Chinese Annals of History of Science and Technology **7** (2), 070–080 (2023)
doi: 10.3724/SP.J.1461.2023.02070

Stagnation and Degeneration in the History of Science and Technology in Ancient China: Some Thoughts concerning Military Technology

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Abstract: In ancient China, after a technology developed to a certain height, it often fell into stagnation, and even gradually degenerated in the long-term stagnation. This phenomenon was very prominent in military technology. This paper focuses on analyzing the development of crossbow and firearms in ancient China, makes a preliminary discussion on the reasons why stagnation and degeneration would ensue when the military technology reached a certain height, and puts forward the concept of "satisfaction point" to discuss the intrinsic cause and critical point of the turning from development to stagnation and degeneration.
Keywords: ancient China, history of science and technology, military technology, stagnation, degeneration, satisfaction point

摘　要：在中国古代，技术发展达到一定高度后，往往会陷入停滞状态，在长期的停滞中甚至逐渐出现退化。这种现象在军事技术上表现非常突出。本文着重分析了中国古代弩和火器的发展历程，对中国古代军事技术发展到一定高度后停滞退化的原因作了初步探讨，并提出"满足度"的概念，以表述从发展转向停滞退化的内在根源和临界点。
关键词：中国古代，科技史，军事技术，停滞，退化，满足度

Today I would like to talk about some lessons that I learned in doing research on the history of science and technology in ancient China, mainly based on the work that I did in researching the military technology of ancient China. My topic is "Stagnation and Degeneration in the History of Science and Technology in Ancient China."

My research on the military technology of ancient China has always been based on

Received: May 24, 2023. Revised: September 15, 2023.
This article was originally an oral presentation during the Third Symposium of Young Scholars on the History of Technology, organized by the Committee on the History of Technology of the Chinese Society for the History of Science and Technology, on November 10, 2012. It has been translated by Yu Yueyuan 俞月圆 and copyedited by John Moffett.
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the concepts of development and progress, and my focus has always been the invention, creation, development, and progress of technology. During my research, however, as I came into contact with more and more materials, I felt that there were often some cases that showed neither development nor progress, but stagnation and degeneration instead. There were many such examples. Indeed, through the entire period of ancient China, there was very pronounced stagnation and degeneration in the majority of mainstream military technologies at certain periods. I will focus on introducing two examples today for discussion.

The first example concerns the crossbow.

The crossbow is an outstanding and representative example of both the machine and military technologies of ancient China. Its development as a military weapon took place in the late Spring and Autumn period 春秋 (770–476 BCE). It was at this time that it first drew attention and became valued, developing further during the Warring States period 战国 (475–221 BCE) (Zhong 2008, 236–245).

Later, in the Han 汉 dynasty (206 BCE–220 CE), a peak in the development of crossbows was reached, and they became perfected in every way. This is best epitomized in the Han dynasty bronze crossbow trigger-mechanism. According to the materials that are available to us now, the earliest example of the use of metal (bronze) to make trigger-mechanisms can be found in the early Warring States period. By the Han dynasty the production of bronze trigger-mechanisms had become highly standardized, and thanks to its greatly improved mechanical structure, this trigger-mechanism could be fired with very little effort. In addition, a graduated scale has been found on the sight (wangshan 望山) of Han-style trigger-mechanisms that is similar to the rear sight on modern rifles, indicating that the shooting technique of crossbows at that time was also very subtle. This is evidence of technological progress. Moreover, in the Han dynasty, crossbows and their bronze trigger-mechanisms were made and used in very large quantities. This is reflected in the records found among the large number of bamboo slips unearthed at Juyan 居延, as well as the many engraved bone slips unearthed at the site of the Han dynasty Central Government Office in Chang'an 长安, indicating that the number of crossbows used in the army peaked at this time (Zhong 2008, 397–406).

Strangely enough, having reached such a peak, crossbows basically underwent no further development in ancient China; rather, there was a process of stagnation and gradual degeneration. This was first manifested in the trigger-mechanism. After the Han dynasty, bronze Han-style trigger-mechanisms were still in use in the Three Kingdoms 三国 (220–280), Jin 晋 dynasty (265–420), and the Northern and Southern dynasties 南北朝 (420–589). However, the trigger-mechanisms from these periods that have been discovered so far were very poorly standardized. They exhibit great variation in their size and shape, indicating an obvious decline in standardization.

