining that pacific reason and feeling have always been justified; later we may say something on war as an instrument of human progress. Meanwhile it may be noted that the history of pacific philosophy in China has been told by Tomkinn (1).

today, when many find it hard to distinguish 'terrorists' from 'freedom-fighters', we are witnessing an unprecedented 'democratisation', or better, universalisation, of sophisticated explosives and highly developed firearms. One can only hope that it is a phase which will give way to the just, equitable and healthy society of the future.


d We shall remember the case of the chi hau chingh (p. 223 above) which must mean 'flying-fire spears' and not 'flying fire-spears'. It does not therefore attest the presence of rockets in +1292, as has so often been thought (e.g. von Romocki (1), vol. 1, p. 48 ff.; Feldhaus (1), col. 853), though by that time they may well have existed (cf. p. 312 below). Davies (10) got it right.

e See pp. 477 ff. below. Of course, it may have originated as a recreational firework.

f 唯有此士才易為之，亦能能之而不易之之火器 yù huò zuò zhǐ，yì dōng néng néng zhī ér yì bù néng zhī 之火器

g 城火 he fēng huò 火箭 fú jù 火器 fú qì 地老鼠 dì lǎo shǔ，火鼠 fú shǔ

h +1267.

i We owe this point to Dr Nigel Davies of RARDE.

j There is quite a literature on the origin and development of rockets in China, but most of it is misleading when not positively wrong, as for instance the paper of Strubell (1). At an earlier point (p. 108) we drew attention to the possible significance of the fact that in the German languages gunpowder is called least, normally a vegetable drug, like wol in tae we. Now we find that the Dutch word for rocket is speelpijlen, if as it was a direct translation from huo chien, i.e. fire-arrow. It was Winter (5), p. 10, who drew attention to this. Such strange similarities are at least worth meditating.

k +1267.
forms also, as we shall see (p. 514 below). Within the military realm we find it mostly enclosed in weak-casing bombs which released a dozen or more of these mini-rockets to annoy the enemy's horsemen—and foot soldiers too. This was perhaps the most primitive form and first appearance of jet-propulsion in warfare.

Perhaps the type-specimen is the 'water-melon bomb' (hsi kua phao), and significantly it appears in the oldest stratum of the Huo Lung Ching (Fig. 190), which would date it to the first half of the +14th century at least. Here we translate the relevant passage: 3

The 'water-melon bomb' is the most efficacious weapon for defending city-walls, best used from a high position when (the enemy) is below. Inside the bomb there are one or two hundred small (iron) calthrops, and fifty to sixty 'fire-rats' (hsueh lau shue). [On the surface of each fire-rat tube three little hooks are fastened, and each such tube has a fuse going to it. All these are put into the bomb first before it is filled with gunpowder, and this should be packed in it loosely, not pressed down. The bomb is now sealed, two layers of hempen cloth with twenty layers of strong paper being glued over it, after which it is dried in the sun. The circumference of the bomb is divided into three parts, and three small holes are bored to take in three fuses. Another hole is bored directly at the top, and a small two-inch long bamboo tube is put in. A fuse goes right into the bomb through this, to make the bomb explode evenly, and the four fuses are connected together (at the top).]

When the enemy appears below the city wall the main fuse is lit, then when the burning reaches the point of junction with the four subsidiary fuses, one throws it down into the midst of the enemy. The four fuses are necessary to prevent the flame going out as the bomb is dropped. [At the moment of explosion, even the coating can cause some damage, but in a trice the calthrops are scattered all over the ground, while the fire-rats rush about in confusion, burning the soldiers. Thus the attackers can only run away, and as they do so the calthrops hurt their feet and injure them when they fall over. They never dare to come back beneath those city walls again.]

Thus it would seem that each fire-rat had its own fuse and was not just ignited by the flames of the main explosion. The illustration is instructive, first because it shows inside each mini-rocket a rectangle which we think indicates the bored cavity that gives equal burning; and secondly because the three hooks on each fire-rat are clearly shown. These evidently were designed to attach themselves to the clothing and accoutrements of men and horses, causing lesions and other damage as they burnt themselves out.

Another projectile of similar type was the 'rumbling-thunder bomb' (hung lei phao), also in the oldest stratum of the Huo Lung Ching. 4 It was more like a grenade in size, 5 and contained poisons as well as gunpowder, but it had its...
Troops carry these bombs in bags made of oiled string. In combat the soldiers light them, and throw them into the enemy’s position or camp; as they explode, the (iron) calthrops are thrown about underfoot, causing wounds, while the ground-rats rush in all directions and get into the enemy’s armour, hopping and bouncing up and down, so as to bring about alarm and confusion. Opportunity should be taken of this to press the attack by fire, using guns and bombardments. In this way the troops of the enemy never fail to be defeated.8

Finally the ground-rats occur again, this time fitted with sharp little spikes, in a device called the ‘fire-brick’ (hua chuan), though very different from our meaning of the term. It was just a bomb (Fig. 192) made in elongated rectangular shape and filled with individually fused mini-rockets amidst the gunpowder. On ignition the brick was hurled into the enemy’s camp to set it alight and sow confusion.6

(ii) Rocket arrows

The classical ‘fire-arrow’ (hua chien) is shown in the Wu Ching Tsung Yao (+1044) with the explanation that it is sent on its way from bow or crossbow, the amount of gunpowder attached to it depending on the strength of the bow. Therefore it is an incendiary arrow using a low-nitrate composition. But the hua chien in the Huo Lung Ching is entirely different, for it is a perforating shock-weapon rocket-propelled. The name might remain the same, but the device was something entirely different.

Some time between +1150 and +1350 it occurred to someone who had seen ground-rats leave the ground and fly a short distance through the air, that if such a tube were attached to a feathered stick, i.e. the arrow-shaft, it would propel it with sufficient force to enable one to dispense with bow and crossbow altogether. This was a fundamental discovery. The oldest stratum of the Huo Lung Ching says:4

One uses a bamboo stick 4 ft 2 in. long, with an iron (or steel) arrow-head 4 5 in. long [smashed with poison] and some smear that on the rocket-tube too. Behind the feathering there is an iron weight (thih chih) 0 4 in. long. At the front end there is a carton tube bound on to the stick, where the ‘rising gunpowder’ (chhi huo) is lit [and it is oiled to prevent its getting wet.] When you want to fire it off, you use a frame shaped like a dragon, or else conveniently a tube of wood or bamboo to contain it [or launcher boxes of different kinds].

8 Tr. auct.
6 HLC, pt. 2, chs. 3, pp. 56, 74; WPC, ch. 130, pp. 18a, b, 19a, b.
4 One of the two specifications stipulates also poisonous smoke-producing material. Two centuries later (c. +1556) the fire-brick is mentioned again by Chhi Chi-Kuang (Chi Hsiao Hua Shu, ch. 18, p. 964; Lien P’ing Shih Chi, Tsu Chi, ch. 5, p. 249), but now classed with obsolete weapons no longer made in the arsenals. Wang Ming-Hao still talks about it too at the end of the century (Huo Kung Win Tsu, p. 1296).
8 Ch. 13, p. 3a, b.
5 Even the neck on the end of the arrow is depicted.
4 HLC, pt. 1, ch. 2, pp. 22a, b; HKPF, ed. Hsiyangyang ed., HCT, p. 20a. Sentences in square brackets come from WPC, ch. 126, pp. 44, 5r. Tr. auct.
4 火磚  火箭  起火
The illustration (Fig. 193) shows two launching cylinders, one with a dragon head. Very significant is the mention of the balance-weight at the tail; it must soon have been obviously necessary to make up for the weight of the rocket-tube, and as the gunpowder burnt away it would have added force to the rocket's velocity. This was a second aspect of the invention. A passage from the Wu Pi
Chih spells it out more clearly. It says: 'An iron weight (thieh ch'ai) is fixed at the rear end (of the rocket-arrow), behind the feathering, of such a mass that the fulcrum of the balance is situated just four finger-breathths (su chih) away from the mouth of the rocket-tube.' Davis and Ware called this the centre of gravity; but unfortunately the text did not specify whether the point was to be forward of the rocket-tube's orifice or aft of it.

The Wu Pei Chih, besides reproducing the early picture, gives further information. First, it describes several different kinds of rocket war-heads. But secondly, and much more important, it illustrates the drill necessary for boring out a cavity in the gunpowder within the rocket-tube so that it would burn equally as it flew. This was another great discovery, the third, and it must have been made early on in the rocket's development. In one illustration (Fig. 194) the cavity is shown within the rocket-tube; in another (Fig. 195) the drill is diagrammatically drawn. The accompanying text says that the rocket-arrow is most valuable in land engagements, and not at all inferior to the bird-beak musket (cf. p. 432). It can be very deadly. But the centre of the charge must be bored out, for the 'fusée-eye' (hsian yen), either with an awl or a bow-drill; the artisans prefer the latter, but the result is not so good. It goes on:

If the hole is straight-sided (i.e. parallel with the walls of the tube) the arrow will fly straight; if it is slanting the arrow will go off at a tangent. If the hole is too deep the rocket will lose too much flame at the rear, if it is too shallow it won't have enough strength, so the arrow will fall to the ground too soon. If the rocket-tube is 5 in. long, the cavity must extend into it some 4 in. The shaft has to be absolutely straight, and the (rocket-tube and end-weight of the) arrow must balance perfectly when suspended 2 in. from the neck, or throat (ching) i.e. the nozzle, of the rocket-tube, while the feathering should be almost as long as the rocket-tube itself.

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1 WPC, ch. 127, p. 124, tr. auct.
2 Ch. 126, pp. 59-60, 7a. Thus there was the 'flying knife rocket-arrow' (fei hsieh ch'en), the 'flying spear' (fei chih chiang ch'en), the 'flying sword' (fei chien chien chen) and the 'swallow-tail' (yen hsii chien). We refrain from reproducing them.
3 This is the principle of 'concentric burning', used in order to keep the area of combustion surface as near as possible constant. Cf. Anon. (161), Vol. 1, pp. 580-1, Vol. 2, p. 363-4.
4 From Pang Lu (+1608), ch. 10, p. 44a, equivalent exactly to WPC, ch. 126, p. 2b.
5 WPC, ch. 126, p. 34; PL, ch. 12, p. 46b.
6 This was the 'horn' of early European rocket-makers. Kyeser was perhaps the first to mention it (+1405), and of course it is in Schmidlap (+1995) and many others. Cf. Ley (2), pp. 60a, 65.
7 The technical term at that time for the cavity.
8 WPC, ch. 126, p. 56, 46, tr. auct. adv. Davis & Ware (1), p. 532. The passage is a good deal older than might be supposed, for it is verbally identical with what the great general Chih Chi-Kuang said in his Chi Hiie Houa (1560) (ch. 15, p. 14.6, 8).

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**Fig. 194.** A picture of the rocket-arrow from PL, ch. 12, p. 44a, important because it shows the cylindrical cavity within the rocket tube which was needed for even and equal combustion during flight.
Here comes the fourth part of the invention. By +1300 at least the rocket-makers must have known that it was desirable to constrict the orifice of the rocket-tube in such a way as to increase the flow-velocity of the issuing gases, and therefore the retro-active force of the combustion. This was the principle of the 'choke', later called in Europe the Venturi\(^d\) 'waist' or nozzle.\(^c\) Finally, a description is given of large-diameter rocket-arrows (ta thung huo chien\(^3\)), weighing as much as two catties, with a range of some 300 paces (500 yards), and again a drilling apparatus is illustrated.\(^d\)

In Chhi Chi-Kuang\(^2\)'s time (+1550 to 80) the rocket-arrow was much prized as a war weapon.\(^4\) It would fly into the enemy's rear as well as his front line, to left or to right, keeping everyone in alarm, not knowing where it was going to strike—and the launching side would of course know either, since accurate aiming was distinctly difficult if not impossible. Hence the tendency to release flocks of rocket-arrows at the same time, from the launching-frames which we shall described in due course (pp. 486ff.); as also the practice of poisoning the arrow-tips to make a direct hit much worse. It was said to be as potent as the hand-gun, penetrating wooden planks an inch thick and piercing metal breast-plates. As for the drilling of the rocket cavity,\(^5\) it was recommended that the boring tool be frequently wetted with water to reduce the friction which was capable of igniting the composition, and that a drill should be discarded for re-sharpening after half-a-dozen borings. Apparently rockets deflagrated or exploded quite often in the making, so directions were given for dispersing the work and the stores of powder among separate buildings. Great care was taken in making and rolling the strong carton case of the rocket-tube, but sometimes iron tubes were employed, especially for the constricted end (the choke) whence the gases escaped.

Exactly what kind of gunpowder was used for the rockets of the Yuan and Ming is not very clear, but the Hua Lung Ching lists several compositions the names of which would have been appropriate.\(^6\) For example, there was 'flying gunpowder' ('fei huo yau'), 'wind-opposing gunpowder' ('ai feng huo yao'), 'flying-in-the-air gunpowder' ('fei kung huo yao'), 'day-rising gunpowder' ('ji hhi huo yao') and 'night-rising gunpowder' ('yeh chi hhi huo yao'). But while the text gives

\(^{b}\) Giovanni-Battista Venturi (+1745 to 1822) was a hydrodynamician very little noticed by historians of science, in spite of his important book (Venturi, 1). Cf. Anon. (1811), vol. 1, pp. 506-7; 240-9. Hence the Venturi flow-meter, and a device embodied in most of our gas-gener' water-heaters.
\(^{c}\) WFC, ch. 126, pp. 83, 92.
\(^{e}\) Today a conical 'spindle' is used, on top of which the packing of the gunpowder is done, cf. Brock (1), p. 112.
\(^{f}\) HPC, pt. 1, ch. 1, pp. 66a-71f; parallel texts in HAKFY and HCT.
many constituents of each of these, including saltpetre, actual quantities are listed only for two of them (the last-named), and then the sulphur is so low as to cast doubt on the validity of the percentages. Perhaps the original quantities were all removed as a security measure before the book was printed. But we know (p. 351 above) that the nitrate must have been in the neighbourhood of sixty per cent to work a successful rocket.

The technical affinities between the fire-lance and the rocket have already been pointed out (p. 472), and one might therefore well expect to find some attempt at combining the two. This indeed occurs, under the name of the ‘tigers-catching-up-with-the-sheep rocket-arrow’ (t h u ch u i y a n g c h i e n)4. The explanation says that this is a five-foot-long shaft (Fig. 196)5 with a trident at the business end and two rocket-tubes just behind it. At the rear end there are two more gunpowder tubes secured to the shaft, but these are fire-lances, not rockets, and are ignited automatically as the rocket is nearing the end of its course, said to attain 500 paces (850 or 89 yards). It can set light to the enemy’s wooden defences and ships; one man can use it a hundred men will be terrified of it, especially if poison is applied to the trident.6 Verily, recondite is the craft of this weapon,7 says the text—but on the principle of the survival of the fittest it can hardly have been all that effective. Still, a flock of them could have been rather a nuisance. Such was what could really be called the ‘flying fire-lance’.8

Thus it would appear, looking back, that in spite of its seeming simplicity four distinct inventions had to be combined in the development of effective rocket flight. First, there was the basic idea of applying a ground-rat tube to a projectile, and secondly the balancing of the whole to give the arrow an adequate range. Thirdly there was the drilling of an internal cavity to promote equal areas of combustion surface, and fourthly the addition of a waist, throat or choke, in fact a Venturi constriction,9 to accelerate the flow-velocity of the discharged gases, thus increasing the propulsive reaction.10

At some time during the +14th or +15th centuries it occurred to some ingenious Chinese artisttiser that if a rocket could be made to go, it could also be made

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4 Ch hi hau often appears in the accounts of rocket-arrows in the military books.
5 The standard rocket composition is 57.6:22.7:15.6 (Brock 1, p. 188).
6 HLC, pt. 2, ch. 2, p. 224, 6 (not the oldest stratum); WPC, ch. 127, pp. 33, 44. Nevertheless, on intrinsic grounds, this weapon could be considered rather old, quite probably developed soon after the rocket itself.
7 From WPC, that in HLC is identical, save that the former has (more logically) ‘two tigers’ (erh hu’).
8 Standard rocket ranges at the end of the +16th century are usually given as 600–700 paces, or about 1000 yards (Hua Kang Wu Ta, p. 1293).
9 The second part of this sentence is only in the longer WPC version.
10 T g hau kuan mien. Could one not suspect a Taoist echo here? Cf. p. 117 above.
11 Cf. pp. 121, 225 above.
12 Among rocket engineers this is often called a Laval convergent-divergent nozzle, after the Swede Carl de Laval who introduced it for gas turbines in 1889. Cf. Baker (1), p. 18.
13 The arrow-shaft itself can hardly be counted as an invention, but presumably the stick of later rockets must derive from it, and therefore indirectly from the shaft of the even more ancient fire-lance. Modern pyrotechies say simply that the stick ‘balances and directs the flight’ (Brock 1, p. 183). Spinning, fins and wings, ultimately, it seems, took over this function.

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Fig. 196. A manifestation of the technical affinity between the fire-lance and the rocket, the two combined in one device. The ‘tigers-catching-up-with-the-sheep rocket-arrow’ (t h u ch u i y a n g c h i e n), from WPC, ch. 127, p. 38. Two rocket-tubes are placed behind the trident, but that is not the only warhead, for two fire-lances are carried just ahead of the feathering.
to come, at least theoretically. Hence the 'flying powder tube' ('fei khung shah thang'). This was in fact three tubes attached to the same staff. A first rocket-tube sent it forward towards the enemy, then as it burnt out it ignited a charge in the leading tube which expelled a blinding lachrymatory powder over the enemy, before igniting a return rocket-tube and so sending the contraption back to its point of origin. Thus the enemy would not know from which direction the attack actually came. The idea was a striking one, but it would have involved great skill to get it to work even approximately in practice.

(iii) Multiple launchers and wheelbarrow batteries

It must have become obvious very early that if one was to attempt any kind of aim at all with elongated rocket-propelled projectiles it was no use flourishing them about at random, one should rather launch them from some kind of frame, preferably movable on an axis so as to allow of some choice of trajectory (Fig. 197). Rocketry followed in fact just this course, and we can easily describe the different forms which the frames took. But first it is necessary to eliminate a confusing intrusion, namely co-viative or projected arrows fired from fire-lances approximating to guns, and therefore nothing to do with rocket flight at all. This is all the more confusing because the drawings and descriptions are completely mixed together in the military compendia, and unless one studies the pictures and reads the texts with great care one will certainly come to grief, as has happened to not a few scholars already. The soldiers of Sung, Yuan and Ming did not bother about classificatory distinctions, as we do; all they were interested in were the practical effects.

The reason why we say 'approximating to guns' is that so much depended on whether or not the arrows had a plug or wad behind them which completely blocked the bore of the firearm's barrel. If not, they were simply shot out as co-viative projectiles along with the flames of the fire-lance at comparatively short range (cf. pp. 236 ff. above); if they did then they partook of the nature of cannon-balls, as presumably was the case with the arrows protruding from the muzzles of the early European bombard of Walter de Milamete (+1327, cf. pp. 10, 287–8 above). In the sub-section on fire-lances (13) we saw how difficult it can be to distinguish these two types of weapon. If the barrel was of wood or bamboo it was probably a fire-lance, if of bronze or iron it was perhaps a proto-

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* WPC, ch. 129, pp. 73, 84. Hsi Hui-Lin (1) deserves credit for having taken notice of it. There was a model of it in the National Military Museum in Peking in 1942.
* A closely similar 'come-and-go' rocket occurs in the Sibiu MS. of Konrad Haas, dating from about +1560 (von Braun & Ordway (1), p. 11). The question of how derivative from the Chinese sources this could have been might admit of a wide solution.
* It is surely needless to emphasise the great role played at the present day by all forms of launchers, whether for military use or for space-flight. Cf. Humphries (1), p. 140 and opp. p. 150.
* Davis & Watt (1), p. 523, called them all guns or bombardis, but they were not very sensitive to the distinction we have to make here.
30.

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gun. If there was no vase-shaped bulge, indicating a thicker wall for the explosion-chamber, then it was a fire-lance; if one is mentioned or illustrated, then it
was probably a kind of early gun. If the range is said to be short, it was a firelance; ifit was some 500 yards or more, as often stated, then it was more likely to
be a gun. This is why long ranges are so confusing, because they do not necessarily imply rocket-propulsion, as some have thought. a
Among the fire-lances or pro to-guns we have already described, the two simplest cases involved only one arrow,b but there was another which shot three at a
time,c and yet another which discharged many.d To these we can now add several more, the 'triple tiger-halberd' (san chih hu yueh 5 ) delivering three arrows: the
'sevenfold tube arrow' (chhi thung chien 6 ) sending out seven/ the 'nine-dragon
arrows' (chiu lung chien 7 ) shooting nine at a time,g and the 'hundred-aimed bowlike arrow-shooter' (pai shih hu chien 8 ) , letting off ninety-six from six tubes at one
ignition. h All these are relevant to the present discussion only because they are
scattered disorderly in the books among the true rocket-launchers, to which we
must now turn. It is significant that none of the projectile arrows in these quasiguns ever show rocket-tubes.
The most succinct means of surveying the launchers is tabulation, and this is
done in Table 6, passing from the simplest to the most complicated. We must
remember that all the data come from books written just before and after + 1600,
but it may be assumed that the simpler forms would go back one or two centuries before that time.; Broadly speaking, three materials were used for the launchers, basketry (er. Fig. Ig8), bamboo tubing, and woodwork. All were provided
with internal grids or frames to hold the individual rocket-arrows apart (Fig.
Igg) ,j and there was a marked tendency to make the launchers more or less
Bows and crossbows are of course not at issue here at all.
The 'single-flight magic-fire arrow' (tanfei shen huo chien l ) , and the 'magical (fire-) lance arrow' (shen ehhiang
chim2). See p. 240 above and Figs. 51, 52. The former was of cast bronze, and does have something that might
have been a wad, while a long range and great impact force are noted. The latter was of iron wood, yet it also
has something that could have been a wad, and again a long range is mentioned. This last was the weapon
associated with the expeditions of + 1406 and + 1410 against Annam. See also p. 240 above. One can only call
these weapons quasi-guns leaving open the exact shade of diff'erence between fire·lances and true guns. Much
would depend on the tightness of the wad-and the long ranges may have been exaggerations.
C
The 'awe-inspiring fierce-fire yaksha gun' (shen w,,; lieh huo yeh-chha eMung3 ); see p. 240 and Fig. 53 above.
d The 'lotus bunch' (i po lie"'); see p. 243 and Fig. 54 above .
• HLC, pt. I, ch. 2, p. 260, b; WPC, ch. 127, pp. 4b, 5a. Here a bulge over the explosion-chamber is
mentioned, but not shown in either drawing. It is called an 'iron gun' (thieh eMung9 ) with three barrels, but
there is no indication of any plugs or wads. Since this is the oldest part of the Huo Lung Chi'g, this quasi-gun
may well go back to the beginning of the + 14th century.
f
WPC, ch. 127, p. 70, h. The arrows were to be tipped with poison.
g WPC, ch. 127, p. Ba. This has no text.
h WPC, ch. 12 7, pp. lOb, 11 a. The tubes were of carton, and it is significantly said that fire should be
reserved until the enemy is quite near. We refrain from reproducing any of these.
i It will be seen that two items are in the Huo Lung Ching, but neither in the oldest stratum.
j
From time to time there is mention of arrow-lengths (nos. 4, 8), poison applied to the tips (nos. 4, (2), and
tail.end balance-weights (nos. 7,9)' etc. but we need not go into further detail. Also the usual romantic names
are in the Table, so we omit them here.
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Fig. 198. Conical rocket-arrow launcher made of basketwork (WPC, ch. 106, p. 164).