Then the graduated scale on the sight slowly disappeared, and it is certain that by the time of the Northern Song 北宋 dynasty (960–1127), the graduated scale on Han-style trigger-mechanisms had been lost. The evidence for this comes from Shen Kuo's 沈括 *Dream Pool Essays* (*Mengxi bitan* 梦溪笔谈). He reports that someone in Haizhou 海州 (near present-day Lianyungang 连云港) robbed a tomb and acquired an ancient trigger-mechanism with a gradated scale on its sight. Shen Kuo ([1088] 2011, 473) deduced that the scale must have been used for aiming, and that the underlying principle was based on the "*gou-gu* method" (勾股法) of traditional Chinese mathematics. This indicates that the graduated scale had been lost by the Northern Song dynasty, which explains why people of the time had no idea what the newly-discovered scale might have been; only an outstanding scientist like Shen Kuo could figure it out with his mathematical knowledge.

Worse still, despite as Dr. Joseph Needham noted, having developed to a level of perfection that was almost comparable to modern rifle components, the entire Han-style bronze trigger-mechanism was gradually lost after the Song dynasty. How this happened is not yet completely clear. Perhaps in the Song dynasty, especially in the Northern Song dynasty, the Han-style trigger-mechanism was still used in some crossbows, as can be vaguely seen in some illustrations of *Collection of the Most Important Military Techniques* (*Wujing zongyao* 武经总要) of the Northern Song dynasty. For example, this work depicts *chuangnu* 床弩 (large crossbows that need to be mounted to shoot, Chinese arcuballista), the trigger-mechanisms of which seem to be Han-style ones (Zeng and Ding [1047] 1959, 12). Yet, it is still unclear what the trigger-mechanisms of the handheld crossbows of that time actually looked like, in particular whether the handheld crossbows of the Southern Song dynasty 南宋 (1127–1279) used Han-style trigger-mechanisms. As for the Ming 明 (1368–1644) and Qing 清 (1644–1911) dynasties, we are certain that Han-style trigger-mechanisms were not in use. Crossbows in these periods were similar to the wooden and bamboo crossbows that we can still see among the ethnic minorities of Yunnan 云南 and Guizhou 贵州 Provinces. These crossbows do not use metal trigger-mechanisms; rather, a small lever made of wood, bamboo, or bone is installed in the slot behind the stock of the crossbow. When this small lever is pulled, the bowstring is pushed out and the arrow released (some years ago, Professor Zhang Baichun 张柏春 instructed his graduate students to do an in-depth investigation and technical analysis of the crossbows of ethnic minorities in Southwest China) (Yi and Zhang 2003).

Today, scholars basically agree that crossbows in China started with these relatively primitive wooden and bamboo crossbows that did not have metal trigger-mechanisms. The latter, as explained earlier, appeared in the Eastern Zhou 东周 dynasty (770–256 BCE) and reached their highest form of development in the Han dynasty. In this case, then, the development of crossbows in ancient China followed a cycle, going

backwards, step by step, after the Han dynasty.

The second example concerns firearms.

There is a debate in academic circles about the date of the invention of gunpowder, but let us set this aside. So far we can only date the time when gunpowder was used on the battlefield and firearms were invented back to the Northern Song dynasty (Zhong 1995, 55–63). After that, Chinese firearms developed for several centuries. The concept of "the firearms era of East Asia" (东亚火器时代) is now in common use, the most important element of which is the development of early firearms. Starting from the Northern Song dynasty, the development of early firearms in China lasted for around 450 years, during which Chinese gunpowder and firearms technology led the world. The development and application of firearms in China and the spread of Chinese gunpowder and firearms technology drove the transition of world military history from the cold weapon era to the firearms era.

Major progress was made during the Southern Song and Yuan dynasties, which was an outstanding period of development. During this time, explosive firearms developed from ones with paper casings to those with iron casings. Tubular firearms, on the other hand, developed from paper-barreled ones to bamboo-barreled ones to metal-barreled ones, and from jetting flames to firing bullets. This period saw the emergence of the metal-barreled firearm, *huochong* (hand-gun 火铳), which is the forerunner of all guns and cannons of later times. Another significant development was the invention of the retro-rocket (Zhong 2021).

During the Yongle 永乐 period (1403–1425) of the Ming dynasty, the development of early firearms reached its peak. At that time, the copper *huochong* represented the highest level of firearms technology, and was mainly of two types, handheld ones and ones that needed to be mounted to shoot. In terms of structure and manufacture, they had made great progress and were well standardized compared with those made in the preceding Hongwu 洪武 period (1368–1399) and the Yuan 元 dynasty (1271–1368). From the *huochong* of the Yuan and Ming dynasties discovered so far, once metals were used to make barrels, tubular firearms gradually exhibit signs of becoming standardized. By the Yongle period, they were already highly standardized, which is obvious from comparisons with the *huochong* of the Hongwu period and Yuan dynasty (Cheng and Zhong 1990, 223–224, 230–231).

After reaching this peak, however, the development of early Chinese firearms came to a standstill. After the Yongle period, during the one hundred years or so from the Xuande 宣德 period (1426–1436) to the Zhengde 正德 period (1506–1522), Chinese firearms show hardly any signs of significant development. Moreover, compared with those made during the Yongle period, the copper *huochong* made from the Xuande period to the Zhengde period even show signs of retrogression: for one thing, they were not as finely made as those of the Yongle period; neither were they as

standardized (Cheng and Zhong 1990, 232–233). Therefore, for these one hundred years or so, stagnation and degeneration were the main characteristics.

From the Jiajing 嘉靖 period (1522–1567), the development of Chinese firearms entered a new phase, and there was a new trend. This was stimulated and driven by the introduction of Western firearms. First was the arrival of the Frankish culverin (folangji pao 佛郎机炮) and the matchlock musket (huosheng qiang 火绳枪 or niaochong 鸟铳), which inspired Chinese imitations. This marked the second stage of development of Chinese firearms. Subsequently, during the Tianqi 天启 (1621–1628) and Chongzhen 崇祯 (1628–1644) periods, Western cannons (also known as *hongyi pao* 红夷炮/红衣炮) were introduced and once again imitated. Firearms technology in China was upgraded to a higher level. However, this stage of development of Chinese firearms which mainly involved the imitation of Western firearms only lasted to the first half of Emperor Kangxi's 康熙 reign (1662–1722) in the Qing dynasty. This was basically caused by the Qing rulers voluntarily giving up the development of firearms.

The imitation of Western cannon during the late Ming and early Qing dynasties mainly relied on missionaries, who designed, directed, and supervised their manufacture. During Kangxi's reign, Ferdinand Verbiest made the greatest contribution in this regard. In the early years of Kangxi's reign, the country repeatedly suffered from domestic strife and foreign threats. In response to this urgent military need, Verbiest helped the Qing court cast a large number of artillery, which played a significant role in a series of wars, including the suppression of the revolt of the Three Feudatories, suppression of the Dzungar uprising, the reclamation of Taiwan, and combating the invasion of czarist Russia into Heilongjiang 黑龙江 Province. Then, in the twenty-eighth year of Kangxi's reign (1689), after the country had been pacified, the Qing court cast sixty-one heavy cannons called "The Great Generals that Guard Military Accomplishments Forever" (武成永固大将军). These cannons represent the highest level of Chinese imitation of Western firearms in the late Ming and early Qing, and also mark the end of the climax of the imitation of Western firearms during this period (Zhong 2015). After that, during the reigns of Kangxi, Yongzheng 雍正 (1723–1736), Qianlong 乾隆 (1736–1796), and Jiaqing 嘉庆 (1796–1821), no such large-scale artillery was made. The Qing court gradually stopped entrusting missionaries with important posts, and the development of firearms basically stopped; stagnation and degeneration resumed. Firearms technology during Qianlong's reign barely maintained the level of that of Kangxi's reign, and it became worse and worse thereafter. Prior to the First Opium War (1839–1842), Qing manufacture of firearms still followed "the ancestor's system" (祖制) of Kangxi's time, while the retrogression of technology was comprehensive. Just before the outbreak of the Opium War, in order to strengthen coastal defenses, some cannons made to the ancestor's old standard were rushed out to

the southeast coastal areas. Yet, their technological level and quality of manufacture were clearly inferior to those of the Kangxi and Qianlong reigns.