Fig. 199. Bamboo or wooden rocket-launcher with internal grid to keep the arrows apart (WPC, ch. 123, p. 54).
The small bamboo rocket-arrow tube (hsiao chu thung chien). Each tube holds ten short rocket-arrows, only 9 in. long, and poison is applied to the head of each. The total weight (of the tube and its contents) does not exceed 2 lb., and each soldier can carry four or five of them (on its sling) easily. The enemy would not know what exactly they were transporting. At a distance of some 100 paces (about 170 yards) away, the rocket-arrows are all fired as one. These arrows, though small, are fast, and the enemy cannot avoid them; so one soldier can do as much harm (with these arrows) as several dozen others (using more conventional arms). These rocket quivers can be carried by the personal guards of the commander, or by the detachment of soldiers surrounding the flag, or else by men scattered among ordinary fighting units. The rocket-arrows should be tested to ensure that they can penetrate thin wooden planks. If the bamboo tube is slightly raised at the time of firing, the arrows can reach over 200 paces (say 340 yards). This weapon should not be overlooked just because the arrows are so small.\(^a\)

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\(^a\) This may have been suggested by the shape of the age-old quiver for carrying arrows about, as Mr Michael Rosen has intimated to us.

\(^b\) WPC, ch. 126, pp. 14b, 15a; PL, ch. 12, pp. 49b, 50a, tr. auct.

\(^c\) Rough translations of the entries for nos. 1, 9, 10, 12 and 13 have been given by Davis & Ware (1), pp. 539-541; Davis (10).

\(^d\) 小竹筒箭
Ho Ju-Pin gives much longer ranges for rockets, as much as 600 or 700 paces (up to 1150 yards) if made by expert technicians, but adds that they can also be let off at quite short ranges, 20 or 30 paces (c. 40 yards) when they will still do a lot of damage.°

Where the story becomes rather fascinating is the mounting of four flared rectangular wooden 'long-serpent' rocket-launchers (Fig. 203) in rows on wheelbarrows (Figs. 204, 205), together with two rectangular wooden 'hundred-tiger' rocket-launchers (Fig. 206), one on each side. Thus 320 rocket-arrows could be despatched almost at one time. Each wheelbarrow was further provided with three multiple-bullet proto-guns or fire-lances, two spears for repelling close attack, and curtains of leather for hiding the movements of the gunners. Two soldiers looked after the fighting and two others provided the motive power.° In this way veritable batteries of rocket-launchers (Fig. 207) could be wheeled into position, and (hopefully) away again, doubtless under cover of other troops.° Such manoeuvres, explicitly carried out in conjunction with true cannon, might form an interesting chapter, not yet written, so far as we know, in the history of artillery and rocketry.°

(iv) Winged rockets

Among the various stabilising devices which have been introduced in modern times for controlling rocket flight, fins and wings have been outstanding.° By +1741 fins were fitted to rocket-bombs by the pyrotechnist François Frezier,° and they have continued to be used in many recent times, especially in the German 'V' of the Second World War.° But wings are also very often part of the design, as in the 'StyX',° 'Mace'° and 'Matador'° rocket-missiles, as well as the later

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* Pf., ch. 11, pp. 376ff.
° A photograph of the scale model reconstruction of this combat-vehicle is given in Fig. 205.


° It may not be generally known that rocket frames or multiple launchers can still be seen at the present day if one goes to Tainan in Southern Taiwan at the time of the lantern festival (Yuan Haino). The firework rockets are collected together in 'bives' (feng phau tsi) or 'feng tsi phau aoi') and let off simultaneously. There is a graphic description by Jih Yieh & Chuang Yung-Ho (1, 1).

° Topologically the two are closely connected, the fin being a wing of reduced size, and generally placed towards the tail of the rocket rather than half-way along its length. Cf. Humphreys (1), p. 153ff., 155, fig. 69, pl. 76, 77, 78.

° Frezier (1); Taylor (1), pp. 8-9. Frezier had many Chinese connections (perhaps without knowing it), for he made much use of iron filings in his fireworks, specialised in treuhimes (rotating rockets), and called his Roman candles lancen-ê-fes. Perhaps Reinhard de Soms was the first European to put wings on rockets, as he did in +1547 (Dahlem (1), p. 288).


° Taylor (1), pp. 24-5.


Fig. 203. The "long-serpent enemy-liquidating arrow-launcher" (ch'eng shih pu ti chien), a slightly flared rectangular container, from WPC, ch. 127, p. 13. The pierced frames for keeping the rocket-arrows separate are seen on the left, and above them the 'touch-hole' (hsu min) for the fuse which sets them all off at the same time. As the caption explains, each rocket-arrow is 9 ft 9 in. long, with a gunpowder tube 4 in. long, and an iron counter-weight just behind the feathering.

Fig. 204. Four of these 'long-serpent' rocket-launchers mounted side by side on a wheelbarrow (WPC, ch. 132, p. 98). Underneath were two square-section 'hundred tigers' rocket-arrow launchers, and on each side a multiple-bullet proto-gun or fire-lance was carried (since this was ridged it may have been a true gun). Two spears were carried in case of close-quarter combat, and there were leather curtains for the protection of the soldiers operating the assault-barrow.
“Thunderbird” and ‘Nike–Zeus’ types; and here must also be numbered the Ohka Kamikaze winged (and manned) rocket-aircraft, also of World War II. The ‘Space Shuttle’ of our own times is another case in point, launched as a rocket but capable of returning to earth as an airplane.

Consequently it is very reasonable to ask, who first gave rockets wings? We find it in the oldest stratum of the <i>Huo Lung Ching</i>, which must mean the middle of the +14th century, and quite possibly soon after +1300. The passage (cf. Fig. 208) runs as follows:

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* <i>HLC</i>, pt. 1, ch. 5, p. 18a; <i>HKPT</i> ibid.; Hsiangyang ed., <i>HCT</i>, p. 34a, tr. auct. Passages in square brackets are from the slightly expanded WPC version, ch. 131, pp. 124, 134.
Fig. 207. A whole battery of the assault-barrow rocket-launchers facing to the left, from HPC, ch. 132, p. 104. This drawing easily conduces to an optical illusion, but one must keep in mind that one is looking down upon the battery from a viewpoint high up and behind it to the right. Batteries of this kind must have been quite formidable when everything worked well.

The 'flying crow with magic fire' winged rocket-bomb (shen huo fei ya¹).

The body (of the bird) is made of [fine] bamboo laths [or reeds] forming an elongated basketwork, in size and shape like a chicken, weighing over a catty (0.6 kilo). It has paper glued over to strengthen it, and it is filled with explosive gunpowder (ming huo cha yaº). All is sealed up using more paper, with head and tail fixed on before and behind, and the two wings nailed firmly on both sides, so that it looks just like a flying crow.

Under each wing there are two [slanting] rockets (la chi hao ér hao chik³). The fourfold (branching) fuse, connected with the rockets [and about a foot long], is put through a hole drilled on the back (of the bird). When in use, this [main fuse] is lit first.

¹ This refers to the 'rising' gunpowder rocket compositions; cf. p. 483 above.
² 神火飛鴉
³ 男火炸藥
The bird flies away more than 1000 ft, and when it eventually falls to the ground, the explosive gunpowder in the cavity of the bird is (automatically) lit, and the flash can be seen miles away. [This weapon is used against enemy encampments to burn them, but also at sea to set ships on fire. It should never fail to bring victory].

The illustration suggests that the shafts and feathering of rocket-arrows were retained, but the text does not say so. In any case this must surely be the oldest account of the invention of the winged rocket in any civilisation.

One must naturally suppose that the wings were fitted with the four rockets to the weak-casing bomb because it was found that they gave added stability and accuracy to the flight. But what suggested them in the first place? The answer is immediately at hand—namely the use of expendable birds as incendiary carriers. It must be significant that these always accompany and precede the winged rocket-bomb in the military compendia. There were, for example, the 'fire-bird' (hua chin) and the 'nut sparrow' (chhiao hing) both carrying nutfuls of burning moxa tinder attached to their necks or legs, so that when they perched on the housetops of the enemy city they would set the roofs on fire. Both these had come down with little or no change from the Wu Ching Tsung Yaw of +1044, but again significantly they were there followed by no rocket-propelled artificial bird. Going back further, we can find the former easily in the Hu Chih Ching of +1004, and even in the Tai Pei Yin Ching of +759. The practice was probably age-old, and there is no point in pursuing it further. Thus the winged rocket had to await the latter part of the +13th century at earliest—but even so it long preceded the winged rockets of the West.

There are another winged rocket-bomb, or rather grenade, in the Wu Pei Chih, the 'free-flying enemy-pounding thunder-crash bomb' (fei khang chi tsei chien-thien-let phax). A rocket-tube (sung yao thang) is contrived within the body of it, and when the wind is favourable the fuse is lit, whereupon it flies over to the enemy. When the rocket-composition is nearly burnt out, the charge is automatically ignited, releasing a poisonous and irritating smoke as well as water-calthrops the thorns of which are tipped with tiger-poison. The whole thing is no more than 3.5 in. in diameter, made of dozens of layers of oiled paper, but on each side it has artificial wind-borne wings (hsia feng chhih) which will take it, in suitable conditions, right over a city wall (Fig. 211).

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Fig. 209. Model of the winged rocket-bomb to show the structure and design (photo. Nat. Historical Museum, Peking, 1978).

Fig. 210. Model of the complete winged rocket-bomb (photo. Nat. Historical Military Museum, Peking).
Such were the beginnings of the winged rockets of the present day that reach beyond the stratosphere.

(v) Multi-stage rockets

Today it is a commonplace, not only the pabulum of science fiction, that if we wish to leave the earth and travel into outer space, mankind can only do so by using rocket-craft with combustibles that fire in several successive stages, boosters to begin with, then smaller rockets, finally to take advantage of gravitational pulls within the emptiness, and cruise away among the stars and planets. Artificial satellites launched by multi-stage rockets are now familiar to everyone.\(^a\)

\(^a\) Aided of course by small bursts from rocket-motors from time to time to change or adjust direction.

\(^b\) They may circulate anywhere between 500 and 25,000 miles above the earth, and the higher they are the longer they will endure before descending and being burnt up by the friction of the earth’s atmosphere. They must also avoid the van Allen radiation belt, which is most dangerous between 2000 and 12,000 miles. Cf. Taylor (1), pp. 82-E; von Braun & Ordway (2).

I shall always remember seeing the pin-point light of ‘Sputnik I’ crossing the sky, man’s first artificial satellite, as we sat at dinner in the open air on the harbour mole at Valencia in Spain in 1957.
and space probes can be sent to remote inhospitable parts of the solar system where men are not yet ready to venture themselves.\(^a\) In seeking for the origin of multi-stage rockets let us start from the present day and work backwards, tracing their development to its source.\(^b\)

The 'Apollo' moon-landings of 1969 were accomplished by means of a three-stage rocket of enormous size, 'Saturn V'.\(^c\) Such space projectiles have been developed along with those more menacing and dangerous missile carriers known as IRBM and ICBM.\(^d\) Indeed it is an extraordinary fact that the very same rocket vehicles which can be, and have been, used for the exploration of extra-terrestrial space by human beings, can also be turned against themselves for fratricidal purposes of mass extermination—like fire itself, everything depends on what you do with it. The American 'Thor', 'Atlas', 'Titan' and 'Minuteman' have all been rockets of three or four stages, as also the Russian ones 'Scrag' and 'Sasin'.\(^e\) It was the Russian pioneer Konstantin Tsiolkovsky about 1889 who first realised that space-flight would necessarily demand what he called 'rocket-trains' or multiple rockets firing in successive stages.\(^f\) Only so could a sufficiently high speed be attained to overcome the pull of earth's gravity. Also in the nineteenth century came the application of Edward Boxer about 1855 of two-stage rockets for the purpose of life-saving at sea; they shot a cord over the endangered vessel so that a cable and a breeches-buoy could follow. By 1870 every British lifeboat station was equipped with these, and they are still in use at the present day, having saved many tens of thousands of lives.\(^g\) Boxer based the design on the rockets of François Frézier, published in his book of +1741.

But the idea of two-stage rockets goes much further back, into the +17th and +16th centuries. It has long been known that the Lithuanian military engineer\(^h\) Kazimierz Siemienowicz described them in his book Art Magna Artillteriae pub-

\(^a\) E.g. 'Mariner 4' and 'Venus 4'; Taylor (1), pp. 130-9.

\(^b\) Dollflus (1) suggests that the first payload-carrying rockets were those of French displays from +1772 onwards which shot live dogs and sheep high into the air, after which they descended safely by parachute (pamph. 4 f6o). Some of these seem to have been two- or three-stage rockets. Similar systems were used later on, for 'very lights' on battlefields from 1837, and for reconnaissance cameras from 1860. On the history of the parachute as such see Vol. 4, pt. 2, pp. 594 ff.

\(^c\) This was eight years after the first human being had been put into space. Yuri Gagarin in 'Vostok I'. See Taylor (1), pp. 94 ff., 125 ff.; von Braun & Ordway (1), pp. 176 ff. By the time the last stage fell away, the 'Apollo' spacecraft was making 24,000 mph (Fig. 215).

\(^d\) Intermediate-Range Ballistic Missiles and Inter-Continental Ballistic Missiles.


\(^f\) See Baker (1), pp. 178 f; Olszewski (2); von Braun & Ordway (1), pp. 124-5; Ley (2), pp. 107 ff.; Taylor (1), pp. 14-5. Tsiolkovsky even envisaged liquid oxygen and hydrogen as fuels, the very solution adopted nearly a century later in 'Saturn V'.

\(^g\) Taylor (1), pp. 11 ff; Humphries (1), pp. 143 ff., 178. The second-stage rocket was lit by a small detonating charge of gunpowder.

\(^h\) Siemienowicz spent his life in the Polish service.
lished at Amsterdam in +1650. But more recently a MS. conserved at Sibiu in Rumania and written by Konrad Haas about +1500 shows also a clear presentation of the same idea, and it is thought to have reached Siemienowicz by way of the book of Schmidlap (1), often printed in the second half of the +16th century. Less clear is the attribution to Biringuccio, which would take the matter back to +1540.

But all these European devices were much posterior to the two-stage rocket described in the Huo Lung Ching. Since it occurs in the oldest portion of the book it must be dated to the second half of the +14th century, and quite probably to the first half also. Describing the ‘fire-dragon issuing from the water’ (huo lung chih huai shui), it says:

A tube of bamboo (mao che) 5 ft long is taken, the septa removed, and the nodes scraped smooth [with an iron knife]. A piece of wood is carved into the shape of a dragon’s head (and fitted on at the front) while a wooden dragon tail is made for the rear end. [The mouth must be facing upwards, and] in the belly of the dragon there are several ‘mysterious mechanism rocket-arrows’ (shen chi huo chien). At the dragon head there is an opening through which go all the fuses of the rockets (inside).

[Beneath the dragon head on both sides there are two (big) rocket-tubes weighing a catty and a half each. Their fuses (and orifices) should face downwards (and backwards), and their front ends must face upwards (and forwards); and they are fixed tight to the body (bands of) hempen cloth secured with skin- and fish-glue. The fuses of the rocket-arrows within the belly lead out from the head of the dragon, and they are divided into two. Oiled paper is used to make them firm, and they are so arranged as to be connected with the front (ends) of the (outside) rocket-tubes (huo chien tang). And under the tail of the dragon on each side there are also two (big) rocket-tubes, fastened in the same style. The fuses of the four rockets are twisted into a single one. In a naval battle the apparatus can fly 3 or 4 ft above the water.

Upon lighting it will fly over the water as far as 2 or 3 li. At a distance it really looks like a flying dragon coming out of the water. When the gunpowder in the rocket-tubes is nearly all finished (that in the rocket-arrows within the belly is ignited, so that) they fly forth, destroying the enemy and his ships. [It can be used either on land or sea.]

Thus the automatic lighting of the second-stage rockets is clearly stated. Although strangely prefiguring submarine-launched weapons of ‘Polaris’ type, it was not in fact fired from under water, but rather from near the water-level on shipboard, and its trajectory was evidently very flat. Fig. 214 shows the illustration from the Huo Lung Ching; those in later books simply re-drew it. This invention has been noted by a few writers, but its full significance has hardly ever been appreciated.

(vi) The rise and fall, and rise again, of military rockets

For reasons which have already been explained (p. 472), the origin and development of the rocket is an exceptionally difficult study in technological history. We must unravel it as best we can, but a definitive account will have to await further research.

To begin with, we have two fixed points, +1264 when an empress was frightened by the ‘ground-rats’ or ‘earth-shock’ of a firework display (p. 135 above), and the neighbourhood of +1280 when Al-Rammah in Syria described rocket-arrows as salm al-Khitai, ‘arrows of China’ (p. 41 above). Equally, in spite of arguments to the contrary, we do not believe that rockets were described in the Wu Ching Tsung Yao of +1044 (p. 226 above); while on the other hand they were prominent among the fireworks mentioned by Fêng Ying-Ching and Shen Pang in +1592 (p. 134 above). The details in the Huo Lung Ching affirm rockets clearly

The same principle was even applied to fire-crackers in traditional China: cf. Ball (1), p. 280.

The view that the rocket was a modern ‘Exocet’ missile (made from the flying fish Entocoelus), so prominent in the Falkland’s campaign, as Dr Christopher Cullen remarked to us at Louvain.

We also give in Fig. 215 the reconstruction made by Chiang Cheng-Lin for the National Historical Military Museum in Peking. Cf. Anonymous (7).

E.g. Hai Tai-Tung (5); Hsi Hai-Lin (1); Sandermann (1), p. 171.

One meets from time to time in the Western literature with dubious stories about Chinese rocketry. For example, Hockel (1) has written about ‘Wan Hoo’, a supposed official of the Ming period, who invented a kite-like monoplane propelled by about 30 rockets, but perished in its first experimental flight. There is a whole series of uncritical references to this, as in Ley (2), p. 84–5; Gibbs-Smith (10); Zim (11), etc. and it has even been entertained by Chinese writers such as Hai Hai-Lin (1). But in spite of much correspondence, as with A.T. Phillips in Australia, we have never been able to get any firm reference to Wan Hoo, and we suspect that he is a myth invented probably during or after the Chinoserie period. The matter is reminiscent of a similar story about a dirigible airship ascribed to the Yuan (Vol. 4 p. 2, p. 59) and probably equally without foundation.

The application of rocket-propulsion to land vehicles has never in fact been of much practical use (Taylor (1), p. 18 E) except for test-track sleds (Humphries (1), p. 179, fig. 112), because although rocket thrust is so high per unit weight, and realisable with extreme rapidity, its fuel consumption is extremely great. But rocket-assisted take-off for aeroplanes has become commonplace (cf. Humphreys (1), p. 165 E, fig. 100), and a glider like that ascribed to Wan Hoo was successfully flown by Fritz von Opel in 1945.

One even even found Wan Hoo in Norwegian, cf. Holmeid et al (1), vol. 16, p. 508.

Of course it does not follow that the ground-rat were a new invention of that year, nor that civil fireworks were their only employment. They may well have been a century or more old at the time. We have suggested (p. 474 above) that the incorporation of these mini-rockets in cavalry-confusing bombs was the most primitive form of the use of rockets in warfare.

Their ‘ascending fire’ (shih huai) were undoubtedly rockets, and they also knew of the ground-rats (ti tao shui) and the similar ideas of which whizzed about on water surfaces (shui shui). Something like this last is in Al-Rammah (Parfitting (3), p. 202).
They may have been for use mainly in naval warfare, and as the trajectory was very flat the weapon may be regarded as an ancestor of the modern 'Exocet'.

Fig. 214. The first of all multi-stage rockets, the 'fire-dragon issuing from the water' (huo long chiu shui), a device from HLC, pt. 1, ch. 3, p. 272. It therefore belongs to the middle, perhaps to the beginning, of the +14th century. It was a two-stage rocket, for when the carrier or booster rockets were about to burn out they automatically ignited a swarm of smaller rocket-arrows which issued through the dragon mouth and fell down upon the enemy. The design seems to have been for use mainly in naval warfare, and as the trajectory was very flat the weapon may be regarded as an ancestor of the modern 'Exocet'.

Fig. 215. Reconstruction of the two-stage rocket described in the previous illustration (photo, Nat. Historical Museum, Peking).

by about +1350 (p. 479 above), so the period in which we mainly have to look lies between about +1050 and +1280.

Now it will be remembered (pp. 148ff. above) that between +969 and +1002 there was a crop of military inventions by Thang Fu, Yo I-Fang and others, in which new sorts of firearms figured, but we do not believe that these were rockets. Fire-arrows were standard equipment on battleships in +1129, but again there is no justification for interpreting them as rockets. By +1206 a term not previously used appears, 'gunpowder arrows' (huo yao chien), fired off by Chao Shun's men during the defence of Hsiangyang against the Chin Tartars (p. 168 above), but though these may have been rockets the expression could easily have referred to low-nitrate gunpowder used on incendiary arrows, as it had been for at least a couple of centuries previously. On the other hand the 'fire-arrows' launched in +1245 during the military and naval exercises in the Chhien-thang estuary (p. 192 above) most probably were rockets. There is here a zone of probability which we can only assess in the light of the following circumstance.

This is the description of the fireworks used at festivals on the West Lake at
Hangchow around +1180 (p. 132 above). Here lies what is probably our best starting-point. Though he was writing a hundred years later, Chou Mi would have been quite well informed of what went on, and among the pyrotechnic devices he named 'meteors' or 'comets' (liu hsing) as well as 'water-crackers' (shui pas) and others that flew in the air like pigeon-whistles on kites (feng ching). Like Feng Chia-Sheng himself, we are strongly inclined to take comets here to mean rockets, because, though possible, it is surely less likely that the pyrotechnical masters took bows or crossbows and shot balls of fire into the air. At the other end of history we know from Chao Hsiieh-Min's monograph on fireworks, the Hsueh Lu of +1753, that liu hsing was by then the common name for rockets, but he also uses the extremely significant expression 'flying rats' (fei shu). This is reminiscent of another term, equally conjunctive though seemingly self-contradictory, the 'meteoric ground-rat' (liu hsing ti luo shu) which we find in the Wu Pien of +1550. Intermediate in date is a weapon described in the Wu Pei Chih and called the 'comet, or meteoric, bomb' (liu hsing phao). This was a rocket-arrow, with a shaft 4 ft. 5 in. long, a poisoned arrowhead, and a small carton bomb about the same diameter as the rocket-tube fixed in front of it. As the rocket burnt out, it ignited the bomb (Fig. 216).

Unfortunately, it would be highly deceptive to take everything bearing the name liu hsing as a rocket. For example, we have already encountered (p. 180) the 'magic-fire meteoric bomb that goes against the wind' (tisan feng shen huo liu hsing phao), certainly current by the mid 14th century; it was probably thrown in antique style from a trebuchet, and perhaps got its name simply from

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* In fact, the Shun-Hsi reign-period, +1174 to 89.

* Wu Lin Chia Shih, ch. 3, p. 10.

* This probably means the water-rats or rocket-skimmers, perhaps igniting a small explosive charge as they burst out.

* That is, pigeon-whistles suspended in that way—or of course live birds could have carried them. On pigeon-whistles, see Vol. 4, pt. 2, p. 517f.


* Strictly speaking, 'meteors' is the better word, for properly comets were hui hing (cf. Vol. 3, pp. 431, 432).

* Cf. Davis & Chao Yiu-Tuhung (9), p. 104.

* Ibid. p. 103. Earth-rats and water-rats are mentioned many times (pp. 101-2, 103-4).

* Ch. 5, pp. 63b ff. Such names make one think of bats and other flying mammals. Indeed fei shu was an occasional synonymic name for the bat. 'Ground-rat' had always been a good term for the small rocket because it scuttled about at random. But there could never have been any confusion in the names of the airborne ones, partly because the flight was so different, and partly because they had long had their own special names. The commonest bat, Vespertula noctula, was called pen fei (or tzen shu); cf. PTKM, ch. 48, p. 433; R. 489. To Ya-Chhiian et al. (1), p. 355-56. Other species, such as the flying squirrel Petaurus simaticus also had their special names, in this case li shu or fa shu (9), ch. 19, ch. 6, pp. 437; R. 486.