Above I have raised only the two examples of crossbows and firearms. I have not yet conducted an overall study of stagnation and degeneration of the military technology of ancient China. However, based on my impression gained from doing long-term research on the history of military technology in ancient China, I think that these examples were not exceptions. Rather, they likely represent a common phenomenon, though some other cases are not so obvious or prominent. My basic opinion is that this was a universal phenomenon and that relatively serious stagnation and degeneration existed in all major areas of technology, including chariot making, shipbuilding, metal weapons manufacturing, military machinery manufacturing, and city-building. Basically, after a technology reached a certain level, progress would stop and long-term stagnation would begin, during which degeneration inevitably occurred. There may not be many extreme examples like the crossbow, where the technology went back to the starting point, but varying degrees of degeneration were very common.

You could pay attention to this phenomenon in your future research to see whether this is the case. Moreover, did this stagnation and degeneration in military technology also exist in other technological categories, or across the whole realm of the technology of ancient China? My basic view is that it did. This is because ancient military technology essentially embraced the application of all categories of technology. If stagnation and degeneration were widespread in military technology, then it would be inevitable that other categories of technology would have this feature. The research interests of you in this room cover different aspects of the history of technology. You can pay some attention to this problem in the future.

The next question is what should be made of this phenomenon of stagnation and degradation?

This question covers an even wider scope. It can be examined from different angles and to different levels. It can be approached by doing case studies, thoroughly analyzing prominent examples, but it can also be studied from an all-encompassing, macroscopic point of view. I personally believe that no matter what kind of research approach is adopted, one should not forget to pay attention to the characteristics of Chinese civilization. I strongly agree with Dr. Joseph Needham's initial approach to researching the history of science and technology in China. We all know about his *Zhongguo kexue jishu shi* 中国科学技术史, the original name of which was *Science and Civilisation in China*, indicating that his actual aim was to research and uncover the mutual relationship between the development of science and technology in ancient China and Chinese civilization. Later when he delved into studies of specific areas, however, the coverage became wider and wider and a comprehensive summing up

became impossible, leading to his failure to form a final overall conception. Nevertheless, the Needham Question that he put forward propelled the academic community to think deeply about the relationship between the development of science and technology in ancient China and Chinese civilization.

In examining the history of the stagnation and degeneration of science and technology in ancient China, it is particularly important to analyze the issue at the macro level, keeping the characteristics of Chinese civilization in mind. There are many perspectives from which such an analysis can be made. Here I would like to talk about some insights about the characteristics of Chinese civilization from the perspective of ancient Chinese military affairs, mainly in relation to the development of military technology.

If we carefully study the military history of China, we can reach the conclusion that the basic characteristic of ancient Chinese civilization is that it was introverted. It was mainly concerned with the stability of agricultural regions and agricultural society, which served as the basis of the country. The dominant ideologies of dynasties including the Song and Ming were mainly opposed to territorial expansion. It is undeniable that Chinese civilization exhibited a process of expansion during its formative periods, which include the Xia 夏 (c. 2070–1600 BCE), Shang 商 (1600–1046 BCE), and Zhou 周 dynasties (1046–256 BCE). Such years of expansion resulted in the unification of major agricultural regions on the East Asian continent, culminating in the unification of China by Emperor Qin Shihuang 秦始皇 (r. 221–210 BCE). By this time, the most important agricultural regions in East Asia—the middle and lower reaches of the Yellow River, the middle and lower reaches of the Yangtze River, and the Pearl River Basin—had all been incorporated into the territory of the central government. After unification, the Qin government immediately built the Great Wall, setting up a boundary between the central agricultural region and the northern nomadic region. Since then, the major concern of central governments was the stability of the agricultural region within the frontier marked by the Great Wall. In connection with this, how to defend this central agricultural region against the threat of northern nomads became another major theme. These two themes have always been the fundamental concerns of Chinese central governments after the Qin dynasty (221–206 BCE).

In the dynasties that followed the Qin, defense strategies against the nomadic people in the north always changed between the active and the passive with the rise and fall of national strength. When the nation was strong, rulers would take the initiative to attack and actively manage national defense. When national strength was on the decline, however, rulers would draw their forces in for passive self-defense. Nevertheless, even when the nation was at its strongest and the strategies were the most active, the main goal was repelling the enemy, destroying the enemy's military

strength, and eliminating its ability to threaten the central agricultural region. Once this goal had been achieved, the majority of the forces would soon be withdrawn south of the Great Wall, relying on the wall to protect the border. Consider the history of the Han and Tang (618–907) dynasties: Massive forces were never stationed in the northern steppe and the Western Regions. When the government reached its goal of defeating the Xiongnu 匈奴 or the Tujue 突厥, they withdrew their main force south of the Great Wall and resumed their usual defensive posture.

During Emperor Han Wudi's 汉武帝 (Liu Che 刘彻, r. 141–87 BCE) reign, China was at its strongest after the Qin dynasty. It was precisely this period that has particular significance in reflecting the introverted characteristics of ancient Chinese civilization.

Emperor Han Wudi conducted large-scale military operations against the Xiongnu and enlarged defenses along the Great Wall. The Great Wall defenses of the Han dynasty were essentially the maximum limit of the northern defenses of all subsequent dynasties. More importantly, it was Emperor Han Wudi who adopted the suggestion of Dong Zhongshu 董仲舒 to "dismiss the hundred schools of thought and revere Confucianism only" (罢黜百家，独尊儒术), after which Confucianism became the dominating ideology of China. Confucianism held a fundamentally negative attitude towards territorial expansion and the use of military force in foreign lands, one that was clearly manifested in the Meeting concerning Salt and Iron 盐铁会议 during the reign of Emperor Han Zhaodi 汉昭帝 (Liu Fuling 刘弗陵, r. 87–74 BCE). The *Discourses on Salt and Iron* (*Yan tie lun* 盐铁论), which records the discussion of this conference, expresses the Confucianist ("Xianliang Wenxue" 贤良文学, which means Man of Virtue and Man of Learning) attitude during a time of unification towards expansionism using military force. Its basic proposition was that the fundamental task of a dynasty was to maintain the long-lasting peace and stability of the central agricultural region. As for the surrounding remote and barren lands, they would be useless to acquire and costly to defend. Carrying out long-distance expeditions would merely exhaust the army and expend the nation's wealth in vain, harming the stability of the country.

At first, Emperor Han Wudi was determined to defeat the Xiongnu and eliminate their threat. The more talented an emperor was, the more likely he was to enjoy his great achievements. Although Wudi put Confucianism in a position of supremacy, he was initially unimpressed by some of its conservative ideas, and turned a deaf ear to criticism against his conducting military operations in various places. In his senior years, however, due to years of military action, the national wealth accumulated during the reigns of previous emperors[1] was exhausted, the people were restless, and dissent flared up across the country. Faced with such a situation, Wudi came to his senses, and

1 Especially Emperor Wendi 文帝 (Liu Heng 刘恒, r. 180–157 BCE) and Emperor Jingdi 景帝 (Liu Qi 刘启, r. 157–141 BCE), whose reign periods are referred to together as the "Wen-Jing Times of Prosperity" (文景之治).

issued a harshly self-critical imperial edict. This is "The Imperial Edict concerning the Proposal of Stationing Luntai and Self-Accusation" (Luntai zuiji zhao 轮台罪己诏), which announced the giving up of the stationing of troops in the distant Western Regions, offering the people a chance to recuperate. This edict marked Wudi's final acceptance of the Confucian view on the expansion of territories using military force, after decades of practice of the reverse. It also marked that after the contradictions and controversies of the early period of unification, introversion had been chosen by ancient Chinese society as its basic preference in terms of ideology and was consciously recognized by both the ruling class and their subjects. From that time, this ideology dominated the policies and behavior of Chinese governments of successive dynasties. While there were still debates and twists and turns concerning some specific issues in different periods, in the end, the ruling class and the literati would always reach a consensus based on Confucianist ideas, and each time following a lengthy argument, the ideology of Confucianism would take one step deeper into the hearts of the people. One of the most famous debates after the time of Wudi was the Meeting concerning Salt and Iron during Emperor Han Zhaodi's reign, mentioned above, which was in effect a promotion of Confucianism at the time of unification. Another example would be the great criticism by Wei Zheng 魏徵 (580–643) and others aroused by Emperor Tang Taizong's 唐太宗 (Li Shimin 李世民, r. 626–649) decision to start a military expedition to Koguryo in his senior years. The opinions of Wei Zheng, a well-known representative of the elite who combined the identities of an official and literati, are reflected in the *Essentials of Political Matters of the Zhenguan Period* (*Zhenguan zhengyao* 贞观政要) and a large number of his memorials, and have become deeply rooted in the hearts of the Chinese people for hundreds of years.