* WPC, ch. 108, pp. 168, 174. The description says that the use of the weapon is a good way of causing commotion among enemy troops, especially cavalry, as well as doing some incidental damage, after which one should press the attack. But the artists forgot to put in the feathering (liang), though it is mentioned in the text, and moreover the arrow is called chia-chi (9) rather than chieh (9)—outlining features which led Davis & Ware (1), pp. 523-4 to regard it as a fire-lance or incendiary whip-arrow, i.e. javelin.

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Fig. 216. That the earth-rat turned into the rocket is well illustrated by the expression 'meteoric ground-rat' (liu hsing ti luo shu) found in +1550, and another, the 'flying rat' (fei shu) of +1753. Here we have a confusing instance of similar nomenclature, the 'meteoric bomb' (liu hsing phao), from WPC, ch. 108, p. 168. The bomb was simply a carton of gunpowder fixed forward of the rocket-tube head, which automatically set off the explosion as it was about to burst out.
the light of the burning fuse as it passed through the air. Equally there was the "fire-crossbow meteoric arrow-shooter" (chou nu liu hsing chien)\(^3\). This had nothing to do with crossbows either;\(^4\) it was a bamboo proto-gun\(^5\) firing ten poisoned arrows at a time, which came out 'like a flock of locusts' (Fig. 217). It happens that we can perhaps trace this weapon a long way back, because we read\(^6\) that in +1049 a certain magistrate, Kuo Tzu\(^7\), presented prototypes of a 'combat wheelbarrow' and an 'invincible meteoric crossbow' (hsu ti liu hsing nu\(^8\)); at that time it would have been a fire-lance sending out the arrows as co-viative projectiles.\(^9\)

The dearth of battle accounts specifically mentioning rockets has already been mentioned, but we can find a few, though not for the vital century that we have now been able to define, between +1180 and +1280. For example, bombs containing ground-rats are prominent in the account of the campaign of Liu Chi\(^10\) in Chekiang against inland rebels and coastal pirates around +1340.\(^11\) Launchers are in evidence around +1380, when 'wasp's nests' (ti weng\(^12\)) are included in lists of army supplies.\(^13\) And after the Ming had begun, they were much used in a battle of +1400 when the imperial army under Li Ch'ing-Lung\(^14\) was fighting the Prince of Yen\(^1\) (the future Yung-Lo emperor, but though effective they did not save the day against him.)\(^15\)

Yet another relatively late reference concerns the Timurid Persian embassy from Shāh Rakh to China in +1419, when we find mention of rockets not so much for war as travelling on wires to light lamps and other fireworks at ceremonies to amaze glittering assemblies. In his diary Ghiyāth al-Din Naqqāş wrote:16

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1. "Hic Est Cai," ch. 17 (pp. 355-60). Cf. p. 123 above. The 'great wasp's nest' (ti weng the\(^1\)) is here described as including ground-rats, though not in HLC, pt. 1, ch. 3, p. 114, b, or WPC, ch. 135, p. 148. The "fire-brick" (huan max\(^1\)) always has them...
2. HLC, ch. 135 (p. 2094 g).
3. Ming Shi Lu (Thai Tong sect. 61), p. 64 (p. 64); cf. Goodrich & Feng Chia-Shing (1), p. 172, who give further references. See also Chang Hu-tuan\(^17\) Hsü Yüan Wen Chien Lu\(^8\) (Things Heard and Seen in the Western Garden), ch. 73, pp. 48, 50, and 53.
4. The Quatumlím (1), p. 382; Behnsek (1), the latter reproduced in Yule (2), vol. 1, p. 98. The log of the expedition formed the appendix to the Razaat al-Qāfi of Muhammad Khāvend Shāh. An exactly similar passage occurs in the Zohraíté Tarihk of Haithāl Alī, or Maitra (1), p. 90.18

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**Fig. 217.** Another example of a weapon which though called 'meteoric' had nothing to do with rockets, the "fire-crossbow meteoric arrow-shooter" (chou nu liu hsing chien); nor did it have anything to do with crossbows either. It was a bamboo fire-lance or proto-gun which shot forth arrows as co-viative projectiles. PL, ch. 12, p. 512.
At that season the Feast of Lanterns takes place, when for seven days and nights, in the interior of the imperial palace, a wooden ball is suspended from which numberless chandeliers branch out, so that it appears to be a mountain of emeralds; and thousands of lamps are suspended from cords. Rats of naphtha are then prepared, and when lit they run along the cords and light every lamp they touch, so that in a single moment all the lamps from the top to the bottom of the ball are kindled.

Actually this use of rockets travelling along cords has come down as a ploy in China to our own time, under various names such as 'the phoenix flitting among the peonies' (fēng chhiuan nou tan'). And it got to the West as well, since we find dragons propelled in the same way in 17th-century European pyrotechnic books.

All in all therefore we shall be fairly safe in placing the Chinese origins of the rocket in the second half of the 12th century, no doubt when Hungchow had entered that period of great peace and prosperity which it had as the capital of Southern Sung. By the time that al-Rammāh got to know of them they had been in use for something like a century and a half. When, one may ask, did their history in the West begin?

It is generally agreed that rockets are first mentioned in connection with the Battle of Chioggia between the Genoese and the Venetians in +1380, though they may well have been used a little before that. From then onwards there are many references. By +1405 Konrad Kyesser in his Bellifortis knew that a rocket must be a tubular gas-tight container open at one end, with a hollow 'Slee' bored in its charge, and a stick or arrow-shaft 'to steer it'. In +1440 Giovanni da Fontana knew rocket-propelled missiles well, as did Leonardo da Vinci in his

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1 There is something here reminiscent of the 'lamp-trees' which we discussed in the fireworks sub-section (p. 136 above).
2 Sun Fang-To (t.), p. 8 (pp. 302-3).
3 E.g. in +1385, Leurechon, Herret & Mydorge (t.), p. 272. Cf. Brock (t.), pp. 166-7. Later these rocket-propelled 'cable-cars' were called canesmini (von Braun & Ordway (t.), pp. 6-8). And in +1795 unmistakable 'water-rats' were described by Jones (t.) as well.
4 And in this case it does look as if the 'lying rats' were initially a civilian pyrotechnic device applied to warfare only rather later. Yet if the rocket stick derived from the rocket-arrow shaft (cf. p. 477 above) then the two uses perhaps grew up together.
5 We are glad to be able to report that our estimate of dating is shared by our friends Mr Hu Tao-Ching, the eminent historian of science at Shanghai, and Mr Phan Chiu-Hsing, of the Institute of the History of Science in Peking.

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Codex Atlantis (+1514) and other MSS. Rockets applied both for war and for peaceful pyrotechnics were now commonplace, and in the 17th century there grew up a large literature on them, from which one need only mention Ufano (t.) in 1613, Appier-Hanzelet (t.) in 1625, and Furtenbach (1, 2) in 1629 and 1650. But for some reason or other, probably the early and rapid development of gunnery in Europe, rockets played no great part in warfare after that, being mainly confined to fireworks displays. India was the part of the world where the rocket-arrow achieved greatest prominence, and from the time of the Mogul emperor Akbar (+1536 to +1605) onwards. No records which would fix the date at which India received the rocket-principle from China have been found, but it must have been some time in the +14th or +15th century, for the oldest literary reference which Gode could find was of about +1500, the Kautukacintama of Prataparudradeva of Orissa. This agrees with the earliest historical references which Winter noted, namely in +1299, possibly +1425; and it is certain that Duarte Barbosa saw pyrotechnic rockets when attending a Brahmin wedding in Gujarat in +1515. The word for rocket in Sanskrit is kâu, bâna; which explains the following passage written by Francois Bernier concerning an event of which he was an eye-witness in +1658. After describing the battle-array, cannon, swordsmen, etc. of the prodigious great Mogul armies in the combat of Aurung-zeb against Dara at Samugarh, he goes on to say that 'they hardly made use of any more art than what hath now been related; only they placed here and there some men casting bânes, which is a kind of granado fastened to a stick, that may be cast very far through the cavalry, and which extremely terrifieth horse, and even hurts and kills sometimest'.

But it was in the late +18th century that military rockets became really prominent, especially in the Second, Third and Fourth Mysore Wars, after the last twenty years from +1780 onwards. Haidar Ali, the Râja of Mysore, then invaded the Carnatic, but soon dying, his struggle against the British was carried on by Tipu Sahib his son. Before the fall of Seringapatam and Tipu's death in 1799, these princes had had 6000 rocketeers in their armies, and the East India Company's troops suffered severely from them.

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4 Partington (t.), p. 175. Interestingly, he describes various kinds of ground-rat bombs (McCordy (t.), vol. 2, pp. 198, 203-4, 210).
5 Cf. Kalmar (t.); Partington (t.), pp. 157-8, 177.
6 Brock (t.), pp. 181 E.
7 Cf. Elliott (t.), vol. 6, p. 470.
8 (t.), pp. 11, 15.
9References continue in later works, such as the Ramist Sanskrtrana of Eknath (1750) and the Râmâna Saumagrimdhrana of Râmâdas (1650).
10 (t.), p. 9 E. Winter lists fourteen other accounts, including the Battle of Gwalior in +1518, Akbar's expedition to Gujarat in +1772, Aurungzeb's campaigns of +1657 onwards, the fights against the French in +1750, the Maratha wars after +1732, and finally the last appearance of rocket-arrows in the attack on Juhist as late as +1828.
11 (t.), vol. 1, p. 177; Cf. Eode (t.).
12 Gode (t.), p. 30, says that it may be connected with a similar earlier word meaning arrow, but suspects a borrowing from some other language for the meaning of rocket.
13 (1), pp. 1671 et al., p. 1090.
14 See V. Smith (t.), pp. 540 E, 585 E.
As Winter says, the rocket became far more extensively employed in India than in any other nation during the 17th and 18th centuries, perhaps because of a certain lack of barrel firearms, especially light artillery. No one ever described it better than Quintin Craufurd, writing in 1790.

It is certain, that even in those parts of Hindostan that never were frequented by Mahommedans or Europeans, we have met with rockets, a weapon which the natives almost universally employ in war. The rocket consists of a tube of iron, about 8 in. long, and one and a half inches in diameter, closed at one end. It is filled in the same manner as an ordinary sky-rocket, and lighted toward the end of a piece of bamboo, scarcely as thick as a walking-cane, and about 4 ft long, which is pointed with iron. At the opposite end of the tube from the iron point, or that towards the head of the shaft, is the match. The man who uses it, points the end that is shod with iron, to which the rocket is fixed, to the object to which he means to direct it; and setting fire to the match, it goes off with great velocity. By the irregularity of its motion, it is difficult to be avoided, and sometimes acts with considerable effect, especially among cavalry.

Craufurd even used a pile of Indian rockets for the cut on the title-page of his book (Fig. 218). Their average weight was about 9 lb., though it could go up to 30, and their usual range was 1000 yards or more, though they could in certain conditions carry two and a half times that distance. The usual armament was an arrow-head, but the rockets sometimes bore automatically fused bombs, and were often provided with various kinds of launchers.

This Indian rocketry led directly, and perhaps unexpectedly, to a great development of military rockets in Europe. William Congreve (1772 to 1828) who rose to the rank of Major-General in the Hanoverian service, and shone in the dignity of F.R.S., was directly inspired by the Indian example, and engaged in many experiments with rockets from 1804 onwards, to such good effect that a Rocket Brigade or Regiment was formed in 1808. It was urged that since no wheeled carriages were needed, rockets gave 'to cavalry the power of artillery', and that when provided, every carriage, because of the lightness of the projectiles, was 'a volley-carrriage, instead of being armed with a

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3. Winter (1); Baker (1), p. 12; Goode (6), p. 222 quoting Moor (1), p. 599. The sticks were in fact often 16 or 18 ft long. One of Moor's remarks suggests a connection with the Chinese ground-rams, for he says that 'other red-capped ground-rockets have a serpentine motion and on striking the ground rise again and bound along till their force be spent'.
4. The story has been told many times, as by Correyard (1); Gibb-Smith (10); Brock (2); Hume (1); Winter (3); Baker (1), pp. 13 ff.; von Braun & Ordway (1), pp. 50 ff., pp. 53 ff., (2), pp. 30 ff.; Reid (1), pp. 184, 190; Kasatans (1).
5. As he himself tells us in his introduction, Congreve (1), p. 15.
6. Brock (2), pp. 153 ff. Other arms soon followed suit, e.g. those of Austria, Russia, Switzerland, Mexico and Bengal.
7. The Congreve rockets went up to 35 lb. with balancing poles 16 ft long, and carried incendiary, explosive or shrapnel war-heads; their range could exceed 3000 yards. They were fired from tripod launchers, or from specially graded ramps in fortifications, or from scuttles within the hull of ships. Cf. Congreve (1, 2).
single bouche-à-fus. Moreover, rockets carried their own recoil, as it were, with them, so that they were particularly suitable on shipboard for naval actions. In due course the Rocket Brigade saw a great deal of service, including a considerable role at the Battle of Leipzig in 1813 and even a presence at Waterloo two years later. As time went on, further improvements were made, such as the invention of the spinning 'rotary' rockets (which needed no stick) by William Hale about 1840, and these were used during the American-Mexican war of 1846-8. But the Achilles' heel of all the early nineteenth-century military rockets was their great inaccuracy of delivery, especially at long ranges, as that after the thirties of the century the steadily increasing precision of conventional artillery and small-arms led to their virtual disappearance. By 1850 the Rocket Brigades of most of the powers had been disbanded.

It was natural that rockets figured on both sides in China during the Opium Wars. Stores of rocket-arrows were found when the Tinghai forts of Choushan were captured in 1840. In the following year at Anson's Bay Congreve rockets were used, one of which set fire to the largest war-junk there, which blew up with all her crew on board. A dozen years later, in the Canton River, in 1856, Admiral Kennedy wrote that 'as a rule the Chinese rockets did little harm, as often as not doubling back from whence they came', but 'one of our cutters was struck by a rocket, which burnt a large hole in her'. Thus did the rockets of Europe contend with those of China seven hundred years after their first invention there.

So now in our concluding discussion we come to the present century and the modern period, on which we must be very brief, even though advances almost incredible have been made. Neither the Chinese nor the British of the Opium Wars could have imagined it, but there is in fact only one vehicle known to man that can be navigated more easily in the vacuum of outer space than in our own atmosphere. This is the rocket, though far greater than those they knew. Jet-propulsion covers other engines, such as turbo-jets and ram-jets, as well as rockets, but all the former need to take in air at the front so that it can burn the fuel and produce the exhaust that rushes out through the rear nozzle. The rocket alone needs no air to feed on, and carries within itself the oxidant and fuel necessary for combustion and the production of a powerful stream of exhaust gases. As a jet reaction motor it is thus absolutely independent of a surrounding atmosphere, and indeed in airless space it becomes much more efficient since it is free from the drag and resistance of a material medium. Moreover, its thrust is independent of its actual forward speed, and it gives full thrust at all altitudes, even in the near vacuum of space. With what amazement Chiao Yü or Mao Yuan-I would have learnt these things, could they have known of them. The rocket has been called the oldest of all practical heat-engines, yet the liquid-propellant type which is its modern form uses some of the most advanced engineering techniques and materials at present known.

The words of this last sentence have taken us across a decisive step—beyond the classical solid charge of gunpowder. That notable mixture had its oxygen built in, as it were, but in the course of time it became clear that separately carried supplies of oxidant and fuel, held apart and combusted in an ignition chamber, would give far safer conditions and immeasurably more powerful thrusts. This was the gateway (it would not be too much to write) to the moon, the planets and the stars. The modern period of liquid propellants was ushered in by two great pioneers, a Russian and an American, and two engineer-propagandists, a German-Hungarian who worked in Rumania, and a Frenchman. The first we have had occasion to mention already (p. 506); he was Konstantin Eduardovich Tsiolkovsky (1857 to 1935), a mathematician of deep insight, who was probably the first to work out the theory of rocket flight, and

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* The history of jet-propulsion as such is a different question. As a principle it must be obvious from the movements of cœlenterates and cephalopods, but mankind seems to take many centuries to see the obvious. At an earlier point (Vol. 4, pt. 2, pp. 163-4, 575-6) we discussed possible explanations of the flying automata ascribed to many ancient thaumaturgic artists, notably Archytas of Tarentum (5. -506), the Alexandrian mechanicians, and Chang Heng himself (c. 132); who might conceivably have used jet-streams of compressed air or steam, as Heron unquestionably did in his aeolipile (ibid., pp. 226, 247). Han Chih-Ho (+590) was almost too early for gunpowder, though Romanovitch (r. +1450) could have used it. On Archytas and Regiomontanus see Dubem (1), pp. 125-6, 290 ff.

Dubem also tells us (pp. 293 ff.) of the Jesuit Honorus Faber, who in +1669 proposed a flying-machine driven by a jet of air compressed by men working a pump inside. This idea was apparently continued in a notorious design by the Brazilian Jesuit Bartholomeu Lourengo de Guimao, to which Dubem (1), pp. 297, 418 ff., (2), pp. 140 ff. has given minute attention. Then in +1715 Marc-Antoine Legrand turned to steam as the vapour to be employed in his jets (Dubem (1), p. 296). It is not quite clear how serious all these ideas were; but they certainly had a post-Renaissance character, and we have no Chinese parallels for them. In any case, the principle had no practical application until modern times, when large quantities of combustible fuel could be carried on board airplanes to provide the exhaust gases and their thrust. It is interesting that we have a familiar example of the jet-principle, two thousand years after the aeolipile, in Segener's rotating garden-lawn water-sprinkler (Ley (2), p. 84).

This paragraph is based on some formulations of Humphries (1) and Gibbs-Smith (10). Cf. Malina (1) and Anson (18), vol. 1, pp. 578-9.
proposed as fuel liquid oxygen and kerosene or liquid hydrogen. But if Tsio-
kovsky can now be called the father of rocket motor science, the father of rocket
motor engineering was the American, Robert H. Goddard (1892 to 1945).7 He also
was a university professor, who worked for many years from 1907 onwards with dog-
ged concentration and very limited support in search of the means of reaching
‘infinite altitudes’ beyond the earth’s atmosphere.8 The world’s first liquid-fuel rocket9
was successfully launched by him in March 1926, and four years later a height of
2000 ft was attained. The one who wrote in German was Hermann
Oberth (1894 to 1982) who was associated with the Verein f. Raumfahrt-
(Space-Flight Society) founded in 1927 and taken over by the Nazis in 1934.8
They changed the name of the Verein’s A 4 to the now universally known V 2, and
it was one of these vehicles which was the first to leave earth’s atmosphere
and reach airless outer space in October 1942, at an altitude of 32 miles.10 Lastly
the French contributor was Robert Ensaunt-Pelterie, who was active and widely
read in the late twenties and early thirties of the present century.1
Long before this time of course the gunpowder rocket had become a common-
place, universally familiar in pyrotechny. Congreve rockets had lingered on till
almost the end of the nineteenth century, and they had acquired a tried
and tested place for life-saving at sea, as also for averting hailstorms (cf. p. 528
below) from 1900 onwards. But rocket-born aerial photography was being re-
placed by airplane cameras, rocket signalling was superseded by radio, water
rockets were almost entirely out-matched by more accurate artillery, and there
was only a limited scope in World War I for rockets carrying Verey lights or
making smoke-screens. It seemed as though there was little future for the use
of rockets in war. And indeed we are told that the main aim of the German Verein
was originally the designing of meteorological rockets.1
Now it is a remarkable fact that while the whole of the new movement, the study
of liquid propellants, derived not from military rocketry, nor from traditional
pyrotechnics, but rather from the idea of the ‘plurality of worlds’, and the con-
venient reaction-motors were the only way that man could ever take to reach
them. Goddard stands in a line of descent, not from Chiao Yü, Tipi Sahib and
Congreve, but rather from Chang Hêng.12 Lucian and de Fontenelle. At an ear-
lier moment13 we found a good deal to say about the role of Chinese thought in
the dissolution of those so long dominant European notions, the Aristotelian
crystalline celestial spheres, and the perfection and immutability of the heavens,
after it became known in the West through the Jesuit mission in the +17th and
+12th centuries.14 Lucian’s True History of the men in the moon, with Cicero’s
Somnium Scipionis, were written before these doctrines had become riveted on
the world-view of Christendom, but in the +17th century Europe broke free, and
a whole succession of writers described extra-terrestrial voyages.15 Thus one could
say that the Chinese invention of the rocket, coming to Europe in the +14th cen-
tury, was complemented by Chinese ideas about infinite empty space which
reached Europe by the end of the +16th.1
Indeed, as Schafer has put it, ‘Tours of space were a commonplace in ancient
China’. Accounts of them16 long preceeded Chang Hêng; in the Lao Hêng, for
instance (+83), we find one about a Taoist, Hsiang Man-Tü, who spent some
years on the moon.17 Recently, Cadorna (1) has translated one of the Tunhuang
manuscripts in the Stein Collection18 which tells how a famous Taoist astro-
nautical master, Yeh Chung-Nêng, conducted the Thang emperor Hsian-1
through the moon (+178), to view the palaces of the moon.19 As Schafer said, the
great palace of the moon, though not the abode of any deity of the first rank,
was often rather fully portrayed in Chinese, both in poetry and prose, especially
as a palace of ice crystals’, an intensely cold, angular, crystalline, brittle habita-
tion of extraordinary spirits, like, yet unlike, men. In spite of the appearance of

1 See von Braun & Oruday (1), pp. 121 ff; Baker (1), pp. 17 ff. His works have been translated into English
3 His classical papers came in 1919 and 1923; cf. Goddard (1), (7).
4 Using liquid oxygen and kerosene.
(1), (2).
6 Levy (2), pp. 121 ff. He was later at the Penemunde base, where the German war-rockets were developed.
8 This 40-ft rocket was driven by liquid oxygen and ethyl alcohol, led to the combustion chamber by
turbo-pumps working on steam from hydrogen peroxide catalysed with sodium permanganate. See Levy
9 See Ensaunt-Pelterie (1), (2). There were other names of some honour in this roll-call too. Nikolai Ivan-
ovich Kibalchischich (d. 1883) developed the idea of vectored thrust, i.e. the swivelling of exhaust nozzles to
change the direction of the rocket’s flight-path; Hans Kamewald, active about a decade later, designed (long
ahead of its time) a reaction-powered space-ship. And Eugen Sänger continued the movement in the thirties.
On these see Baker (1), p. 13; Levy (2), pp. 91 ff.
12 See the earlier translation that was of Waley (3), pp. 159 ff.
13 The same story is in the True Things’ Thang Po Chu, for Chang’s Biography of the Perfect Sage Yeh of the
Thang). Tt. 772.
14 Levy (2), pp. 154 ff.
15 There is a fine description in the Sung Shi; see the J. B. B. Dent translation, Keeping the Faith.
16 The great 14th-century astronomer himself wrote, in his Sia Huan Fu, of an imaginary journey beyond
the sun.
18 There is an interesting recent book by Dick (1) on the notion of the plurality of worlds, though it ignores
the role of Chinese thought in the liberation of European ideas.
19 One need only name Francis Godwin, John Wilkins, F.R.S., Daniel Defoe and Miles Wilson. The genre
of scientific romances has been brilliantly reviewed by Nicolson (1), (2). At the same time the ancient works, which
had lain dormant during the millennium of dominance, were revived and broadened men’s thinking once again.
20 The case is reminiscent of some others previously encountered. For example, it has been said that ‘just as
Chinese gunpowder helped to abate European feudalism (after the +15th century), so Chinese stirrups had
originally helped to set it up’ (Neecham (47), pp. 486–9).
21 (26), pp. 234 ff. It was generally accepted by all that the nature of the vehicles employed, and the extra-terrestrial
travel is often magical, but the point is that for the ancient and medieval Chinese it was in no way unthink-
able.
25 Wang Chihung, an earlier translation that was of Waley (3), pp. 159 ff.
26 The same story is in the True Things’ Thang Po Chu, for Chang’s Biography of the Perfect Sage Yeh of the
Thang). Tt. 772.
27 (20), pp. 154 ff.
some lunar beauties, the emperor could not stand the cold, and begged to be taken back home, which Master Yeh duly did.

In the nineteenth century all these traditions crystallised into what we now call science fiction, on which there is a large descriptive literature, and it was works of this kind which, on their own explicit statements, had the greatest influence on the pioneers of modern rocketry. Reaction-motors, to be sure, were not the only means of interstellar flight envisaged; there were also imaginary anti-gravity substances, and of course great cannon pointing to the stars. Tsiolkovsky was inspired by Eyraud, Jules Verne, Dumas and Greg; Goddard and Oberth in addition by Lassiwitz and H. G. Wells. And not only was the cosmic navigational tradition primarily responsible; it would also be justifiable to say that the military rocket-missiles of World War II and subsequently were a spin-off or by-product of the peaceful urge for space research and exploration. May it be granted that the former do not overwhelm the latter.

In due course all the pioneers of liquid-fuel rocket flight were sucked into the maw of military preparations. Goddard was eventually aided by the American army and navy development establishment (1918), while the Verein’s Berlin Raketenflugplatz was supported by the German military from 1932 onwards. Four years later GALTIT was formed, under the direction of Theodore von Kármán, with Frank Malina and Chihin Hsieh-Sên among its staff; significantly it became ORDCIT in 1945, and applied itself almost entirely to war missiles. Among its achievements was the use of red fuming nitric acid and aniline or benzene as the self-igniting liquids as also the development of strange solid propellants such as mixtures of asphalt or polyurethane and potassium perchlorate, or sodium nitrate with ammonium plicate. Other liquid propellants used today are fluorine, tetratomethane, liquid ammonia, hydrazine hydrate, boron hydride, etc. If the Russian ‘Katyusha’ and ‘Stalin organ’ war-rockets were so effective in World War II it was because they no longer used gunpowder charges, but rather guncotton and nitroglycerine, still generally

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* Taylor (1), p. 21; von Braun & Ordway (1), p. 138. Von Braun, Oehler, and Ley, with many others, were all appropriated by the American rocketry organisation at the end of World War II.

* Gugghenheim Aeronautical Laboratory of the California Institute of Technology. On it see Malina (1, 2), Baker (1), pp. 2-28, Ley (3), von Braun & Ordway (2), pp. 64-5.

* Watendorf & Malina (1).

* Alternatively, Tsien Hsu-Shen. Other Chinese scientists also worked there, notably W. Z. Chien and C. C. Lin.

* Ordnance Department Laboratory of the California Institute of Technology. See Malina (3, 4), Baker (1), pp. 74 ff.

* Ley (3).


* Cf. Clarke (1); Parker (1); Humphries (1), p. 40; Anon. (161), vol. 4, pp. 352-3.

* Nitricellulose was discovered by Schönbein as long ago as 1845.

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30. THE GUNPOWDER EPIC

Since our mind has been running so much on rockets in the preceding pages, it will make an easy transition to begin with those same devices applied to religious observance and weather control, as also the exploration of the earth’s upper atmosphere. Then we can go on to consider the even more universal role with chemically built-in oxygen. If the Russians were the first to launch a successful earth satellite (1957) and the first to put a man (Yuri Gagarin) into space (1961), it was perhaps because of their heavy atomic war head payloads, which necessitated enormous rockets. Yet nuclear energy may well be the ultimate answer to the demands of jet-propulsion for space-flight. So here again we touch upon a paradox already mentioned (p. 506 above) that the very engines which would be capable of destroying civilisation itself are the same great rocket-motors as those which are opening the way to the planets and the stars. It is common knowledge that space probes such as ‘Mariner’ have been sent out all over the solar system since 1962. And finally the first Chinese artificial satellite went up in 1970, from the rocket’s very homeland, since when there have been at least eight more.

In the end the rocket motor could be the means of the preservation of the human race itself, removing it to other habitations as the sun of our solar system cools or overheats. It might turn out that the rocket was the greatest single invention ever made by man. So in spite of all the perils of guided rocket missiles still impending, those Chinese who first experimented successfully with ‘flying meteoric ground-rats’, though we may never know their names, have been extraordinary benefactors of humanity, and citizens of no mean city.

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* Sokolaty (1) takes the story to 1974, Buedeler (1) to 1979, and Cornelissen, Schijfer & Wakker (1) to 1981. Here we reach the truly professional level of current research. The reader equipped with mathematical, chemical or metallurgical expertise will find whole series of collective volumes which discuss the latest advances in our knowledge. For example, there is Progress in Astronautics and Rocketry, which begins in 1950 and numbers some fifty volumes at the present time; all under the aegis of the American Rocket Society.


* The two-stage motors burnt dimethyl hydrazine as fuel and nitrogen tetroxide as oxidiser; they could reach at least 4000 miles in surface-to-surface flight, and with a third stage could put a satellite into geostationary orbit at an altitude of some 25,000 miles. Cf. Hewish (1); Anon. (163).

* New launches of space rockets have taken place in 1981 (Jen Min Jia Pu, 14 Jan). reprinted in CEKGL, 1981, no. 2, p. 91). And a submarine-based carrier rocket was successfully tested in October (China Pictorial, 1983, no. 1). On China’s first communications satellite, lofted by a three-stage rocket on 16 April 1984, see Yang Wu-Min (1).

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Today the rocket vehicle looms very large in the imagination of all those who are conscious of the vastness of our universe, and inspired by the engaging fantasies of eminent scientific men. For example, Francis Crick (1), the molecular biologist, finding difficulty in accounting for the origin of life on earth, imagines a rocket spacecraft which could have brought it (in the form of eukaryote bacteria) billions of years ago, from some other civilization in our own, or some other, galaxy. Of course, this ‘directed panspermia’ only puts the problem back another remove.
which gunpowder has played in rock-blasting by miners and civil engineers concerned with roads, railways and waterways.

(i) Ceremonial and meteorological rockets

The recreational use of gunpowder in fireworks, especially rockets, has been so widespread in all parts of the world for so long, and so many good histories of them exist,\(^8\) that we need say no more of them here. But the meteorologists soon found rockets invaluable for exploring the nature of the upper air and the fringes of space. We have already had occasion to mention meteorological rockets (p. 522), and indeed they are in active use at the present day.\(^b\) Soundings-rockets go up to the hundred-mile altitude level, launching-rockets that carry payloads such as satellites reach two or three hundred miles, and are effectively in outer space. A great many types have been used, such as the 'Viking' and the 'Datasonde'; and some, such as 'Aerobee' and 'Skua', still are.\(^c\) The instruments with their readings are often recovered by parachute.\(^3\) Their sensors have given meteorologists a great wealth of data, on winds, temperatures, the earth’s magnetic field, the ionosphere, cosmic rays, infra-red and ultra-violet radiation, X-rays, etc.

But rockets have also played a part in that other, even more prestigious (if still in some sense equivocal), branch of meteorological endeavour known as ‘weather modification’. In November 1946 Vincent Schaefer made the fundamental discovery of glaciogenesis when he dropped dry ice\(^d\) pellets from an airplane on to a cloud, which within five minutes gave a snow shower. It was quickly realised that the provision of nuclei for snowflake, hail or raindrop formation was the issue, and in the following year Bernard Vonnegut, searching the literature for the crystal forms most similar to ice, suggested the iodides of silver and lead.\(^e\) So arose the technique of ‘cloud-seeding’, which since that time has become so world-wide a practice that laws have even been introduced to control it. The effect may also be produced just by the shock of an explosion, hence rockets carrying charges, as well as those with silver iodide, have come into use.

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\(^8\) E.g. Brock (1, 2).
\(^b\) Cf. von Braun & Ordway (2), pp. 150 ff.
\(^c\) Cf. Firiger (1); Almond, Wacławski et al. (1); Schmidlin, Ivanovsky et al. (1).
\(^d\) Russian geophysical rockets have sometimes shot up, and safely recovered, living experimental animals, such as dogs, recalling the +18th-century experiments mentioned above (p. 506), but more usefully.
\(^e\) See the book of Dennis (1). Solid CO\(_2\).
\(^f\) On the growth of snow-crystals see Mason (1). It was J. K. Wilcke in +1761 who first made snow-crystals artificially, and this bore fruit in the following century when iodiform and camphor were found to be nucleating agents; cf. Dogiel (1) and Spencer (1). In our own time Mason & Maybank (1) have shown that particles of clays and other minerals from the earth’s surface are more probably the cause of precipitation than meteoric dust. One of these agents is gypsum (calcium sulphate), and this salt was mentioned as a six-pointed crystal, precisely in this context by Chu Hsi\(^1\), the great Neo-Confucian philosopher and naturalist, in the +17th century. The hexagonal symmetry of ice-crystals was in fact known in China long before Europe; by Han Ying\(^2\) about +1555, and many other students of Nature, earlier than Johannes Kepler in +1610, as has been shown by Needham & Lu Gwei-Djen (5).

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\(^1\) 李
\(^2\) 金
30. MILITARY TECHNOLOGY

Unfortunately the results are not always reliable and conclusive, not statistically certain; controlled experiments are very difficult to carry out, so that the subject is still to a certain extent controversial. In a recent study Mason (2) has considered three programmes, one in Tasmania, one in Florida, and one in Israel, but only the last has shown consistently positive results over several years. Sometimes the technique works, sometimes not. Nevertheless it is very widely employed, and when I used to holiday in the Sarthe, in France, years ago, I remember being shown rockets which the vineyard workers used to shoot off at impeding hailstorm clouds in order to get them to discharge their hail before ruining the wine-grapes. The technique is hard to use because of the height and speed of the clouds.

Horwitz (8), the only historian, so far as we know, who has tried to trace the origins of the empirical practice, thought that it became widespread only towards the end of the nineteenth century. There may have been more than one root of it, for example a general belief, hard to document, that big battles brought on unusual rain, and a folk-superstition that weather-witches causing whirlwinds could be shot if one fired guns into the air. But Horwitz found in the autobiography of Benvenuto Cellini (+1500 to 71) an early reference to the letting off of cannon at storm-clouds, with good results; and something similar occurs in a book on thunder by Abraham Hosemann in +1618. No other relevant passage has been reported.

But in spite of its seeming modernity, the idea of weather modification does not appear to have originated in Europe. In South-east Asia we find a large group of folk customs which consist essentially in firing off large conventional rockets at the storm-clouds of the monsoon, with the double object of honouring the tempest spirits and initiating the precipitation of rain. We may take as a typical example the ceremonies at villages near Chiangmai in northern Thailand. First, the home-made rockets, mounted on bamboo biers or carriers decorated with branches, rest for some days in front of the stupa of the local Buddhist temple (wat) before being carried into the rice-fields for firing; then to the accompaniment of gongs and drums they are taken to the launching-ramp

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* See Foote & Knight (1); Dennis (1), pp. 75-6, 206-7, 208 ff., 292 ff. Hail-storms are among the greatest dangers for the samagra (cf. Lichine, Fürfeld al. (1), p. 35; 116, 433, 518; Schoonmaker (1), p. 162). They can wipe out a valuable crop completely. On the French anti-hail measures see Desens (1); on the Russian anti-hail rockets see Bibilasvili et al. (1) and Dennis (1), fig. 5, 14. Fog dispersal is a related subject, on which see Dennis (1), pp. 163 ff.


* (1), p. 121.

* Studied and photographed in 1961 by Mr Hugh Gibb, to whom we are grateful for much information and many pictures. He also followed the ceremonies at Nonkhpa in northern Thailand.

* There is no irrigation in these parts, so people are particularly dependent on the monsoon rain. In central Thailand, where extensive irrigation systems exist, the rocket custom does not. In Cambodia at Angkor the fire-hail also depends on rainfall because the Khmer irrigation systems of old have disappeared. Hugh Gibb witnessed rain-making ceremonies there in which water was splashed on kneeling women by Buddhist priests—there were no rockets. He suggests therefore that the rockets were Laotian or Thai (and ultimately Chinese) in origin, rather than Mon-Khmer.

30. THE GUNPOWDER EPIC

tower (Fig. 220) and at the right moment let off by a man who climbs up and lights the fuse. Very often this is a Buddhist priest or abbot, and the bhikkus always supervise the firing. This custom is attested from many places in Laos as well as Thailand, and the Tai people of the Hsi-shuang-bana region in Yunnan. Another first-hand description has been given of a similar custom at the village of Nong-song-hong near Nongkhai, the Bun-hang-fai (Deed of Rocket-firing). The rockets were very large indeed and sometimes decorated with wooden serpent-head (naga) carvings; the rationale was said to be the placating of the rain-gods, so ensuring a good harvest. Winter (5) found further examples of large commemorative rockets in Burma, but there essentially at the funerals of Buddhist priests. This certainly goes back to the beginning of the last century, because William Carey described it in 1816; the pyre was lit by rockets running along cords, and at the same time large rockets were set off. This Burmese custom is attested from 1839 by Malcolm, and certainly continued into this century; indeed it is said to go on still. The roles of Chinese and Indian influence respectively in these intermediate countries have not yet been elucidated, but there is an interesting passage in the travels of Tavernier which shows that in the +17th century China was still looked to as the home of pyrotechnic art. About +1645, during his stay in Western Java, he was present on an occasion when at the court of the King of Bantam:

There were five or six captains seated round the room, examining some fire-works which the Chinese had brought with them, such as grenades, rockets, and other things of that kind, some running upon the surface of water—the Chinese surpass all other nations of the world in this respect.

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* Many are over 40 lb high. The long bamboo stick or tail of the rocket is prominent.

* The rockets frequently have naga painted on them, symbolising the serpent-king having dominion over all waters, parallel to the long or dragon, in China.

* See the description of the 'sky-rocket festival' (Bun-hang-fai) in NE Thailand by Klausner (1), pp. 89 ff.


* On these see Alley (9), p. 9. Here some of the rockets are, or were, three-stage ones.


* The bamboo guide-stick was measured as 45 ft in length.

* Local tradition took it back a thousand years, which would be an exaggeration, but not necessarily a very gross one.

* (17), pp. 188-90.

* He mentions the size as 7 to 8 ft long and 3 to 4 ft in circumference. But apparently these two were made to run along ropes more or less parallel with the ground, not pointed upwards at the sky and the clouds.

* (5), vol. 1, pp. 208-9. Here the rocket cylinders were 10 ft long. He cites another witness who said that a single one might contain ten thousand pounds of powder. Both Carey and Malcolm described the rockets as made of hollowed-out logs bound with hoops of iron or rattan.


* These would have been the floating rocket-propelled nan shib shi or 'water-rats', on which see p. 473 above.

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** 木老板
The connection between the rocket-firing and the monsoon rains is not very close, for the rains may come before the rockets are let off, or be delayed for a good while afterwards—but this never dampened the belief that there was a connection. Some local people, however, deny it, saying that the custom is a form of reverence for the Hindu rain-god, Indra. Perhaps what was originally a practical act became converted with the passage of time into a religious observance.

It is not easy to find out how far back these weather-modification rockets go. But in view of the antiquity of the gunpowder rocket in China, it seems overwhelmingly probable that they came down from there, and it could have been at any time after about +1200. Today anti-hailstorm rockets are widespread in China, often locally made, and stationed at many thousands of posts among the communal farms up and down the country. It looks as if a prediction could safely be made that somewhere in the vast literature of medieval China a passage or two will be found which will point to the beginnings of the practice of using rockets for weather modification—unless indeed the Thais thought of themselves, using the jet-propelled vehicle that came from further north. After all, why not?

Still, our belief is that there was a very ancient aurana-bolic tradition in China, as one might call it, a conviction that shooting missiles up into the heavens could give useful results. One of the earliest of Chinese legends concerns the ten suns which appeared in the time of the Emperor Yao, and would have burnt up the face of the earth, if the Archer-Lord Hou Yi had not skilfully shot nine of them down. One of the commonplaces of Old China Hands was to make superior

* It would be good to find mention of them in Chou Ta-Kuan's description of Cambodia in +1297, the Chen-Lu Fing Te Chi. But though Pelliot (pp. 21 translated foins fired from high scaffolds (a pêng), the text itself (e.g. in TSSC, Pien i tien, ch. 107, p. 266) says only yen huo (smoke fireworks) and pan chung (fire-crackers) as big as trebuchet bombs (pao), let off at the New Year ceremonies. Chhen Chung-Huaing (3), p. 53, has no comment on this pasage. Cf. Pelliot (59).

b And guns and anti-aircraft guns too.

c Cf. Anon. (164). Our friend the climatologist Thu Chi-Hu Phu confirms this information. Some can attain an altitude of a mile or more.

d The only clue we have is an intriguing note which occurs in Bastian's account (1) of his travels in China.

In vol. 3, p. 410 he reports, without any reference, a remark said to have been made by the Kiang-Hsi emperor about +1600. If the lamans seek vainly to drive away the rains on the Gobi desert by firing off cannon, it must be because such a practice is lacking in respect for the spirits of the lakes and rivers. One would not expect the custom so far north, and one can only hope that further research will throw more light on the whole matter.

e There can in fact be nine supernumerary or 'mock' suns in a complete parhelic display, brought about by ice-crystals in the upper atmosphere; see Vol. 3, pp. 475 ff. The legend must surely have originated from this.

Parhelic phenomena were first described in Europe by Christopher Scheiner in +1590, but (as Ho Ping-Yii & Needham (1) found) a full thousand years before that, all the components had been named and noted in the Chin Shu, ch. 12, pp. 84-98, tr. Ho Ping-Yii (3).

f The legend is very old in China; see Granet (1), pp. 377 ff. and passim. One of the earliest references is that in the poem Thien Hiep (Questions about the Heavens) perhaps of the -5th century (Chiu Tzu Su Chuang, p. 36; Hawkes (1) tr., p. 49). Another is in the Chu Han (Calling Back the Soul) probably by Ching Chih-kü (13 c. -150) (Chiu Tzu Su Chang, p. 120; Hawkes, ibid., p. 104). The first clue is in the Hau Non Tzu book, ch. 8, pp. 56, 6a, tr. Morgan (1), p. 86. See also Werner (1), pp. 181-2 (4), p. 470 Allain (1), pp. 391 ff.

For a Japanese (Shinto) parallel see Anon. (167).
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comments on the noise of gongs, drums and fire-crackers\(^1\) with which people continued to salute solar and lunar eclipses centuries after their true nature was well known among the literati, but this again had an oruano-bolic element because it was associated with an Immortal named Chang (Chang hsien\(^2\)), an archer who used his bow to shoot at the Celestial Dog (Thien-Kou\(^3\)) supposed to be devouring the luminaries,\(^4\) and guns were frequently let off at him.\(^5\)

These practices go back very far. In the Tzu Chuan for the 4th year of Duke Chao (-537) one can find an interesting reference to weather phenomena in connection with shooting.\(^6\)

In the spring, in the first month of the year according to the imperial calendar, there fell much hail (po\(^6\)). Chi Wu Tzu\(^7\) asked Shen Feng, saying 'Can one stop hail from falling?' Shen Feng replied 'When a great sage is in power hail does not fall, or if it does it causes no harm. Formerly, when the sun was in the northern part of its course, everyone gathered up the ice and piled it in the prince's ice-house. When it was taken out for use, people took peach-wood bows, and arrows of jujube-wood, to shoot and chase away all evil influences.\(^8\) If this was done, thunderstorms, frost and hail did no harm, and the people suffered no epidemic diseases.'\(^7\)

Whether the bows were pointed upwards to the sky the text does not say, but very likely they were. Then at the other end of history, in +1695, we have a curious story describing the customs at a place in Kansu province, and now the link with gunpowder technology comes out clearly, though there is no word of rockets. Liu Hsien-Thing wrote as follows.\(^8\)

Mr Tzu-Than\(^9\) said that in the neighbourhood of Phing-liang, in the fifth and sixth months of summer, there were often violent gusty winds bringing yellow clouds down from the mountains along with icy hail, the biggest stones of which were the size of one's fist, and the smaller like chestnuts. It ruined people's crops like a diabolical disaster. As soon as the local people saw such a cloud coming they beat upon gongs and drums, and fired off cannon (chhiang phao) to disperse it. Sometimes they hit it fair and square, and then yellowish (lit. blood-red) rain fell, and so the cloud gradually disappeared.

Sometimes it entered the mountain-caves, and people pursued it there and surrounded it, after which they smoked it out with gunpowder. After a long time what was in there died, and when they dug it out they found either a big snake or a big toad, and every one had a piece of ice in its belly.

Apart from the piece of mythological embroidery at the end, the passage, referring to about +1690, points rather clearly at oruano-bolic activities in which rockets could easily have been involved. The practice of using firearms against hail-storms is moreover attested by oral tradition from Hobei in the Ming period (+1400 onwards) All this, in sum, may be regarded as supporting a Chinese origin for the weather-rockets of the south.

(ii) Rock-blasting in mines and civil engineering

But the greatest field for the use of explosives in a peaceful context has always been rock-blasting, whether in mining, quarrying or civil engineering. Just as the history of gunpowder blends into, and was indeed a continuation of, the history of incendiary weapons (p. 94 above), so also that of mining explosives was a continuation of that of the much earlier technique of 'fire-setting'. And we find ourselves here up against an exact parallel to some of the terminological difficulties already encountered (p. 130), for just as huo chien\(^9\) originally meant an incendiary arrow but later on a rocket, the thing changing fundamentally though the name did not; so also now when huo shou\(^10\) (firemen) or huo chiang\(^11\) (fire-artisans) are mentioned, they were in early times assuredly engaged in breaking up rocks by fire-setting, while in later times they were using gunpowder. In order to trace, therefore, the development of the use of explosives in mining or civil engineering we must make a judgment on other grounds, weighing the probabilities in the light of what has already been established about the history of gunpowder, and the changes in its composition as time went on.

What exactly was fire-setting? It must have been noticed in many parts of the world in high antiquity that forest fires would crack, rend and split the hardest rocks, and it would soon have been found that pouring water over them while still hot would increase the effect because of the expansive force of steam formed in the cracks.\(^12\) There may be a 7th-century mention in Jeremiah,\(^13\) but the celebrated description of the Egyptian gold-mines by Agatharchides in the 2nd century, reported in Diodorus Siculus,\(^14\) is precise and unquestionable. Thenceforward fire-setting is found in mining all through the ages, in the 11th-century Pisian mines of argentiferous galena in Sardinia, or the Rammelsberg mines of Germany in +1359. Agricola's account in +1555 is very detailed. Indeed the art survived almost until our own time at Kongsherg in Norway, and in Burma, India and Korea, going on two or three centuries after the introduction

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\(^{1}\) Diodorus Siculus, v. 3, Booth tr., p. 320, says that the Phoenicians were led to silver mines in the Pyrenees by observing the cracked rocks and ore outcrops after such natural fires. Good accounts of the history of deliberate fire-setting in the Western world are to be found in Collins (1); Hoover & Hoover (1), pp. 118-19, translating Agricola, De Re Metallica, bk. 3; Sandström (1), pp. 38 ff., 271 ff.

\(^{2}\) xix, 9; 'Is not my word like as a fire? saith the Lord, and like a hammer that breaketh the rock in pieces?' Perhaps also Job xxvii, cf. Bromehead (p), pp. 565 ff.

\(^{3}\) m, 1, Booth tr., pp. 89, 158, given in modified form by Hoover & Hoover (1), pp. 279-80.

\(^{4}\) Cf. de Groot (i), vol. 6, pp. 941 ff.

\(^{5}\) Patern saint of pregnancy and childbirth since at least the 10th century; see Dorf (1), vol. 11, pp. 981 ff.; Werner (4), pp. 546 ff.


\(^{7}\) Williams (1), vol. 1, p. 819.

\(^{8}\) Our attention was drawn to both the following passages by Dr Wang Pching-Fei of the National College of Meteorology, Nanking, at the request of our friend Dr Thu Chhi-Phu.

\(^{9}\) Peach-wood was a classical demolishing in China. Cf. Fig. 1762a in Vol. 5, pt. 3.

\(^{10}\) Tr. Courveur (1), vol. 3, pp. 70 ff., Eng. tr.