This introverted nature of ancient Chinese civilization resulted in a modest impetus to military technologies. One of the most pressing needs was to defend against the invasion of the northern nomads. The economic and technological conditions of the territories of successive Chinese dynasties were far superior to those of the northern nomads, so were their military technologies and weaponry. There was a minister and strategist of the Han dynasty, Chao Cuo 晁错 (200–154 BCE), who wrote the "Memorial on Military Matters" (Yan bingshi shu 言兵事疏) during Emperor Han Wendi's 汉文帝 reign to analyze and compare the military advantages of the Han dynasty and the Xiongnu. The memorial points out that the Han dynasty was clearly superior to the Xiongnu in terms of weaponry and their advantage was incomparable, so there was no need to worry in this respect. What the Han dynasty lacked were horses and the ability to ride and shoot, especially the ability to conduct cavalry operations and expeditions into the extremely difficult environment of the steppe-desert. When it came to Emperor Han Wudi's reign, the weaponry of the Han dynasty was more advanced than that of Han Wendi's time, so when Wudi was preparing to

attack the Xiongnu, the most important thing was to develop the management system for horses and to train cavalry. The same was true with other Chinese dynasties. They had an advantage over the northern nomads in terms of both technology and weapons. Even the Song dynasty, which was the weakest in military power, was stronger than the Liao 辽 (907–1125), Xixia 西夏 (1038–1227), Jin 金 (1115–1234), and the Mongol regime (1206–1271) in the north in terms of military technology and weaponry. Another major need was to maintain the stability of agricultural society by preventing and suppressing domestic revolts. Those who started such "revolts" were usually peasants, in comparison to whom the government forces had a greater advantage in equipment. Therefore, the impetus to develop military technology contributed by this factor was even weaker.

This situation led to two very interesting phenomena. The first was that development was stopped voluntarily. Just now when talking about the example of firearms, I mentioned that Chinese learning about and imitation of Western firearms was voluntarily given up during the middle years of Kangxi's reign. This was because both internal and foreign threats had been taken care of—the Three Feudatories and the Dzungar had been suppressed, Taiwan had been reclaimed, and the battle of Yagsi against the Russians had ended in victory. Kangxi probably thought that the weaponry that he possessed was sufficient and there was no need to develop it further. The second phenomenon was that control was prioritized over development. Successive dynasties from the Qin and the Han formulated extremely severe regulations and laws to strictly prevent military technology and weaponry from being leaked to ethnic minorities or the common people. At the same time, rulers of these dynasties failed to maintain an emphasis on developing military technology and weaponry. There is a peculiar connection between these two aspects: Putting a stop to development was usually for the purpose of gaining effective control, because in the eyes of the rulers, any substantial development would not only be useless but also dangerous should control of the weaponry be lost.

Such a characteristic of the civilization limited the driving force which is necessary for the development of military technology, and this is closely related to the stagnation and degeneration in the development of military technology. When technological development reached a certain level, it seemed that technology could satisfy need and there was no incentive to develop it further, so development was stopped. Later, that which did not advance would inevitably degenerate in the midst of stagnation. The stagnation and degeneration of technological development should be considered together with the limited driving force for further development. I wished to give a name to the point in history when military technology in ancient China stopped developing, but could not find a satisfactory one. For today's talk, I came up with a working name: "satisfaction point" (manzudu 满足度). What I want to convey through

this term is that the development of military technology in ancient China was subject to intrinsic characteristics of the civilization. When the military technology of ancient China developed to a certain level, stagnation or even degradation would ensue due to a lack of driving force. This "satisfaction point" was determined by the characteristics of ancient Chinese civilization, and was the "satisfaction point" of the civilization.

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