\(^{11}\) Kuang-Yang Thu Chhi, ch. 3 (p. 138), tr. autct.

\(^{12}\) D. S., v. 3, Booth tr., p. 320, says that the Phoenicians were led to silver mines in the Pyrenees by observing the cracked rocks and ore outcrops after such natural fires. Good accounts of the history of deliberate fire-setting in the Western world are to be found in Collins (1); Hoover & Hoover (1), pp. 118-19, translating Agricola, De Re Metallica, bk. 3; Sandström (1), pp. 38 ff., 271 ff.

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gunpowder blasting. According to Collins, gunpowder did not kill it, but dynamite eventually did. 'Hot mining', as it was called, consisted of lighting veritable pyres of wood in the drifts (tunnels) and in stopes (halls) after which, when the fumes had cleared away sufficiently, the rock was found to have spilled off in large flat chunks.

Drenching with water was obviously easier in civil engineering than in mining operations, but for two millennia a persistent Western tradition held that vinegar was sometimes used instead of water. This seems to have started with the account in Livy (59 to +17)\(^2\) of the widening of gorges in the Alps by the Carthaginian general Hannibal during his descent into Italy in -218 during the Second Punic War. It was continued by Pliny (+23 to +79)\(^3\) in his description of gold-mining\(^4\), but most modern writers have considered it a myth. Hoover & Hoover suggested emending *infusus aceto* to *in foasa acuto*,\(^5\) and Sandstrom pointed out that since the distillation of wood produces 'wood vinegar' or pyrolytic acid, dousing a large timber fire with water would give the characteristic smell, and hence a misunderstanding.\(^6\) We might however be prepared to allow that if veins of calcium or other carbonate were present, the resulting gas might help the splitting, and this may gain some credence from the fact, generally unnoticed, that exactly the same tradition occurs in China, where it would seem to have originated independently. For the oldest references are Thang ones, for example, the cutting of Li Chih-Wu's\(^7\) by-pass canal around the San Mên Hsi\(^8\) gorge channels on the Yellow River in +741, where vinegar (sulfur?)\(^9\) is distinctly mentioned. Then in +839 Liu Yu-Hsi\(^10\) (+772 to +841) was reconstructing a road in southern Shenzi,\(^11\) and had to remove large boulders which held up the project. In his *Liu Pin-Kuên Wên Chi* he wrote that 'blazing coal (or charcoal) was used to roast them, and strong vinegar (jen hu)\(^12\) poured on them,\(^13\) whereupon the rocks were burst into fragments as fine as coal-dust, so that they could be swept away (and removed in barrows).\(^14\) The same prescription occurs again a thousand years later in official instructions for building roads in mountains in Szechuan.\(^15\) Meanwhile, in +1189 Yang Wang-Hsi\(^16\) was on a tour of inspection of that province.


\(^3\) *Natural History*, Book V, chapter 17.

\(^4\) *Natural History*, Book V, chapter 17.

\(^5\) "Of course, the vinegar might have been used to facilitate the extraction of the charcoal if it were desired to retain a residue of the material for other purposes."

\(^6\) "Perhaps the vinegar was used to facilitate the extraction of the charcoal if it were desired to retain a residue of the material for other purposes.""
Fig. 221. The beginnings of gunpowder blasting in European mines. A medal struck to commemorate the visit of Prince William of Orange to the Elizabeth Albertine silver mine in +1604. The princely family is shown at the bottom as sole of the main shaft, having descended by the rope railway behind. In the upper corner on the left, a figure is seen setting off a blasting-charge. Diameter 6·5 cm., wt. 84 gm. Photo. Graham Hollister-Shortt, by the kind cooperation of Werner Krober of the Bergbau-Museum, Bochum.

scarce, in +1643 at Freiberg, near Chemnitz, by Kaspar Morgenstern, and in +1644 at the Roros mines in Norway. Later we hear of its use in +1682 by the Staffordshire copper miners, and in +1690 for the boring of the great Languedoc tunnel, planned by Leonardo da Vinci but realised two centuries later by P. P. Riquet. We need not follow it further into the eighteenth century (Figs. 221, 222), but the dates of important accompanying developments are worth noting. The earliest and simplest method was 'plug-shooting', with holes drilled about 2 in. in diameter and 3 or 4 ft deep, gunpowder put in loose, and

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the opening plugged with a wooden bung. In +1686 Henning Hutmann invented a machine for drilling the holes, and in the following year Karl Zumbe introduced 'stemming', or tamping with clay. It is often said that Hans Luft of Clausthal was the first to use carton cartridges fitting the hole in +1689, but that cannot be so because these were reported by Sir Robert Moray in the first volume of the Philosophical Transactions in +1665, translating a letter from Monsieur du Son. Bickford safety fuse did not come until 1831 in Cornwall, where mining gunpowder had been used for a century at least, and then about 1863 came Alfred Nobel's dynamite. This answered to the need for an explosive more violent, brisant and shattering than propellant gunpowder, and there were many later variants of it. Such is the story, more or less, of gunpowder applied to mining and civil engineering.

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* Darmstädter (1), p. 150. On modern developments see Lankton (1).
* Ibid. p. 152. The explosive could also be fired on a rock surface after being covered over with tamped clay.
* Here the hole was made self-closing by greased wedges at the moment of the explosion. An illustration of such a cartridge (+1724) is given in Sandström (1), fig. 177. According to Vergani (2) the merit of introducing water-resistant brass cartridges belongs to Giacomo Coenedera, in the Venetian mines, from +1664 onwards.
* Such as blasting gelatin, i.e. nitroglycerine and nitrocellulose. Detonator caps for the cartridges could be of nitrite, mercuric fulminate or lead tins. Common salt, it was found, would slow the detonation down, and reduce the danger of igniting methane or coal dust in the air. At one time this was avoided by filling cartridges with quicklime instead of explosive, a device introduced by George Elliot in +1883 (Darmstädter (1), p. 800);
Robert Boyle's enthusiasm for the technique was well justified. In 1671 he wrote:

It has long been, and still is in many places, a matter of much trouble and expense, as well of Time as Money, to cut out of Rocks of Alabaster and Marble, great pieces, to be afterwards squar'd or cut into other shapes; but what by the help of divers Tools and Instruments cannot in some Quarries be effected without much time and toil, is in other places easily and readily perform'd, by making with a fit Instrument a small perforation into the Rock, which may reach a pretty way into the body of it, and have such a thickness of the Rock over it, as is thought convenient to be blown up at one time; for at the farther end of this Perforation (which tends upwards) there is placed a convenient quantity of Gunpowder, and then all the rest of the Cavity being fill'd with Stones and Rubbish strongly ramm'd in (except a little place that is left for a Train), the Powder by the help of that train being fir'd, and the impetuous flame being hindered from expanding itself downwards, by reason of the newly mention'd Obstacle, concurring with its own tending another way, displays its force against the upper parts of the Rock, which in making its self a passage, it cracks into several parts, most of them not too weildy to be manageable by the Workmen.

And by this way of blowing up Rocks a little varied and improv'd, some ingenious Acquaintances of ours, employ'd by the Publick to make vast Piles, have lately (as I receiv'd the account of themselves) blown up or scatters'd, with a few barrels of Powder, many hundred, nay thousand, Tuns of common Rock.

We are now in a position to follow the parallel evolution of the techniques in China, and we have to do them both together, because, as already pointed out, Chinese writers make no clear distinction between fire-setting and gunpowder-blasting, all, to the scholar-officials, being examples of attacking rocks by fire. We can only guess, therefore, what was happening, in the light of the knowledge already gained (pp. 358 ff. above) of the development of the explosive mixture.

The older account comes from before the time of Agatharchides, and concerns the activities, about -270, of the great engineer-governor of Szechuan, Li Ping, who built the marvellous irrigation system of Kuanhsien. In the Hua Yang Kao Chih ¹ (Records of the Country south of Mt Huà), a historical geography of Szechuan down to +138, Chiang Chhü ² says:

In Chhing¹ the Mo ³ river took its rise in the Meng ⁴ mountains and flowed through the country to Nan-an ⁵, where it joined the Min⁶ river. There is burst against the mountainside, its wild torrent foaming below the precipice and causing great damage to boat traffic. This long-standing evil Li Ping remedied by sending soldiers to chisel (tou²) away the rocks and so rectify the current. Legend relates that this angered the water...

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¹ Ch. 5, pp. 74, 99, 102, tr. acut. adjuv Torrance (2), p. 68.
² CSS, ch. 18, p. 15; a translation of the whole passage has been given in Vol. 4, pt. 2, p. 96.
³ Chiao Chiang-hiu ³'s Hsü Hsüen Shih, c. Lo Chung-Pang (6), p. 60.
⁴ His activity continued during the following reigns, down to +180.
⁵ A special tool normally used for drilling door-plates guileous, i.e. round holes. Its proper technical name wood perhaps be some kind of tallow auger or reamer (cf. Merges (1), pp. 190 ff.), Balaman (4), p. 795).
⁶ Chu Chi-Chien & Liang Chiang-Huang (3), p. 64.
⁹ Chiao Yeh Chia-shu T'ai, ch. 2, pp. 194 ff.; Chiao Yeh Chia-shu T'ai, ch. 2, pp. 120, 129; Pulleyblank (1), pp. 96, 302.
¹⁰ Yang Liu-Sheng (11), pp. 15-16.
¹¹ Kao Phien, the general who campaigned successfully in Annam (+865 to +92), was subsequently legate and commissioner against the rebel forces of Huang Chhsao (+873); in CTS, ch. 108, p. 58, tr. acut. phrases in square brackets from the parallel passage in HTS, ch. 204, pp. 38, 44.
¹² The great general (K) +92 +94 who reconquered Annam (+92 +94).
great southerner, Wang Shen-Chih, who when Governor of Fukien founded the Min State in the Wu Tai period, and was posthumously canonised as Thai Tsu in that dynasty. Of an event of +904 it says:

Again, Pao Kuang Tzu once heard that the Prince of Min, Wang Shen-Chih, had difficulties with the great rocks in the channel (of the sea route between Fukien and Vietnam) which blocked the way for ships. One night he dreamt that Wu Tzu-Hsi appeared to him and said ‘You must open that channel;’ so he ordered the judge Liu Shan-Fu to go and offer sacrifices and pray to the gods. After three libations, suddenly there came a great wind with peals of thunder. Looking down from high above, he saw an extremely long yellow thing using all its force to strike the stones. After three days, everything was calm, and the waterway was open.

This has an implication similar to that of the passage about Kao Phien, and the text goes on to say that Wang Shen-Chih ‘borrowed the strength of spirits’ (chia shen chih li). The Shih Kuo Ch瀚 Chia (Spring and Autumn Annals of the Ten Kingdoms in the Five Dynasties period), written eight centuries later, but quoting a contemporary stele inscription, gives a similar account, saying:

On the sea [route, at the border between Min and Yueh], near Huang-chih-chan, the strong waves [caused by strange great rocks] created great difficulties for the ships, capsizing them and destroying their freight. So [Governor Wang] Shen-Chih prayed to the god of the sea [burning incense and making grain sacrifices], after which, all of a sudden, a great wind arose, with rain and a storm of thunder, the crash of which struck (the rocks) open, and made a haven. The people of Min attributed it to his beneficent administration, and the Thang emperor gave the harbour the name of Kan-thang-chiang.

We are here at the borderline between fire-setting and rock-blasting by gunpowder explosion, but the dates are uncomfortably early when we recall that the first mention of the mixture is to be placed around +850, the first use in war +919, and the first publication of the formula in +1044. Also it is a bit paradoxical that the more matter-of-fact story belongs to +662, while the more miraculous one relates to +904. But upon reflection one remembers that both these patricians had marked Taoist connections. Kao Phien had a whole entourage of Taoists and alchemists, including Liu Yung-Chih (Phan-Hsi chen) (Chuko Yin, Thsai Thien and Shenthu Pheh-Chia), all of whom advised him during the

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Fig. 223. The removal of rock obstructions to navigation in rivers and arms of the sea, whether by fire-setting or gunpowder blasting. A drawing from Lan Chih-ling’s Hung Huaik Yin-Tsan Thu Chi (Illustrated Record of the Events that had to happen in my Life), 1849, cf. Fig. 876 on p. 262 of Vol. 4, pt. 3. This one, from ch. 16, pp. 194, 204, is entitled ‘meeting my mother at the Fang rapids.’ Trackers can be seen on the path along the river hauling the ship upstream, and the waterway was clearly a dangerous one.

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this, but (Kao) attacked them (kung), hiring workmen who had the technique of getting rid of them [with sledge-hammered sharp wedges (chhan) and chisels (tso)], after which the boats could pass without difficulty.

But then we come upon something new. Although there is here no mention of fire-setting, a fairly close contemporary source, the Pei Meng So Yen (Fragmentary Notes Indited north of Lake Meng), after repeating the account given by the historians, goes on as follows: Some say that (Kao) Phien used a kind of technique that simulated thunder and lightning (i shu chiai lei ien), and so he opened the rocky passage of the waterway. But we don’t know the details of how this was done. Could this have been rock-blasting with gunpowder?

Immediately afterwards the same text continues with a story about another...
campaign against Huang Chhao. Wang Shen-Chih had Taoism in the family, for an ancestor of his was a Taoist of I-Shan near Fuchow, and prophesied the rise of his descendants to imperial, or at least kingly, rank. Later, about +887, other Taoists such as Hsi Hsuan-Ching and Hsü Ching-Li assisted Wang Shen-Chih with advice, perhaps participating in the rock clearance of +904; and indeed the whole dynasty of Min was much given to Taoism.

These connections are quite important, because alchemy and early empirical experimental chemistry were so strongly Taoist in character, and since gunpowder was so great a discovery it would assuredly have been kept secret for many decades afterwards. Our chief hesitation in accepting the events associated with Kao Phien and Wang Shen-Chih as true rock-blasting concerns the proportion of nitrate probable in the mixture, but since such an action can be brought about at 50% saltpetre or even rather less, given adequate confinement, the possibility is just as admissible. If it should be true, it would have one rather considerable corollary, namely that gunpowder was after all first used in China for peaceful ends, not indeed for recreational fireworks (as convention had it), but for the assurance of transport and communications, enhancing human physical strength. At any rate, from this point onwards the case is altered, and gunpowder explosions for civil engineering purposes can reasonably be looked for.

Quite early in the new period we come upon something which constitutes a conundrum of considerable interest. In +1066 Thang Chi wrote a book on the inkstones of his court, and the mines or quarries where they were procured, entitled Hsi-Chou Yen Pha. The last chapter in this lists the tools used for 'attacking' the rocks (kang chi), and besides many obvious instruments such as large and small iron hammers (thie ia hieo chihia), long and short chisels (chhang tsun tsu), crow-beak picks (ya tsui chih), shovels and baskets, we find also chhang. This is of course the word later used for the metal-barrelled hand-gun, arquebus or musket, first thus appearing (p. 294) in +1288. What could it be doing here? Now chhang, according to the dictionary of the axe in which the handle is fitted, but would not make any sense in the present context. One then remembers how cartridges of paper or carton to hold the gunpowder in the drilled rock-holes were current in Europe by +1665 (p. 537), and that suggests

that just possibly such tubes of gunpowder were used here. Against this there is the consideration that gunpowder sufficiently high in nitrate might not have been available by +1066, only twenty years after the Wu Ching T'ang Yüo (pp. 145 ff). Yet two of the formulae there (pp. 117 ff) had a saltpetre content of 60% or above, and we know that modern slow-burning gunpowders normally contain between 60 and 70%. We incline, therefore, to the belief that at this date gunpowder was used in the Hsinchow mines to break up the rocks and liberate the mineral suitable for polishing into inkstones. Perhaps the word chhang was re-introduced for the metal barrel when it came in two centuries later.

During the following centuries gunpowder blasting could have been used quite often, but we have not come across many examples of it. In +1310 Wang Chheng-Tê organised a great deal of rock-cutting, as for the Hung Khou Chhú in Shensi, part of the Wei Pei project, using hundreds of masons with metal tools (chin chihng) and 'fire-artisans' (hau chiang). These latter could have been blasting experts, but there is no specific mention of explosives, and they 'used fire to burn and water to splash on' the rocks (yang huo fen shai tshia), so the work, which accounted for 600 ft of progress each day, was very likely just fire-setting. On the other hand, by +1541, gunpowder blasting, followed by dredging of the detritus, was clearly employed by Chhen Mu when improving the waterway at the point where the Grand Canal crossed the Yellow River. Thus one might at least say that the use of gunpowder in civil engineering began as early in China as it did in Europe, and perhaps a good while earlier.

Where mining was concerned, however, there may have been many hesitations about the use of gunpowder, as Golâ (1) has pointed out. According to the general view (p. 534 above) it was dynamite that killed fire-setting, not gunpowder. In modern times, for which we have eye-witness accounts, gunpowder was only very sparsely used by Chinese miners, neither for gold nor silver, nor yet for coal or iron; only in quicksilver mining is it attested. Golâ gives four reasons for these hesitations; (1) in general Chinese miners had access only to inferior gunpowders, and these rarely or never granulated (corned); (2) the cost...
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and labour involved in shot-hole-drilling was rather high, especially in hard rock; there was great danger of igniting fire-damp (methane) in coal-mines (the most numerous of all Chinese workings), and of delayed charges in small mines where each miner sold what he himself got; finally, the fire-setting technique continued to be available and was much employed. For the safe use of gunpowder, specialist miners, as well as a disciplined work-force, were necessary, yet very often the labour in small Chinese mines was essentially that of peasant-farmers turning an honest penny during seasonal periods slack in agricultural work. Thus there were several reasons why we could expect only a very slow development of rock-blasting in China in the specifically mining context.

At an earlier point (p. 506) we spoke of the ubiquitous life-saving rockets introduced by Edward Boxer in 1855 for throwing life-lines to shipwrecked sailors. But there was another beneficial action of gunpowder which has perhaps saved even more lives, namely its embodiment in the humble railway fog-signal, which alerts the locomotive crew to danger ahead under conditions of minimal visibility. As White has found, this valuable little detonation was introduced by Edward A. Cowper (1819 to 93) in England in 1837, and since then it has come into use wherever there are railways all over the world.

(iii) Gunpowder as the Fourth Force; its role in the history of heat engines

All these peaceful applications of gunpowder, however, tend to pale into insignificance by comparison with the part it played in the genesis of the steam-engine; and by the same token its predecessor, Greek Fire, the oil that we call petrol or gasoline, was destined to fuel, when the time was ripe, the internal-combustion engine. The title of this sub-section is taken from Varagac (1), who distinguished seven successive energy-sources discovered and applied by mankind, the first three being fire, agriculture and the working of metals, then gunpowder followed by steam, electricity and sub-atomic power.

For half a dozen decades past the idea has been hovering among the minds of historians that the cylinder and the cannon-barrel are essentially analogous, and that the piston and piston-rod may be considered a tethered cannon-ball. The piston and cylinder of course long preceded the metal-barrel gun, and bombarding, going back to the Alexandrian mechanicians and the Roman force-pumps, as also to the Chinese piston-bellows; but the military engineers of China can have had little idea of what they were starting when they first used metal to make

their fire-lance tubes (cf. p. 234 above), and then later their metal-barrel hand-guns and bombardets. One can now see the significance of our definition of true guns (p. 498 above) as opposed to co-axial projectiles and proto-guns, for only when the projectile exactly fitted the bore did the analogy with cylinder and piston make itself manifest. It all began with incendiary and hurtful fire as such, but when it ended with propellant explosion, then the door was open for all piston engines. The djinn was now well and truly in the bottle, and it was the Chinese military inventors who put it there in the first place.

There was really a convergence here of two strands of cylindrical structures; in the pumps and bellows the force was applied from the exterior to the contents, but in the cannon the force, and a very great one, was applied from the inside outwards, doing work. We already long ago came across this antithesis when we found that the morphology of the rotary steam-engine of the early nineteenth century, with its classical solution of the problem of inter-conversion of longitudinal and rotary motion (piston-rod, connecting-rod and eccentric crank) had been anticipated by that of the water-powered reciprocating blowing-engines of China. But the physiology was exactly the inverse, for the water-power bellows applied the force to the piston from outside, while the steam-engine applied it from inside. As for the dating, we used to say that the reciprocating furnace-bellows and flour-sifters were in general use by about +1390, but we now know that the whole assembly developed much earlier. First it was pushed back to the +11th century by Cheng Wei (1) who studied a painting of +965; and then Jenner, translating ch. 3 of the Loyang Chihhsien-Chi (Description of the Buddhist Temples and Monasteries of Loyang), found unmistakable terminological evidence of it—a bolting- or sifting-machine about +530. The book says that at Ching Ming Su (1873), south of the city:

there were roller-mills and mills for grinding, trip-hammers (for pounding), and bolting-machines (for sifting and shaking), all driven by water-power (yu nien wei ching pho, chih yung shui kung). Of all the marvels of the monasteries these were considered the most remarkable (chihh chien chih mien, tsai wei ching shao).

This water-powered shaker or sifter assuredly worked by the mechanism which we find depicted later on. The reciprocating conversion design thus preceded the rotary steam-engine by no less than thirteen centuries. And the steam-engine, and later the internal-combustion engine were in the truest sense children of the cannon. But now the work they did was beneficent work.

* Successful mechanical rock-drilling was not introduced until the middle of the nineteenth century, and then in North America, cf. Lankston 3.
* Cf. Anon (159).
* In American parlance, railroad torpedo.
* No one seems to have said this in so many words, but the idea was current coin in Cambridge in the thirities, when Desmond Bernal was writing his Social Function of Science. Cf. Needham (66) p. 95; Needham & Needham (1), p. 292; also Needham (48), p. 7, (64), p. 143.

* This was of course true also of all the late +17th-century air-pumps. It was precisely the exploration of the properties of the vacuum which led to the atmospheric steam-engine and ultimately to the fully developed steam-engine.
* Vol. 4, pt. 2, pp. 359 ff., 372, 379, Figs. 602, 603, 607 b; Needham (48), fig. 8.
* See Vol. 4, pt. 2, Fig. 461.
* How direct the genesis was will appear a few pages below.

1 景明寺 2 有廬堂宿樹, 皆用水功 3 伽藍之妙, 業務稱首
30. MILITARY TECHNOLOGY

Perhaps Bernal was the first to formulate the analogy when he remarked that
the steam-engine has a very mixed origin; its material parents might be said to be the
cannon and the pump. Awareness of the latent energy of gunpowder persistently sug-
gested that uses other than warfare might be found for it, and when it proved intractable
there was a natural tendency to use the less violent agents of fire and steam.  
And he also wrote:

A new and important connection between science and war appeared at the breakdown
of the Middle Ages with the introduction ... of gunpowder, itself a product of the hall-
technical half-scientific study of salt mixtures ... In their physical aspect the phenomena
of explosion led to the study of the expansion of gases, and thus to the steam-engine; and
this was suggested even more directly by the idea of harnessing the terrific force that was
seen to drive the ball out of the cannon, to the less violent function of doing useful civil
work.  

Seven years later, Vacca was speaking at an Italian symposium on the origins
of specifically modern science in Europe rather than in China. 

A further advance was made [he said] by the invention of firearms, and of machines to
use the expansive force of steam. Gradual familiarisation with the mechanics of explo-
sions as they occur in firearms led to an almost ceaseless series of attempts to harness
their power, from Papin's rudimentary efforts down to the modern internal-combustion
engine.  

In 1948 Bernal discussed the connection again.

Ultimately [he wrote] it was the effects of gunpowder on science rather than on warfare
which were to have the greatest influence in bringing about the Machine Age. Gunpow-
der and the cannon not only blew up the mediaeval world economically and politically;
they were major forces in destroying its system of ideas. As John Mayow put it: 'Nitre,
that admirable salt, hath made as much noise in philosophy as it hath in war, all the
world being filled with its thunder.' The force of the explosion itself, and the expul-
sion of the ball from the barrel of the cannon, was a powerful indication of the possibility
of making practical use of natural forces, particularly of fire, and was the inspiration behind
the development of the steam-engine.  

* (3), p. 24. It may have been natural, but it occupied many men's minds for many years in Europe all the
same. 
* (3), p. 166. But as we shall see, the way to steam power lay not through gaseous expansion, rather through
the partial vacuum created after an explosion. 
* Giovanni Vacca (1672-1923) was an Italian soldier whose work we have often quoted in
previous volumes. 
* (6), p. 11. We shall explain the reference to Papin shortly, but the same remark about expansive force
applies. Expansive pressure on both sides of the piston alternately only came into play after the atmospheric engine
had succeeded.  
* Quasi inimicum in Fines exit, si sal hoc admirable non minus in Philosophia quam Bello Streptat
above.  
the analogy with the cannon no further. So also in (2), pp. 256 ff., 316 ff. He tells the story of the steam-engine
without emphasising this connection.

30. THE GUNPOWDER EPIC

But it was left for Lynn White in 1962 to express the matter even more clearly.  
The cannon [he wrote] was not only important in itself as a power-machine applied to
warfare; it is a one-cylinder internal-combustion engine, and all of our more modern
motors of this type are descended from it. The first effort to substitute a piston for a
Cannon-ball, that of Leonardo da Vinci, used gunpowder for fuel, as did Samuel Mor-
land's patent of 1661, Huygens' experimental piston-engine of 1673, and a Parisian
air-pump of 1674. Indeed, the conscious derivation of such devices from the cannon
continued to handicap the development [of internal-combustion engines] until the
nineteenth century, when liquid fuels were substituted for powdered.  

And in 1977 he returned to the same theme, saying that

Francis Bacon had more reason to be excited about a cannon than perhaps he himself
realised. The cannon constitutes a one-cylinder internal-combustion engine, the first of
its genus.... Lamentably, inventors along this line of technological growth fell into the
very trap against which Bacon had warned them; focus on tradition rather than on the
qualities of Nature itself. They were so conscious of the cannon and gunpowder as prece-
dents for their efforts that it was not until the mid-nineteenth century that they finally
realised that the Chinese chemical mixture ... was inherently too awkward to give power
to continuously operating engines. Only then did they turn—and with immense techni-
cal success—to the lighter distillates of petroleum which during the Middle Ages had
been developed by the alchemists of Byzantium, Islam [and China] primarily for use as
'Greek Fire'. Two of the more conspicuous results were the automobile and the piston-
engined aeroplane.  

But in the meantime the gunpowder-engine's failure had led directly, as we shall see,
to the steam-engine's success.

So far we have been dealing in generalities. By +1500 it was becoming clear that
the force of gunpowder ought to be made to do something useful, instead of
just propelling projectiles. It was the merit of Hollister-Shortt that he recognised
the first appearance of such a use in the 'gunpowder trialers', devices introduced
by gunners to test the quality of their powder by making it perform some effect,
some measurable work, and that he then saw the close relation of these to
the gunpowder-engines which appeared rather later. Broadly speaking, one may say
that the heyday of the trialers or testers occupied the century +1550 to +1650.

* (7), p. 100. 
* We shall follow these developments more closely in what follows. 
* Perhaps Lynn White was thinking here of the pyrochlore of the Niepce brothers invented in 1666, a very
complicated machine which used hydromolpump powder as fuel, combusted within the cylinder; cf. Damaul
(3). 
* This carbonaceous material, long used by pharmacists as a dusting-powder and for pill-coatings, consists
* (20), p. 3. 
* (4, 6); much of the information in the following paragraphs comes from this researcher. The only earlier
paper on the subject known to us is that of Fischler (1), and that we have also used. 
* Here one can see a good example of the definition of specifically modern science as the mathematicisation
of hypotheses about Nature, combined with relentless experiment, for this at once led to the quantisation of
phenomena, describing effects in terms of measure and number. 
* Pulveriser or spreuwolfs.
while that of the engines followed in the half-century ending about +1700. The latter were thus directly proenial to the development of the steam-engine, and intimately connected with it.

In +1540 Biringuccio was still taking a piece of paper and burning a small amount of gunpowder on it to see whether it would go off in a puff without burning the paper or no. But soon afterwards designs for more sophisticated mechanical triers were beginning to be pondered. The oldest which has some down to us is that of William Bourne in his book of +1578, Inventions or Devices. He had a cylindrical metal box within which the powder was set off, and according to its strength the explosion pushed up the hinged metal lid so that it caught on one or other tooth of a quadrant ratchet, giving thereby a crude quantitative measurement. This device was again described by John Bate in his Mysteries of Nature and Art of +1634; his cut is reproduced in Fig. 224. So, by firing the same quantity of divers kindes of powders at several times, you may know which is the strongest. The hinged cover appears again in the fine plate of John Babington's Pyrotechnia (+1635) which we give in Fig. 225; it is (A) below on the right, but now the lid when blown off upwards, rotates a graduated discoidal plate which was braked by a spring (Fleming, 1) so that the strength of the gunpowder could be empirically measured. Finally, the hinge cover reached its apogee in the trier which Robert Hooke demonstrated to the Royal Society, a much more workmanlike machine than any that had gone before. On 9 September 1663 Mr. Hooke brought in a scheme of the instrument for determining the force of gunpowder by weight, together with an explication thereof; which was ordered to be registered as follows: The design is shown in Fig. 226. The explosion cylinder had a hinged lid with a touch-hole closed by a strong spring, and at the other end the lid narrowed to a tooth which engaged with a cam or wheel-ratchet; this was on the same axle as a beam or arm which could be loaded with a variable weight. During the following months several tests were made but all failed, yet when notices of gunpowder experiments resume in +1667 the deficiencies of construction had been overcome, and the emphasis had shifted to making the engine do some other kinds of useful work. In January of that year an experiment was ordered for the applying of the strength of gunpowder to the bending of springs, thus storing energy, and this was successfully accomplished. Hooke was also asked to see if weights could not be raised by gunpowder. Robert Boyle suggested that the force of gunpowder might be tried by making it raise a weight of water (which it would expel out of a vessel). How exactly the springs were wound up, or the weights raised, the Journal Books of...
the Royal Society do not say, and on subsequent experiments they are silent too, but the whole sequence is of the greatest interest for it shows a gunpowder trier in the very act of turning into a gunpowder engine.

The blowing off of lids continued to the end of the century and beyond, as can be seen in the book of Surinse de St Remy (1) published in +1657. Though often mounted like pistols, they were quite similar to Babington's device, for upon firing, the cap of the explosion chamber rotated a graduated wheel, which came to rest upon a ratchet tooth and so assessed the force of the charge.

Boyle's suggestion reminds us that another of Babington's triers involved precisely the expulsion of water from one vessel to another. The set-up is seen in Fig. 225 (D, below on the left); a given weight of a gunpowder mixture exploded in (C) sent its gases into the vessel (A) and expelled a measurable quantity of water into (E). For comparing powders, this, said Babington, was 'the certainest way, although the most troublesome.' But now he was measuring the volume of gases formed rather than the mechanical force of the explosion, and the result was directly proportional to the percentage of nitrate in the composition, since that was the oxygen-provider giving mostly CO₂ with smaller amounts of the oxides of sulphur and nitrogen. The displacement of water by air or steam was an ancient principle, going back to the Alexandrians, and therefore very familiar, but in +1635 the properties of the vacuum had still not been explored, so that Babington's device was only obliquely a predecessor of the water-raising systems of de Hautefeuille and Savory.

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* This probably explains the reference to trier "wheels" in Morth (1), +1683, ch. 35, not further elucidated.
* The trier (1) gives two pictures from de St Remy's book and figures two main examples from the 1683 Rhys Collection. De St Remy's preferred method, however, was to cast brass balls of known weight from a mortar at a known elevation (30° to 45°) and measure their range. Fletcher figures a later standard mortar of this kind from the Luzerner Waffenanstalt in fig. 4.
* (1), ch. 68.
* See our arguments relating to this on pp. 110, 148, above.
* Johannes Bernoulli (1), in a Basel dissertation of +1699, described how he ignited with a burning-glass a small amount of gunpowder in a glass bulb which connected with a tube dipping into water. After the boiling which ensured the water was found to be acidified, so he concluded, not knowing what the gaseous combustion products were, that fire was itself an acid ("dauid inmerget dies point,. eed [me at acidum]. But this early chemical experiment was not related to the triers.
* We shall look at these on pp. 516, 518, below.
The other two pieces of apparatus in Babington's plate derive from experiments of Joseph Furtenberg (2) published in +1627. Both are at the top (B, C in Fig. 25). The former was not very practical, driving up a cover-plate with two holes along a vertical graduated scale marked on one of the columns, but the latter was a useful and workable device. Here the cap of the explosion chamber was blown up vertically guided by two wires, tripping as it went a series of twenty hinged ratchet-arms or 'keys', upon one or other of which it eventually came to rest, thus giving a measure of the gunpowder's strength. This system has a descendant among the pieces of apparatus used for determining explosive force at the present day; this is the 'whirling height épreuvezette'. The upper conical riddled opening of a combustion chamber is closed by the tapered end of a 10 kg. weight, and this is whirled upwards by the explosion between a cage of slide-bars, clicking in at the culmination point by means of a catch.

It should be mentioned here, however, that the most widely used contemporary device for measuring explosive force is the 'ballistic pendulum' developed and used at Fort Halstead. This employs a principle quite different from those used in any of the old triers, namely retro-active rocket propulsion. A mass of steel 150 kg. in weight is suspended from a rigid framework by wire, just over two metres long, and within this mass there is a steel tube of 25 mm. bore taking a charge of about 10 gm. and with an unconfined orifice. When detonated electrically the heavy weight is propelled forwards in an arc by the energy release and its swing recorded by a stylus; then the excursion is expressed in percentage terms of a standard charge of picric acid. This has quite superseded the rather qualitative Trauzl test, which assessed the deformation produced by explosions set off within a block of lead.

Hollister-Short remarks that Furtenberg's flying-cap trier could have been a precursor of, or at least a stimulus for, Huygens' gunpowder engine of +1673, since the guide-wires directed the cap just as the cylinder-walls directed the piston. We should not lightly dismiss this idea, which after all is no more far-fetched than the comparison of the piston and cylinder with the cannon-ball and cannon, an analogy accepted on all hands as justified.

But Huygens was not the first to make a gunpowder-engine; he had been anticipated by Leonardo da Vinci (as so often happened with that great Renaissance inventive genius) and Leonardo had a cylinder and piston. We must compare what he wrote with the diagram which he drew (Fig. 227). His words of +1508 were these:

To lift a weight with fire, like a horn or a cupping-glass. The vessel [i.e. the cylinder] should be r braccio wide and 10 in length, and it should be strong. It should be lit from below like a bombard, and the touch-hole rapidly closed, and then [all] immediately closed at the top. [You will see] the bottom [i.e. the piston], which has a very strong leather [ring] like a [pump-] bellows, rise; and this is the way to lift any heavy weight.

As the diagram shows, a weight was suspended from the downward-pointing piston-rod, and gunpowder ignited above the leather-packed piston, then as soon as the gases had rushed out (expelling most of the air) all openings were closed, and as the remaining gases cooled and contracted, a partial vacuum was generated, thus sucking up the piston and raising the weight. Here Leonardo came nearer to the ultimate gateway of success, the vacuum, than any before him, anticipating in a sense the +17th-century physicists by 150 years or so; but

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* Babington (i), ch. 66.
* (i), ch. 67. The Waffensammlung at Vienna has a fine contemporary example from Ambras Castle. It is 57 cm. in height.
* De St Remy (i) described in +1607 a variant in which the cap was weighted and carried a vertical shaft; of which were also caught on ratchets. A late example of this device is in the Kütner's Waffensammlung (Fischer (i), fig. 2).
* Described by Hahn, Hinze & Treumann (i).
* For our information on these matters we are much indebted to Dr Nigel Davies.
* Cf. Connor (i). The test does not distinguish between deflagration and true detonation, but there is a cartridge case deformation test which will do so; Connor (2). Cf. Hughes (i), p. 46.
* The degree of tamping may be varied at will.
* The arresting catches might also provide a clue to the origin of the retaining devices talked of by Huygens and in +1650 described by Papin.

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**Fig. 227.** The weight-lifting gunpowder-engine of Leonardo da Vinci described and figured by him in +1508. In this suggested reconstruction diagram a gunpowder explosion above the piston generated a partial vacuum, which then pulled up the weight suspended underneath.
30. MILITARY TECHNOLOGY

without a deeper analysis of the phenomenon of the cupping-glass he could go no further.6

What was this thing? It was one of mankind’s most ancient medical instruments, a cup-shaped vessel placed on the skin at a suitable site and emptied of air by the burning of a small piece of wool or other combustible material inside it. The vacuum so formed sucks up the skin and flesh so as to bring about cutaneous vasos-dilatation, and if the place has first been scarified it encourages transudation and bleeding. Historians of medicine regard the procedure as pre-historic in origin, and describe it from all the civilisations.7 The oldest vessel used was probably a hollow buffalo horn, which accounts for one of its Chinese names, chiu fa,8 but later short tubes of bamboo were used, and these are still called hau kuan,9 tow or paper being burnt in them. There are many early literary mentions, and cupping was part of one of the seven departments (khoa) of the Thang Medical Administration.10

Now Leonardo certainly did not have the concept of the vacuum and its uses, subsequently so clear, but it was a fine thing to recognise that certain procedures would make vessels suck other things in, and burning gunpowder could be even more effective than the small combustibles used by the physicians. All he had to go on was the Aristotelian truism that ‘nature abhors a vacuum’, but it was enough.11

Perhaps the most extraordinary aspect of the situation was that Leonardo also conceived what one might call the standard experimental set-up afterwards used by Huygens and others, namely a cylinder and piston, the piston-rod of which was attached to a cord passing over two pulleys and then suspending a counter-weight.6 But he did not use this for weight-raising by gunpowder, he set it up about 1505 in order to see how much steam coming off from heated water would expand.16 All this was connected, no doubt, with his steam cannon, the Archimede, in which a jet of high-pressure steam was suddenly admitted behind a ball to shoot it forth through a long barrel.17 Here again was a striking link in the connections we are unravelling between the cannon barrel and the steam-engine cylinder.18

Yet still the expansive force of steam was not the clue or key which would open the gate into the future; that key was nothing at all, the absence even of air, just emptiness. Cesetius had been responsible, about –230, for a simple and fundamental machine, the piston air-pump, known from the descriptions of later mechanicians.19 This simplest of pumps entered upon a new incarnation in the +17th century, when the virtuosi began to explore with excitement the properties of vacuum spaces, for what had been invented originally as a bellows for pumping air into something now found fresh employment as the ‘air-pump’ for getting as much air as possible out of it. The closer scrutiny of the alleged horror vacui began with Galileo himself in +1638, and was continued in +1643 by his disciple Evangelista Torricelli (+1608 to 47), whose mercury barometer was the start of many experiments showing that the air weighs down on everything with a pressure of some 14 lb. per square inch.20 This opened men’s minds to the recognition of the fact that air has weight, and that the vacuum was a physical reality. Then came the long-continued work of Otto von Guericke (+1602 to 86) who invented the evacuating air-pump by about +1650, and then four years later performed the sensational experiment of the ‘Magdeburg hemispheres’.21 He also demonstrated the weight required to tear them apart, the crumpling of evacuated copper globes, and the pistons which raised men or weights into the air when sucked down by the vacuum.22 In +1659 there followed the improved air-pump of Robert Boyle (+1627 to 91),23 and with assistance from Robert Boyle it had attained its final form by +1667.24

Thus was established that all these effects were due to an omnipresent force—the ‘spring and weight of the air’, from which man might draw infinite...
The effect, and greater always have no air.

But in 1670 an acute and interesting question had arisen. What could one do to create a vacuum underneath a piston (and so make it do useful work), otherwise than by the previous use of another piston in an exhaustive air-pump according to the Magdeburgian art? When young Denis Papin from Blois took up his post as assistant curator of experiments under the great Christiaan Huygens at the Académie Royale des Sciences in Paris in +1671, this must certainly have been one of the methods proposed. The example of the powder triers would assuredly have been in mind. Huygens set to work in earnest towards the end of +1672 and by 10 February in the following year described the engine he had constructed for obtaining 'a new motive power by means of gunpowder and the pressure of the air'. It consisted of a cylinder the piston-rod of which was attached to a cord running over two pulleys and suspending a weight (Fig. 228).

Fig. 228. The drawing by Christian Huygens of his gunpowder-engine in +1673, from his Varia Academica, p. 242; cf. Hollister-Short (4), pp. 13 ff. The partial vacuum produced in the cylinder as the gases left and cooled brought down the piston and accordingly raised the weight suspended from the pulley.

At the moment of the explosion, the gases formed swept out most of the air through a valve which was then immediately shut, so that as everything cooled a partial vacuum was produced, and the piston was sucked down with great force—but not the whole way, for, as Huygens noted, about one-sixth of the air and gas remained. The down-stroke was therefore incomplete. Nevertheless, he found the effect striking enough.

The force of cannon powder has served hitherto [he wrote] only for very violent effects such as mining, and blasting of rocks, and although people have long hoped that one could moderate this great speed and impetuosity to apply it to other uses, no one, so far as I know, has succeeded in this, or at any rate no notice of such an invention has appeared.

Huygens went on to prophesy that this motive power could be used for raising water or weights, working mills, or even for driving vehicles on land or water. Huygens proposed to gain constant torque however by making the pulleys of finite form.

1 Huygens was very precise here, because the internal-combustion engine has so high a power/weight ratio. He found by calculation that a single pound of gunpowder possessed enough energy to raise 3000 lb. 30 ft. He also reckoned that a cylinder 3 ft. in diameter would give upwards of 90 h.p. 'Pour faire voir des effets surprenants à des fiers du monde et des hommes qui croient le corde.' But 'ni l'on pourroit bien voir l'air ce serait encore bien autre chose... .'
I think [he wrote] that a flexible wooden tail at the stern of a boat, as I have visualised it, and as I believe they make use of in China, would be a good application for this, if moved by the force generated in this cylinder. Here was unquestionably a reference to the *jukoh*, or self-feeding propulsion-oar propeller, characteristic of small Chinese craft from Han times onwards. Huygens also sketched a form of ballista operated by linkwork as the piston descended.

So matters remained until Denis Papin, now occupying a chair at Marburg, returned to the problem of improving the gunpowder-engine. In + 1688 he published a new version (1), the chief difference in which was that the piston was now furnished with a spring valve closed by atmospheric pressure when the gases had left, after which it was allowed to make a powerful down-stroke (Fig. 229). But the fifth or sixth part of the air and gases always remained. Ruminating on this, Papin made a pregnant statement in his paper (2) of + 1690:

> Since it is a property of water that a small quantity of it, turned into vapour by heat, has an elastic force like that of air, but upon cold supervening is again resolved into water, so that no trace of the said elastic force remains, I readily concluded that machines could be constructed wherein water, by the help of no very intense heat, and at little cost, could produce that perfect vacuum which could by no means be obtained by the aid of gunpowder...

Thus was born the first of all steam-engines. It looked just like the earlier gunpowder-engines, but a spring catch fitted into a notch on the piston-rod so that the down-stroke could be delayed until it was as powerful as possible, and then it went down right to the bottom of the cylinder (Fig. 230). Here the boiler, engine-cylinder and condenser were all in one; it was given to Thomas Newcomen to separate the boiler from the cylinder, and to James Watt to introduce a separate condenser—otherwise all the essential parts were present (Fig. 231).

Here at last was an effective cycle, the removal of air and the condensation of steam, so that the way was open to the 'atmospheric, or vacuum, steam-engine' (+ 1712). Though Denis Papin never harnessed his piston-rod to anything, his historical position in the transition from gunpowder to steam is a central one,

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* Vol. 4, pp. 629 ff. The *jukoh* has a significant place in the history of screw-propulsion, and in + 1790 there was an unsuccessful attempt to apply steam-power to it.
* See also Galloway (1), pp. 41 ff., 43 ff.; Gerland & Traumiller (1), pp. 227 ff.
* 'If, say, [denotes]...'; the world of mechanics is not without 'theorists'...'; and any number of words to that effect. At any rate, not successfully. There are accounts that towards the end of his life, in + 1707, Papin experimented with a small paddle-driven steamboat on the Fulda R. near Cassel, but it is not easy to see how it could have worked even with a Newcomen beam-engine, as the stroke frequency would have been so slow. Our information remains obscure and somewhat contradictory on this last phase. See Galloway (1), pp. 76 ff.; Thurston (1), pp. 224 ff., where more detailed references will be found.

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and Thomas Newcomen himself would surely never grudge him his statue among the flower-sellers and vegetable-stalls that overlook the Loire on the great flight of steps at Blois.

Steam had been on Papin's mind for quite a long time. Nine or ten years before, he had produced his steam-pressure-cooker or 'digester'. In China steam had traditionally been used for many things, especially in cooking, and bread

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* I find it almost impossible to believe that Newcomen never knew of Papin's steam cylinder, at least by hearsay. Papin published several other papers (3, 4, 5) and may be there was someone at Dartmouth, one of the men who might have read French, if not Latin, and gave Newcomen access to Papin's work.
Fig. 230. Denis Papin's steam-engine of +1690, after Gerland & Traumüller (1), fig. 220. It looked just like the earlier gunpowder-engines, but the spring catch on the piston-rod delayed the down-stroke until the cooling condensed the steam and created an approach to a perfect vacuum, after which the suspended weight would be drawn up to the maximum extent. This was the invention which led to Thomas Newcomen's first successful 'atmospheric', or vacuum, steam-engine of +1712.

was (and is) generally steamed there rather than baked. In his Travels in China (1804) John Barrow wrote:*  

In like manner they (the Chinese) are well acquainted with the effect of steam upon certain bodies that are immersed in it; that its heat is much greater than that of boiling water. Yet although for ages they have been in the habit of confining it in close vessels, something like Papin's digester, for the purpose of softening horn, from which their thin, transparent and capacious lanterns are made, they seem not to have discovered its

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* (1). p. 298.
To make a sound like thunder in a copper vessel (liang yüng). Put boiling water into such a vessel [which must be closed extremely tightly], and then sink it in a well. It will make a noise which can be heard several dozen li away.

If the vessel was full of steam when it was let down into the cold water, condensation would have created a vacuum, and if the copper was thin an implosion would have followed, echoing far beyond the well. Perhaps it was characteristic of the place and time that the invention served only military or thaumaturgical purposes, with no attempt to use the strong force that was evidently present. Here there was no piston, but nor was there any in a collateral development which also preceded the steam-engine, and also arose from the properties of gunpowder, namely the vacuum displacement systems for water-raising. As early as +1661 Samuel Morland got a patent or warrant for pumping water from mines or pits more effectively 'by the force of Aire and Powder conjointly', but it was never finalised. Then in +1678 Jean de Hautefeuille published his tract entitled Pendule Perpetuelle which included 'a way of elevating water by gunpowder'. Actually there were two ways (Fig. 232). In the first, a rising pipe from the water 30 ft below delivered into a vessel that was partially evacuated by exploding a charge of gunpowder in it, and the water so sucked up was drawn off by a tap into a reservoir; this in turn could act as a second-stage sump for a further 30 ft lift arranged in the same way. Such cisterns in pairs, with gunpowder successively let off, would give a continuous discharge. But this was doing no better than a set of suction-pumps, so a second system was described, for use where force-pumps were necessary. Here a horizontal pipe was set under the water-surface down below, with an inlet-valve at its central point. At one end of this pipe there rose above the water-level a short vertical tube leading to a gunpowder combustion chamber. At the other end a much longer tube rose up having a succession of non-return valves. As one charge after another was ignited, the water was driven up the rising main as high as the materials would stand. In this second system there was no dependence on the partial vacuum, and the gunpowder could be supplied in culasses like breech-loading cannon. All in all, it reminds one of Shen Kuo valuing petroleum only for the black from it would make, so suitable for ink, and for no other purposes (Vol. 3, p. 566).

*TPYL* ch. 736, p. 83, tr. auct.  *This clause is from ch. 738, p. 34.

*It reminds one of Shen Kuo valuing petroleum only for the black from it would make, so suitable for ink, and for no other purposes (Vol. 3, p. 566).*

*By Morland's (p. 44) Dickinson (4), p. 16.

*By Hautefeuille could well have known of Babbage's fourth trial method, where water was displaced by the combustion gases.*

*If pp. 305-6 above, How close the connection is between the cannon and the steam-engine appears when one realises that Newcomen had to get his cylinders bored smoothly by the gun-founders, Rolle (1), p. 86.*

*The gases and air were exhausted through four non-return valves.*

*But Hautefeuille could well have known of Babbage's fourth trial method, where water was displaced by the combustion gases.*

*If pp. 305-6 above, How close the connection is between the cannon and the steam-engine appears when one realises that Newcomen had to get his cylinders bored smoothly by the gun-founders, Rolle (1), p. 86.*

Fig. 232: Jean de Hautefeuille's methods of raising water by means of gunpowder explosions, after Hellister Short (4), p. 18. The drawing is from the rare tract of +1678. In Fig. 231 a rising pipe delivered into a vessel that was partially evacuated by exploding a gunpowder charge in it, and the water so raised was drawn off by a tap into a reservoir; this in turn could act as a second-stage sump for a further 30 ft lift arranged in the same way. Such cisterns in pairs, with gunpowder successively let off, would give a continuous discharge. But this was doing no better than a set of suction-pumps, so a second system was described, for use where force-pumps were necessary. Here a horizontal pipe was set under the water-surface down below, with an inlet-valve at its central point. At one end of this pipe there rose above the water-level a short vertical tube leading to a gunpowder combustion chamber. At the other end a much longer tube rose up having a succession of non-return valves. As one charge after another was ignited, the water was driven up the rising main as high as the materials would stand. In this second system there was no dependence on the partial vacuum, and the gunpowder could be supplied in culasses like breech-loading cannon. All in all,
these devices would obviate the expense of great numbers of men and horses in mines, drainage-schemes and the like.

But the vacuum came back with a bang in Captain Thomas Savery's 'water-commanding engine'. In this machine, so often described, water was sucked up some 30 ft into a vessel made vacuous by condensation of steam, then forced higher still by a second admission of steam, suitable cocks being turned by hand at the several phases of the system. A continuous discharge was gained by having two vessels in parallel, one being filled by suction while the other was emptied upwards by pressure. This was ready by +1698, but ran into many difficulties largely because of the inferior strength of the materials available. William Blakey improved it nearly a hundred years later, but by then Thomas Newcomen's atmospheric steam-engine, working a rocking beam, the ancestor of all later steam-engines, had been set up in many places since +1712, and the need for displacement systems was no more felt. Still, they are justifiably numbered among the predecessors of steam power.

From all that has now been said it will be evident that the explosive force of gunpowder played a fundamentally important part in the development of the steam-engine. But there is a second chapter yet to relate, that of the internal-combustion engines. Of these the very first was the hand-gun and cannon or bombard itself, which we have traced back to China about +1285; and the gunpowder-engines of Huygens and Papin were of the same category since they exploded the mixture within the cylinder itself and not in any separate vessel. The water of Papin's first steam cylinder was heated directly in it, so his experimental engine was an 'internal' one although there was no 'combustion', but as soon as Thomas Newcomen decided to have a separate boiler, as he did in the early years of the +18th century, the line of descent of the steam-engine separated off from all true internal-combustion engines. Still, for a century and more thereafter men's minds continued to be haunted by the idea of having an explosion right in the cylinder, and somehow taming its violence to give useful power. But the purpose of the explosion was now quite different from that of Huygens; it was no longer to drive out air and gases with a view to creating a vacuum so that the piston would get sucked in (at least some way), it was rather to effect a working stroke more closely similar to that of the cannon itself—though the piston was not free to depart from the machine.

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It is interesting that the evolution of the steam-engine was just about complete by the time that engineering inventors began producing designs for internal-combustion engines. The separate condenser had been evolved by James Watt between +1765 and +1776, the double-acting principle came in about the same time as reciprocating rotary motion, c. +1783, and high-pressure steam was introduced by Richard Trevithick from 1811 onwards. In the light of this it is quite interesting that gas-engines date from about +1826, and all the oil-engines (among which one must include those running on Diesel oil and petrol) from about +1841.

The first way of getting an explosion in the cylinder was to make a mixture of air and coal gas, and then to ignite it on each stroke. This was accomplished more or less by Samuel Brown from +1823 onwards, but his engine was not a success. Ignition at reliable intervals was always the problem, and William Barnett used coupled gas flames in +1838. Others turned to different gases, such as hydrogen and air, or pure methane and air; as in the work of Eugenio Barsanti and Felice Mateucci between +1843 and +1854, and it was these inventors who were the first to introduce that electrical ignition to which the future belonged. But the Newcomens of gas engines was J. J. E. Lenoir (1822–1900) who in +1859 made the first practical types, resembling horizontal double-acting steam-engines, with flywheels, slide-valves and water-cooling. The next greatest step forward came, however, when Alphonse Beau de Rochas (+1815 to 91) described in +1862 the four-stroke cycle basic to the successful operation of all internal-combustion engines. The first outward stroke of the piston draws the explosive mixture into the cylinder and the first inward stroke compresses it; ignition then takes place at or about the dead-centre position and the explosion.

* Part of their impetus undoubtedly came from the fact that the power/weight ratio of steam-engines was so low, that they were not adaptable for small factories and workshops, nor for road transport, let alone for air.

* In which steam is admitted on both sides of the piston alternately so that each stroke does useful work (Dickinson +, pp. 79 ff., 134 ff., 158 ff.; Galloway +, pp. 162 ff., 605 ff.; Newcomb +, pp. 141 ff.). This principle was much more akin to the Chinese, as the history of the double-acting piston-bellows goes to show (Vol. 4, pp. 2, 155 ff., Newcomb +, pp. 15 ff.)

* This again is ancient in China; p. 545 above. Cfr. Newcomb +, pp. 39 ff.


* This is mostly methane, with small amounts of CO, CO2, ethylene and acetylene. Here we cannot go into the history of gases, which forms so large a part of that of modern chemistry itself, nor do more than recall John Baptist de Hémont's suggestion of the word, but a quick reference to coal gas would be the thing (Cow & Cow +, p. 389 ff.)

* In what follows we use the explications of Field +, le Galle +, Uccelli +, pp. 377 ff., 377 ff., 381 ff.; Usher +, pp. 370 ff., and ed. 406 ff.; Burstall +, pp. 333 ff., Gille & Bury +, and Day +

* There had been a string of similar projects and patents almost from the time when gas-lighting was introduced (Cow & Cow +, p. 929). Robert Street's idea (+1794) was vague, but Philippe le Bon d'Humberin in +1790 got rather further.

* James Johnston in +1841 dared to try hydrogen and oxygen, but in those days the liquid forms were (perhaps fortunately) not available.

* Something of the sort had already been suggested by Alessandro Volta in +1775.

* See Leprince-Ringuet +, 31 ff.

* This was always a problem. In +1860 M. Hugon made an engine in which a fine spray of cold water was injected into the cylinder after each explosion, but it was unsuccessful.
drives the piston on its second outward stroke, after which its second inward stroke expels the burnt gases from the cylinder. Now at last the engineers had got their explosions under control, so to that extent the cannon was by 1860 firmly mastered. The real dénouement from our present point of view was, however, yet to come, as we shall see. A few gas-engines are still running, though most of them exist today only in museums; naturally they could never go far from gas supplies, though of course there is a sense in which all internal-combustion engines are gas-engines since the combustible material enters the cylinder as a fine spray mixed with air.

There followed an entr'acte or deviation somewhat analogous to the steam-vacuum displacement water-raising systems in the history of the steam-engine—namely that of the hot-air engine. John Stirling in 1826 and Eric Ericsson in 1849 had the thought of substituting for steam some new motor fluid more economical and easy to deal with. They therefore fell back on air itself, noting that its volume increases by a third between 0° and 100°, doubles by 272° and triples by 544°. Most of the older generation have memories of seeing part of an engine heated by a blow-torch, after which a swing of the flywheel would set the machine going; but although a number of engineers sought to perfect it, there were many disadvantages, such as fire danger and deformations of the working parts, with the result that like the gas-engine it now survives only in museums, and on a small scale for toys and working models. The hot-air engine lies on a siding because no explosion, no internal combustion, was involved, only the expansion of heated air; but some source of heat remained imperative, so a heat-engine certainly was. But the motive power of the future it was not.

The dénouement of the whole story came in 1836, when Luigi de Cristoforis (+1798 to 1862) began to think of making an internal-combustion engine run on naphtha, a project which he perfected by 1841. Now at last those light fractions of distilled petroleum, originally as Greek Fire so hurtful an incendiary weapon, burning men as well as things, were to become a beneficial power-source for daily use. What the Byzantine +7th century had begun and the Chinese +10th century had continued, now, after a thousand years, found its ideal place within the cylinders of internal-combustion engines. Perhaps we should pause here an instant to consider all the oily substances of this kind which can be used as combustibles; for oil-engines. Diesel engines and petrol engines form a single family. We can tabulate the boiling points of these hydrocarbon fuels as follows:

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Boiling Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum ether or petrol</td>
<td>40–70 °C</td>
</tr>
<tr>
<td>Gasoline</td>
<td>70–90 °C</td>
</tr>
<tr>
<td>Lignite or light petroleum</td>
<td>80–120 °C</td>
</tr>
<tr>
<td>Benzene and toluene (from coal-tar)</td>
<td>82–110 °C</td>
</tr>
<tr>
<td>Cleaning oil (turpentine-substitute)</td>
<td>120–150 °C</td>
</tr>
<tr>
<td>Naphtha (from coal-tar)</td>
<td>140–170 °C (mostly xylene, pseudocumene, mesitylene)</td>
</tr>
<tr>
<td>Kerosene (paraffin oil)</td>
<td>150–250 °C</td>
</tr>
<tr>
<td>Diesel fuel oil</td>
<td>250–300 °C</td>
</tr>
<tr>
<td>Carburic oil (from coal-tar)</td>
<td>170–230 °C (mostly naphthalene and carbolic acid)</td>
</tr>
<tr>
<td>Creosote oil (from coal-tar)</td>
<td>230–270 °C</td>
</tr>
<tr>
<td>Anthracene oil (from coal-tar)</td>
<td>270–</td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>300–</td>
</tr>
</tbody>
</table>

Many of the lighter fractions of these oils have been used in internal-combustion engines at one time or another, but eventually engineers settled for the lower b.p. oils in what we universally know nowadays as the automobile and aero engine. Higher hydrocarbons are commonly 'cracked' to give the lower lighter ones.

The history of these power-sources can be briefly told. In 1873 J. Hock made an engine work with kerosene, and two years later Siegfried Marcus introduced petrol much like that of today; both worked in Austria. At the same time another petrol engine was improved by Enrico Bernardi of Verona, and in the following decade Gottlieb Daimler and Karl Benz (1883–5) brought it to its present form, attaining 800 r.p.m. In a parallel development many types of oil-engine appeared, but the greatest advance was made by Rudolph Diesel (1858 to 1913) who in a certain sense married the hot-air engine to the oil or petrol engine by compressing air violently to a temperature of 800°, sufficient to ignite spontaneously a quite heavy oil injected into the cylinder. As everyone knows, there has been a vast expansion in the use of Diesel engines, especially for railway locomotives. Meanwhile, by 1895 the internal-combustion petrol-burning high-speed automobile engine had reached essentially modern design in the hands of the Count de Dion and M. Bouton.

So now, reflecting on what we have found, we can see that the inventions of Greek Fire in the +7th century and of gunpowder in the +9th were not the unmitigated disasters that many people, even Shakespeare, speaking through...
his characters, have thought. Without them we might have had neither the steam-engine nor the internal-combustion engine. And the moral is the same as that which we saw in the case of the rocket—all depends on what you do with it. Like fire itself, which can be used either for cooking food and warming people, or alternatively for torturing and killing people, the uses of every invention depend upon human ethical judgments; a problem for mankind as a whole, and common to all the civilisations. But the tragic aspect of history is that it should take so many centuries to find out the good use of inventions, and to refrain from the evil.

21 Inter-Cultural Transmissions

Looking back over the long countryside through which we have come, the outstanding impression one has is that what took 400 years to develop in China was then conveyed to the Arabic countries and Europe within 40 years or rather less.\(^a\) Two fuses in particular led into this gunpowder train, a previous 600 years of the isolation and purification of saltpetre in China alone,\(^b\) and a previous 200 years of the distillation of petroleum,\(^c\) first in Byzantium, then in Middle and South-east Asian lands and China. All the long preparations and tentative experiments were made in China,\(^d\) and everything came to Islam and the West fully fledged,\(^e\) whether it was the fire-lance or the explosive bomb, the rocket or the metal-barrel hand-gun and bombard. It reminds one of the old rhyme:

The bible and Puritans, hops and beer,  
Came into England all in one year.

A multitude of traits there are which betray the derivativeness—the use of the term for a vegetable drug,\(^f\) the persistence of mineral, plant and animal poisons in the powder,\(^g\) the trumps as the fire-lances of Europe,\(^h\) and the vase-shape of the early bombards.\(^i\) Striking parallelisms there are too, notably the warnings of the fate which might befall the early powder-makers.\(^j\) All in all, the gunpowder formula was China's equivocal gift to the rest of the world, passing through channels which we have attempted to depict in the chart of Fig. 233.\(^k\)

It may also be appropriate to consider the environment or accompanying circumstances in which the basic transmission occurred. From all our work we have been able to distinguish particular 'transmission clusters', times when several important inventions and discoveries came westwards together.\(^l\) For example, there were several which accompanied the transmission of the magnetic

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\(^a\) Cf. pp. 374, 290, 304 above.

\(^b\) The reason why Greek Fire was important was twofold: first its prefiguration of the incendiary properties of low-nitrate gunpowder, and secondly the fact that the first appearance of gunpowder in war was in the form of slow-match for petrol flares-throwers. See p. 32 above.

\(^c\) This can be seen well in the study of the gunpowder compositions, pp. 346 ff. above.

\(^d\) Cf. p. 346 above. There was a difference, however, in that the Arabs, receiving gunpowder weapon technology first, used the mixture (as had been the case in China much earlier) primarily as a more effective sort of incendiary (cf. Ardanus (1), pp. 6, 14, 24–6). Above (p. 145) we noted how the terms napf, and then bārīl, were used for centuries in Arabic to denote gunpowder, ignoring the sulphur (khiḍ), and the charcoal (jābīm). Partington (3), p. 197, acutely remarked that this was explicable if gunpowder reached the Arabs from China, but not if it came to them from Europe, where gunpowder was not used as an incendiary to begin with.\(^e\)

\(^e\) Cf. p. 472 above. Transmissions were going on here as late as +1450.

\(^f\) Pp. 108 above.

\(^g\) See pp. 355 above. It is also striking that these were used to shoot arrows, in the West as in China previously (cf. pp. 287–8, 307 ff. above). Partington (3), p. 101, found a dozen examples down to +1399.\(^h\)

\(^h\) Pp. 111–2 above. And we could add here the use of live expendable birds (cf. pp. 332 ff.), recommended by John Arderne about +1350 (Partington (3), p. 244).


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Fig. 233. Chart to illustrate the inter-cultural transmission of gunpowder technology in the Old World. For discussion, see text.

Transmissions in the reverse direction when Europe was developing capitalism are also shown in this: cf. pp. 356 E above for the breech-loading principle and improved artillery, pp. 105 ff, for the matchlock musket, and pp. 463–6 for flint-and-steel igniters.

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(compass, the windmill and the axial rudder in the +12th century; and there were also other devices along with the mechanical clock, the blast-furnace for cast iron, the segmented arch bridge, and the helicopter top, in the +14th. It remains to be seen what the root of these was. We should place much gunpowder in the +13th. Probably certain forms of textile machinery were among them, paper-making and printing were on the way, but above all there was that deep conviction emanating from China that if men knew more about chemistry, untold longevity could be achieved. Roger Bacon (+1214 to 92), the first European to talk like a Taoist, represented this outstandingly—and yet by a strange paradox he himself was one of the first Europeans to receive the constituencies and effects of gunpowder. This was neither the first nor the last occasion in human history when men would touch and know, and come to handle, the double-edged powers inherent in Nature, pregnant with almost unlimited might for good or for evil. What gunpowder was for Brother Roger, nuclear energy is for us.

So now it is time to draw all the threads of this sub-section together, and tackle the problems of how the Chinese discoveries and inventions spread out over the whole world. The great advantage of pin-pointing the dates of appearance of specific things in the regions of Europe and West Asia is that we know in what decades to look for the means of transmission; and by the same token we have to be clearly aware of the dates at which specific inventions first made their appearance in China. People have often talked about the passage from East to West of the knowledge of gunpowder as such, but in fact it looks as if we ought to be searching for three separate transmissions (a) whoever it was that brought the present of fire-crackers to Roger Bacon, soon before +1265; (b) how the knowledge of fire-lances, bombs and rockets got into the hands of Hasan al-Rammah and Marcus Graecus by +1280; and lastly (c) how the metal-barrel bombard and hand-gun found their way to the European military by about +1390 in time to get into the picture in the MS. of Walter de Milamet. The first three of these things had been current in China, as we know from the abundant evidence already given, from the +10th century onwards, the fourth (rockets) since the second half of the +12th, and the last only from about +1290. Increasing complexity and effectiveness were thus mirrored in increased speed of transmission.

Perhaps the first of these passages is the easiest to understand. As we noted already (p. 49), when Roger Bacon was writing about his fire-crackers, it had been just thirty years since the first friars had visited the Mongol court at Karakorum. In the intervening time several eminent ecclesiastical travellers had followed them, notably John of Plano Carpini, who went as envoy from Innocent IV to the Mongol khan in +1245, returning two years later, and Andre de Longjumeau, who went again on the same mission in +1249. Above all there

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was William Ruysbroeck, another Franciscan, sent by King Louis in +1252 and returning by +1256; particularly important not only because he wrote up all his travels but because he knew Roger Bacon personally in Pavia. Nor were all the voyagers friars, for there was a layman, a French knight, Baldwin of Hainault, sent out to treat with the Mongols by the Latin emperor of Byzantium Baldwin II about +1250. Much better known was Guillaume Boucher, goldsmith, metal-worker and engineer, who had employment at the court of the Great Khan at Karakorum under Küküük (r. +1269–90) and his successor Mongu (r. +1259–90), during which time he was personally known to William Ruysbroeck. He worked alongside many Chinese artisans, and he would have been particularly interested in any piece of technology emanating from Cathay. All in all, there were many channels, some quite direct, through which the fire-crackers (and the knowledge of what was in them) could have reached Brother Roger.

But the West European friars and knights were not the only people in the picture. Herbert Franke (20, 26) discovered a very interesting account of the appearance of Scandinavian traders in +1261 at the Mongol court, which by then had moved a long way east, from Karakorum (Ho-Lin1) to Shantung,2 north of Peking.3 One of the Chinese court secretaries, Wang Yin,4 kept a diary of those years, the Chang Thang Shih Chi,5 and in it he recorded the following event:

In June there came merchant-envoys from the Fa-Lang country (Frankistan) and (Khambil Khan) received them in audience. They presented garments made of vegetable fibres and other gifts. Their home, they said, which they had left three years before, was in the Far West, beyond the lands of the Uighurs. In that country there is always daylight, (chhang te-fu muk6), and you can only tell the evening time by seeing when the field-mice (teh shih)7 come out of their holes.

The women are very beautiful, and the men generally have blue (pi8) eyes and blond (liang8) hair.

Their ships are large, carrying between 50 and 100 men. These people presented a wine-beaker made from the egg-shell of a sea-bird, and wine poured into it became warm at once. It was called a 'warm-cool cup' (seh t'ang cha9).

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1 Corder (1), vol. 1, p. 398; Konnoff (1); Dawson (3); Beasley (3). Chambers (1), pp. 166–7, believes that the intermediary was most probably Ruysbroeck.
2 A place N.E. of the Altai Mountain and S. of Lake Baikal, on the Orkhon River.
3 This place, Dolon Nor, was the summer capital from +1260. The Jurchen Chiai State had already conquered in +1234.
4 In Chubu Chiao from the Zib Chiang Wei Chi, ch. 81, pp. 99, 100; tr. rev. adjunct. Franke (20, 26). The visit is also mentioned in Hsin T'ang Shih, ch. 7, p. 113.
5 He had been enthroned just the year before.
6 Perhaps cotton, more likely linen from flax.
7 i.e. m. +1258.
8 An early observation of circadian rhythms?
9 The suggestion that the effect was due to quicklime in the shell is not scientifically plausible.
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The emperor was very pleased that this group had come so far, and gave them liberal gifts of gold and textile materials.

Could he perhaps have given them some fire-crackers also? In any case it is obvious that these must have been yellow-haired Norsemen, from the 'white nights' of Scandinavia, probably coming by way of Novgorod, for at that time the centre of an independent state. And this was several years before the elder Polo brothers reached the court of the Great Khan. It would have been just in time for Roger Bacon's description.

Next comes the second problem, that of the transmissions of the more complicated devices which reached Hasan al-Rammâh and Marcus Graecus by + 1280 or so. Paradoxically, these do not seem to have taken place during the European campaigns of the Mongol armies, which lasted for about a decade from + 1236 onwards. 8 In that year Bulgaria was overrun, and in the next all Russia was devastated. 9 Kiev was taken in + 1240, and the greatest fight, at Liegnitz, was in the following year, when an army of 10,000 Germans, Teutonic Knights, Poles and Silesians, under Henry the Pious, Duke of Silesia, was overwhelmed. After this the Mongols faltered, failing to take Olmutz, and sheering off from Austria, instead going down to the Adriatic coast, avoiding Dubrovnik (Ragusa) but sacking Kotor and many other places. By + 1246, when Küyük was elected Great Khan, the westward push was over, though Poland was invaded again, Kraków burnt in + 1259, and Budapest destroyed as late as + 1285.

Now the Mongols were essentially mounted archers with strong tactical discipline, 10 and on the whole made little use even of trebuchet artillery, though some such engines appear from time to time. 11 Incendiaric arrows occur in the accounts, however. 12 There is no mention of gunpowder in the narrative of John

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8 S. of Leningrad and W. of Moscow. Scandinavian–Russian commercial communications were intimate all through the Middle Ages.

9 See Cordier (1), vol. 2, pp. 246 ff. 10 With the notable exception of Novgorod.

10 Liddell Hart (1) remarked that the role of tanks and planes in modern warfare, exemplifying the theory of 'fire and mobility', was a natural development of the tactics of the Mongolian mounted archers. Both Rommel and Patton, he says, were students and admirers of generals like Bâto, Bayan and Mangü, Ögotoi and Subotai.

11 As in Howorth (1), pt. 1, p. 1492; Martin (1); p. 67; d’Ohsson (1); Yule (1), vol. 2, p. 168 quotes a Russian archbishop as saying of the Mongols in + 1244: 'Machina habens multiplices, rete et foetor incendiarum'. Trebuchets artillery were more than mere evidence in Hulagu's campaigns against the Muslims of Persia and Iraq from + 1253 onwards. Indeed he mobilised whole regiments of Chinese engineers, with artillery as well; Yule (1), vol. 2, p. 168; Renaud & Favé (1), p. 294–5; Hourii (1), pp. 113, 118; Howorth (1), pt. 3, p. 97; Boyle (1), vol. 2, p. 608.

12 We have already given a translation of the interesting passage Howorth quoted (and cf. p. 89 above). Presumably by this time they fired gunpowder bombs with strong cast-iron casings (den tin deil), cf. p. 171 above. Later still, in the unsuccessful campaigns of the Ilkhan Ghâzân against the Mamlûk Caliphate in + 1299 and + 1301 for the control of Syria, there must have been many opportunities for the transfer of gunpowder technology to the Arabic armies, but the dates by then were rather too late for our present purpose. Cf. Ayalon (1). 

13 And also hot-air balloons or wind-locks like fire-breathing dragons used for signalling or as standards. This is a curious subject demanding further research; we collected and discussed a number of references in Vol. 4, pt. 2, pp. 597–8.

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14 Blaizey (1); Komroff (1); Dawson (1), p. 57. He also remarks (p. 46) that the Mongols feared the crossbow. Cf. Przewodski (1), pp. 295–4.

15 (1), p. 259. 16 (1), p. 128. Professor Owen Lattimore (piv. comm.) recalls reading of the use of gunpowder when the Mongols stormed Merv and Samarqand, but perhaps only in mines set off below the walls.

17 Saunders (1), pp. 125–9 made a special study of the question, and decided negatively.

18 Lot (1), vol. 2, p. 393 remarked that although firearms gave the Russians superiority over the Tatars in the + 15th century, there was no evidence of the transmission of gunpowder technology from the Mongols in the + 15th century, though presumably they would have known of it. The more recent researches of Chambers (1), pp. 57, 63–4, 165–77 support the negative conclusion.

19 Cf. p. 259 above. The classical work on all these foreigners and their gradual, even sometimes rapid, assimilation, is that of Ch'en Yüan (1). Goodrich (2) on their acculturation is well worth reading too. See also Ch'en Yüan (2).

20 His son Huang (Hu-Hsin) continued his benevolent activities. Cf. Vol. 4, pt. 3, p. 797.

21 書角子図象思丁 * 書思思 * 書詩詩 *

22 享幸 * 聖Params * 賽陽 * 享幸 * 享幸
and which afterwards took their Chinese name (hui-hui phao  or hsiiang-yang phao) from their operators and the Sung city that was being attacked. *The oldest of these engineers was 'Ali Yahya (A-Li-Hai-Ya), d. c. 1280) the Uighur artillery general of Kubilai, and it was he who suggested the summoning of the two experts from Persia and Syria 'Abab al-Din of Mosul (A-Lao-Wa-Ting, d. c. +1295) and Isamul of Herat or Shiraz (I-Ssu-Ma-Yin, d. +1274). The former had one son, 'Abub-Mojid (Fu-Mou-Ché, d. +1312) who succeeded his father; and the latter two, Abub Bakr (Pu-Pai) and Ibrâhim (I-Pu-La-Chin, d. +1290)—all became artillery generals in the Yuan service. Whether or not their counterweighted trebuchets hurled explosive bombs, we do not know that gunpowder weapons, such as fire-lances, were abundantly used in the operations connected with the siege;* and since it is unlikely that the Muslim commanders would have been entirely cut off from their original home-lands, it would seem extremely probable that they were among the means of conveyance of the technology, at least to the Islamic peoples.  

In connection with all this it is interesting to reflect that the first soldiers anywhere in the world to use metal-barrel hand-guns were the Chinese detachments in the Mongol service a couple of decades after the fall of Hsiangyang. Gunpowder weapons had certainly helped to put Kubilai on the Chinese throne in the fifities. But although the appreciation of this new technology rose to a certain height among the Mongols of the end of the +13th century, later on, towards the end of the Yuan dynasty in the fifties of the +14th, they undervalued it again, and the great success of Chu Yuan-Chang in driving them out, and establishing the Ming, was partly because he supported all efforts to improve artillery and gunpowder weapons in general (cf. p. 26).  

So much for the soldiers, but we have still two other tribes of men to consider—the ecclesiastics and the merchants. Both could have had some part to play in the transmission of knowledge about gunpowder bombs, mines, fire-lances and rocket-arrows before about +1280. Let us review once more the course of events in this turbulent century. The Mongols were on the up and up. First the Hsi-Hsia Tangut State was conquered, next the Western Liao kingdom of Qara-khtai, and then the Turkeic lands of Khwarizm. When Chinghiz died in +1227, four descendants took over, Ogöttü to rule East Asia, Chagatai to govern Turkestan, Hulagu in charge of Persia, and Bâitu leading the 'Golden Horde' on the Volga in South Russia. The Jurchen Tartar Chìn dynasty in North China was overthrown in +1234, and far away to the West, Mangu invaded Armenia in +1236. The following year saw the fall of Russian Rayzan, and the Mongols invaded Poland. In +1241, along with the victory of Liegnitz, there was the siege and capture of Budapest, but also the death of Ogöttü, to be succeeded by Köyük and then Mangu ten years later. In +1253 Mongol dignitaries went to register the population of the State of Cremona for fiscal purposes, and in the reverse direction (as we have seen) came the journeys of William Ruysbrock and other Franciscan friars to the Mongolien court at Karakorum. They were diplomatic envoys quite as much as missionaries, sent to seek the help of the Mongols against the Muslims, traditional foes of the Frankish Christians. It was a classic case of that encircling strategy by which one seeks to mobilise the forces of allies whose lands lie beyond those of one's immediate enemy. One would give a good deal to know what exactly the friars saw of gunpowder and fire-weapons during their wanderings in Mongolia and China. Although such interests would have consorted ill with their habit, they might have felt it their duty to bring back knowledge and skills which could conserve the safety and power of Christendom against the 'infidel'. With this transmission in mind, the activities of the friars need looking at more closely than hitherto. One of them might even have been accompanied on the way home by some Chinese gunner who knew the multifarious devices of the previous half-dozen centuries as well as the latest inventions, and was not averse to seeking his fortune in strange foreign lands—but so far history has not had word of his name or his activities.  

The overall strategy of the friars, directed against Islam, succeeded beyond all expectation, apart from the fact that the Mongols did the job for themselves, and made no firm alliances with Christian powers. Having subdued Persia, they invaded Iraq at the head of the Persian Gulf, and Baghdad fell in +1258. Two years later the Mongolian Ilkhanate, centred on Iran, had been established, and the great astronomical observatory of Marâghah founded. Then came a second possible medium of transmission, also ecclesiastical, the travels of Rabban Bar Sauma and his friend, the fascinating account of which was translated from the Syriac long ago by Wallis Budge. These two young men were
Chinese Christian (Nestorian) priests of Uighur stock, born and educated in Peking, who pined to go on a pilgrimage to Jerusalem. Neither of them ever got there, but they did travel the whole length of the Old World between +1278 and +1289 before returning to settle down in Persia and Iraq. The friend, Maroq Baynian, was unexpectedly elected to a bishopric at Baghdad, as Metropolitan of Cathay, and then a year later Catholics (Patriarchi) of all the Nestorian Churches, as Mar Yaballaha III, so his duties detained him there indefinitely. But Bar Sauma travelled on to the West as an envoy from the Ilkhân Arghun, visited Italy, and in +1287 was warmly received at Rome (where no unduly tactless doctrinal questions were asked), finally reaching Bordeaux (where he celebrated the liturgy in the presence of the King of England). Eventually he returned to Persia by way of Italy, and built a church at Marâghâh, where he died in +1294. The purpose of this pilgrimage was again partially political, to get Western assistance for ousting the Muslims from Jerusalem, but it never had the slightest chance of success. The dates are rather late for the transmission we are looking for, but our shadowy Chinese gunner might conceivably have come along with the two priests, and handed on his knowledge to discreet persons in the Mediterranean region capable of receiving it.

Lastly, we have to think not only of soldiers, or West Asian scholars, or ecclesiastics whether Latin or Nestorian, but of the European merchants. The name which springs to mind of course is that of Marco Polo, 'Il Milione' (the man who averred that there were millions of ships on China's rivers, and millions of bridges in Hangchow—and fundamentally he was not wrong). But he did not leave China till +1294, which makes him too late for the second transmission, though he might just have accomplished the third. His father Niccolo and his uncle Maffeo, who were in China first between +1261 and +1269, could on the other hand have been responsible for the second, the bringing of news of firearms, bombs and rockets. Marco was with them on their second visit (+1271 to 95), during which he served Kubilai Khan, sometimes on secret service missions, more often in the salt administration; and when he left it was by sea, accompanying a Mongolian princess proceeding with a great fleet to become the Ilkhân Arghun's second wife. This might have been an even more appropriate scenario for the Chinese gunner we have in mind, and now he could have been a gunner in the fullest sense, acquainted with metal-barrel bombardos and hand-guns.

Much less well known is the colony of Italian merchants established at Tabriz in the Ilkhânate. Though the silk trade had been active since +1257, the first name we know is that of the Venetian Pietro Vilioni, who died there in +1264. In +1269 Mongol ambassadors from the Ilkhân arrived at Genoa, and a Genoese merchant, Luchetto de Recco, was stationed in Tabriz in +1280. From +1274 onwards Buscarello Ghisolfi played an important diplomatic role between the Ilkhâns, the Italian city-states and the Pope; he was even twice in London (+1289 and +1300) on the usual ploy of constructing Mongol–Christian alliances against the Muslims, and accompanied an Englishman, Sir Geoffrey Langley, on a visit to the Ilkhân in +1292. Many other names of Italian merchants trafficking about this time in the Ilkhânate are known, both Venetian and Genoese. The colony continued to prosper until about +1356. Its members could certainly have played a part in the second and third transmissions of knowledge which we are considering.

Perhaps there is room for speculation that the third, i.e. that of the true metal-barrel bombard and hand-gun, reached Europe directly overland and not through the Arabs at all. Lattimore acutely noted that the Russian word for cannon is pushka, and that since the Slavs, unlike the Germans, do not confuse p with b in borrowed words, the usual derivation from German Büchse, cannot hold water. But pusha would go some way to meet the case, so perhaps the transition was pusha—pushka—Büchse, and the usually assumed origin from Gr. πυξις (πυξις), a box, is wrong. It is only fair to mention here a persistent Chinese tradition that the Russians were the intermediaries in the travel of gunnery to Europe. The trouble with Arabic intermediation is that it is so hard
to tell when "middā" as the name for the āre-lance emitting co-viative projectiles (or proto-gun) turned into "middā" as the name for the true metal-barrel bombard or hand-gun. This transition had certainly not happened by the time of al-Rammāh (c. 1280), but it probably did happen during the following few decades. Possibly, therefore, the Arabs received the bombard from Russia, Eastern Europe, including the Balkans, or Germany, rather than directly from China. The earliest date for the bombard in Spain has been held to be +1359, but Lavin (1) makes it +1343, when during the siege of Algeciras the Moors within used iron cannon (tiro de hierro), and trueas (bombards). This was well after Walter de Milamet's picture.7

So here we are back again at the deadline of +1327, or better, a dozen or more years earlier.8 We can ignore all the events that happened after that, however exciting they are in themselves, such as the colony of Italian merchants at Yang-

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8. Though this word was also used for the projectiles themselves. Another trait betraying knowledge of Chinese usage. Cf. Partridge (5), pp. 193–4. Even the word 'ganū' could be used for a projectile, as Burtt (1) noticed in *The Armaments of King Arthur* (1914), p. 69.
9. There came flint a ganū
And lemes as the leyvn...

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10. We say this not because of the Ghenti reference of +1315 to hirat na kenn, which, though accepted by Hume (1), p. 119, was rejected by Partridge (5), p. 97 as a forgery, but because there must have been bombards and hand-guns in Europe some little time before Walter de Milamet's picture. A Florentine reference of +1306 is more acceptable, though Arima (5), p. 359, expressed scepticism about it. On the general development of artillery in Europe after this time, see Partridge (5), pp. 98 ff.
APPENDIX A  THE OLDEST REPRESENTATION OF A HAND-GUN?

An outstanding discovery was made by Robin Yates in June 1985 when visiting the Buddhist cave-temples at Ta-tsu in Szechuan. In the Pei-Shan (Lung-Kang) complex (one of seven) he found (cave no. 146) a relief of a hang-gun held by a small demon with two horns (Fig. 235). The hang-gun is being let off, as appears from the blast issuing to the right from its muzzle, and a projectile is also represented in the flames.

As will be seen from the illustration, the figure is at the bottom on the right of a group of seventeen, with a many-armed bodhisatava or Buddha at the top and the back. Twelve of the figures seem to be robed saints, but five have skull- or demon-faces and carry weapons, among which one can make out a spear, a mace, a hammer and a sword, as well as the hang-gun. Perhaps they are demons converted to sainthood. Probably all are attendants of either Kuan Yin or the Buddha of Medicine, whose seated image is the central figure of the shrine.

The object of interest to us here seems at first sight to be some sort of musical instrument, with the right hand of the figure plucking the strings, but a second look makes out the flames coming from the muzzle, and even the spherical ball or bullet among them. Of course, the sculpture cannot have been done by anyone who knew anything about hand-guns, because the explosion-chamber would have been much too hot to hold, and usually there was a socket cast on behind it, into which a wooden 'tiller' was fitted, for grasping. All the same, we may well have here the oldest representation in the world of a hang-gun, using the propellant power of high-nitrate gunpowder, similar to the larger bombard and primitive cannon which followed so quickly afterwards (cf. Table I on p. 290 above). The bulbous shape of the thickened metal wall around the explosion-chamber is too characteristic of these early gunpowder-weapons to be mistaken.

The dating of the carving is somewhat obscure, but from pp. 293-4 above we know that the oldest hand-gun excavated so far is datable at ca. +1280, so that one would expect the date of the sculptured group to be any time between +1250 and +1280. It is generally agreed that the figures are of the Sung period, though Yang Chia-Lo (3) and other experts such as Anon. (262) tend to place them between +1130 and +1170, while yet others, such as Angela Howard, put them even earlier, in the Northern Sung, from the late +10th to the early +11th centuries. Such dates would be too early for a hang-gun, though not for a fire-lance; nevertheless the relief has the form so typical of the earliest hand-guns and bombard, bulbous or pear-shaped (cf. Figs. 82-4, 90, 92, 94-5, 97, 100, 107-110, 116), while an approximately bore-occluding projectile is visible in the flames of the blast. A neighbouring inscription records the name of Wang Tzu-I, whose floruit, as we know from another inscription, was +1186. But even this date would be rather too early to expect a relief of a hand-gun. Possibly the content of the sculpture may help to date the ensemble.

At all events, we may well have here the earliest representation of a hand-gun in any civilisation, and the relief is therefore worthy of close attention.

* It parallels the discovery made at the Musée Guimet in Paris by Clayton Bredt, who found a clear representation of a fire-lance on a Buddhist temple banner of about +430 from Tunhuang (see pp. 222-3).
* It may be significant that the wielder of the fire-lance on the banner (Fig. 45 above) also has horns.
* On many-armed images cf. Vol. 4, pt. 1, p. 115 and Fig. 296.
* But Walter de Milimont's guns have none.
* The same is true of the fire-lance on the banner, because the demon is using one hand to hold the hot tube itself.
* On the other hand, historians of Buddhist art, such as Li Ssu-Sheng and Wang Kung-I, prefer to interpret the figure as the Szechuanese god of the winds, with his bag. If the date of +1280 is substantiated, they might well be right. But could that representation perhaps have influenced the designers of the earliest hand-guns and bombard?

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APPENDIX A
APPENDIX B  THE DEVELOPMENT OF THE MIDFA'

On p. 43 above we discuss this Arabic word, which seems to have the general sense of a tube or cylinder. The illuminating work of Donald Hill (2), which translates and analyses the 'Book of Ingenious Mechanical Devices' (Kitāb fi Ma'rūfat al-Hiyal al-Handastiya), written by Ibn al-Razzaz al-Jazari in +1206, needs to be taken into special account here. Al-Jazari, speaking of his slot-rod water-raising pump, says that 'this machine resembles the ejectors (or projectors, i.e. pumps) of naphtha (zaraqā al-naft), except that it is larger', (Hall (2), p. 188). To understand this, one must remember the Chinese petrol flame-thower described and illustrated on pp. 92 ff. and Fig. 7 above (and also Vol. 4, pt. 2, pp. 144 ff. and Figs. 433, 434) together with our account of the slot-rod water-raising pump (Vol. 4, pt. 2, p. 381 and Fig. 606). A critique of the reconstruction of this by Aubrey Burstall (depicted in our Fig. 610) is given by Hall (2), p. 273.

Again, when in his 'Key of the Sciences' (Maqāṣid al-'Ulūm) Abū 'Abdallāh al-Khwārizmi al-Kātib (+976) speaks of bāb al-midfa' and bāb al-mustaq, both parts of the naphtha-projectors (al-naffātāt wa l-zaraqā), the word bāb (gate) means technically a valve, rather than just a mouth or opening (Hall (2), p. 274). From this we can conclude that the word midfa' originally meant the tube or cylinder of the naphtha-projector; then after the invention of gunpowder in China and its passage to the Arabs it meant the tube of the fire-lance; finally it was applied to the cylinder of the hand-gun and cannon. It still retains this meaning in Arabic today. The fact that already in +1206 al-Jazari recognised the affinity between the cylinder of his water-raising engine and the tube of the flame-thower casts an interesting light on the connection between guns and engine-cylinders which we explore on pp. 544 ff. above.

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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 Chb comes after all other entries under Ch, and transliterated Hs comes after all other entries under H. Thus Chb comes after Ch, and Hs comes after Hu. This system applies only to the first words of the titles. Moreover, where Chb and Hs 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 romanisations of Chinese words occur in entries in Bibliography C, they are followed, wherever possible, by the romanisations adopted as standard in the present work. Interspersed in the title, these are enclosed in square brackets; if they follow it, in round brackets. When Chinese words or phrases occur romanised according to the Wade-Giles system or related systems, they are assimilated to the system here adopted [cf. Vol. 1, p. 50 with indication of any change. Additional notes are added in round brackets. The reference numbers do not necessarily begin with (1), nor are they necessarily consecutive, because only those references required for this volume of the series are given.

Korean and Vietnamese books and papers are included in Bibliographies A and B. As explained in Vol. 1, pp. 21 ff., reference numbers in italics imply that the work is in one or other of the East Asian languages.

* As we originally suspected when we first discussed the term.
A. CHINESE AND JAPANESE BOOKS BEFORE +1800

Each entry gives particulars in the following order:
(1) title, alphabetically arranged, with characters;
(2) alternative title, if any;
(3) translation of title, if any;
(4) cross-reference to closely related book, if any;
(5) notes as accurate as possible;
(6) name of author or editor, with characters;
(7) title of other book, if the text of the work now exists only incorporated therein; or, in special cases, references to studies of it.

(1) references to translations, if any, given by the name of the translator in Bibliography C.
(2) notice of any index or concordance to the book in such a work.
(3) references to the number of the book in the Tairi Teng catalogue of Wang (6), if applicable.
(4) references to the number of the book in the San Teng (Tripalaka) catalogues of Nan-jin (1) and Takakusa & Watanabe, if applicable.

Words which assist in the translation of titles are added in round brackets.

Alternative titles or explanatory additions to the titles are added in square brackets.

It will be remembered (p. 295 above) that in Chinese indexes words beginning with Ch are all listed together after Chi, and Hsi after Hi, but that this applies to initial words of titles only.

Chang Tao-Yeh Tou Pa \* 漢子野四福音
Remaining Additional Poetical Works of Chang Tou Fai
Sung, c. +1080.

Cheng Tru-Yeh 獅子野
Chao Lung Chuan 宗之柔
Book of Examples of Illustrious Loyalty.
Yuan, c. +1199.

Chao Hua Chih 構化之志
Gazetteer of Chao-hua (in Shechuan).
Chihung.

Chang Shao-Ling (ed.) 張昭陵
Revised (1844).

Chao Hua 招華
The Calling Back of the Soul (perhaps a ritual ode).
Chou, c. -256.

Attrib. Sung Yu 宋玉
Prob. by Ching Chhiai (or Tsho) 景采
Tr. Hawkes (1).

Chen Chi 陳起
Record of Armies Drill and Tactics
Ming, c. +1546.

Ho Liang-Chen 郭亮臣
Description of Cambodia
Yuan, c. +1297.

Chen La Feng Chih 鄭樂承
Classified Essentials of the Mysterious Tao of the Central Origin of Things (alchemy and chemistry).

Chen Chih-Yen Ti-Ann Shu Yu La (cont.)
An Account of the Defence and Resistance of Thang (City) in the Chien-Yen reign-period
([+1327]) (by the Sung against the J/Ciin).
Sung, c. +1193.

Original name of the book by Thang Tao which was combined with the Shao Chohg Lu as works in Vol. 4, p. 945 ff., and is stated as a separate brochure.

ABBREVIATIONS

Ch/Fan Farmer Han.
E/Wei Eastern Wei.
H/Lan Later Han.
H/Shu Later Shu (Wu Tai).
K/Chou Northern Chou.
K/Chin Northern Chin.
K/Sung Northern Sung (before the removal of the capital to Hangchow).
K/Wen Northern Wei.
S/Shan Southern Sung.
S/Wen Southern Wei.
W/Wei Western Wei.

Ascr. Chin, +3rd, but probably mostly Thang, +8th and +9th, at any rate after +7th y as it quotes Li Chhiu.

Attrib. Ching Shuo-Yuan 蔣述遠

Ch'ing Hsia Shu 親家書
A New Treatise on Military and Naval Efficiency.
Ming, +1560, pr. +1567, often repr.

Ch'hi-Kuang 慈谿光
Ch'j Chou 仇周
See Ch'i, N. Tz. 夏

Ch'iao Kuo-Chhiai 趙國基
Records of K'o-Chi (Shao-lung in Chekiang) in the Chien-Yen reign-period (+1321 to +1325).

Sung, not long after +1325.

Ching-Chou Chiang 程若秋
Military Strategies in Chiang-nan.
Ming, +1565.

Ch'in Ching-Ming 張金明
Annual Folk Customs of the States of Ching and Chhau (i.e., the districts corresponding to those ancient States: Hopei, Hunan and Chiangsi).
Prob. Liang, c. +550, but perhaps partly Sui, c. +610.

Chung Lung Min 孫興民
See Des Routures (1), p. cii.

Chih-Kung Chhiai 程敬時
Record of Events in the Ching-Khao reign-period
([+1165], year of the fall of Khaifeng to the Ch'in Tartars).
Sung, c. +1190.

Chung Mäng 唐彥

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Sung, c. +1094.

Lu Chen 魯振
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Methods of Compiling Various Outlines for Magical Elixir Preparations (an alchemical anthology).
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Military Practice on the Central and Western Fronts.
Sung, c. +1150.

Pang Foo-Yuan 张秀元
Now extant only in quotations.

Chang Thong-Shk Chi 中堂史記
Personal Recollections of Affairs at the Court of Hsia (Fronts) 1120 to +1121.

Yuan, c. +1280.

Wang Yin 王隿

Chiu Chih 丘成
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Sung, c. +1275.

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Sung, c. +1295.

Chao Chih-Chen 趙志忱
(I T'ai Chhia Shih, i.e., p. 1 藝術編輯, 乙職).

Ch'ing Chih-Chih 丁著章
Collected Writings of (Yang) Ch'ing-Chih (Yang Wan-Li).

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Ming Hua Lu
See Tang Ching Meng Hua Lu.
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Dreaming of the Capital while the Rice is Cooking (description of Hangchow towards the end of the Sung).
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Literary Collections of (Yao) Mu-An. Sung, +1290.
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GENERAL INDEX

by Christine Outhwaite

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(1) Articles (such as 'the', 'al-', etc.) occurring at the beginning of an entry, and prefixes (such as 'de-', 'van-', etc.) are ignored in the alphabetical sequences. Suffixes 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 name, printed following them.
(2) 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.
(3) In the arrangement of Chinese words, Chih- and Hs- follow normal alphabetical sequence, and are treated as equivalents to a.

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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 confusing, the tables of Wang (1) will be found useful. For such periods, especially the Second and Third Periods, the best guide is Eberhard (9). During the Eastern CHIN period there were no less than eighteen independent States (Hunnaic, Tibetan, Hsiung, Turkeic, etc.) in the north. The term ‘Liu chwan’ (Six Dynasties) is often used by historians of literature. It refers to the south and covers the period from the beginning of the 3rd to the end of the 6th centuries, including (San Kuo) Wu, Chin, (Liu) Sung, Chin, Liang and Chian. For all details of reigns and rulers see Mische & Yeats (9).
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