Feng Jiasheng's Diagrams of Iron Bombs (*Huopao*) and Beyond: On the Academic Significance of the Southern Song Iron Bombs (*Huopao*) Unearthed in Chongqing¹

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Abstract: The world's earliest bomb with an iron casing, the iron *huopao* 鐵火砲 (cast-iron bomb, also referred to as *zhentian lei* 震天雷, literally "thunder-crash bomb"), is one of the most important inventions of ancient China relating to gunpowder and firearms. Until recently, however, academics were not able to conduct substantial research on the topic, as no actual remains of a *huopao* had yet been found. Since 2013, in the excavation of two sites of Southern Song ancient cities (Diaoyu Fortress and Baidicheng) in Chongqing, archaeologists from the Chongqing Cultural Heritage Research Institute have discovered a number of iron *huopao* of the Southern Song dynasty. This finding not only provides first-hand material for research on the history of the invention of gunpowder and firearms, which has always been lacking, but also offers new physical evidence for an exploration of the history of war and the military history of the thirteenth century (in particular the Mongol-Song war), and is thus historically significant.

Keywords: iron *huopao* (bombs), *zhentian lei*, history of firearms and gunpowder, the Mongol-Song war, Möngke Khan, Diaoyu Fortress

摘 要: 世界上最早的铁壳爆炸弹“铁火砲”（又称“震天雷”），是古代中国在火药火器领域最重要的发明创造之一，但长期以来没有发现确实可靠的铁火砲（震天雷）实物，使得学界一直无法对其做切实的研究。2013 年以来，重庆文化遗产研究院在对重庆地区两个南宋时期的古城遗址——钓鱼城遗址和白帝城遗址进行的考古发掘中，出土了一批南宋铁火砲实物，这不仅为火药、火器发明史研究提供了长期缺乏的第一手实物资料，而且为深入探讨 13 世纪的战争史、军事史（特别是蒙宋战争研究）提供了新的物证资料，具有重要的学术意义。

关键词: 铁火砲，震天雷，火药火器史，蒙宋战争，蒙哥汗，钓鱼城

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Having invented gunpowder, the ancient Chinese put it to use by creating firearms, which played a significant role in the history of China and the world. Three inventions in the history of early firearms in China are most important. The first is the forerunner of all guns and cannons of later times, the copper *huochong* 火銃 (hand cannon), a firearm that shoots out of a metal barrel. The second is the iron *huopao* 鐵火砲 (cast-iron bomb, also called *zhentian lei* 震天雷, literally “thunder-crash bomb”), a bomb with a metal casing that is the precursor of all explosive shells that appeared later. The third invention is the early pyrotechnic rocket, which inspired the jet-propelled flight of modern times. Concerning the iron *huopao*, the world’s earliest bombs with iron casings, historical records abound in the documents of the Song and Yuan dynasties, but for a long time substantial research on the topic remained impossible, as no remains of actual iron *huopao* had yet been discovered. Since 2013, in the excavation of two sites of Southern Song ancient cities (Diaoyu Fortress and Baidicheng) in Chongqing 重庆, archaeologists from the Chongqing Cultural Heritage Research Institute have discovered a number of iron *huolei* (bombs) of the Southern Song dynasty.³ This finding not only provides first-hand material for research on the history of the invention of gunpowder and firearms, which has always been lacking, but also offers new physical evidence for exploring the history of war and the military history of the thirteenth century (in particular the Mongol-Song war).

1

Chinese alchemists mastered the secret of gunpowder by the beginning of the ninth century at the latest. Gunpowder gradually left the workroom of alchemists thereafter to be applied on the battlefield. In particular from the tenth century to the thirteenth century, when the warfare among the Song, the Liao, the Jin, and the Mongols was intense, the Chinese invented a series of early incendiary firearms, explosive firearms, firearms for shooting, and pyrotechnic rockets. As these preliminary firearms were increasingly used in military confrontations, and because they were brought to the Arab Region when the Mongol army marched westwards, the world history of warfare can be said to have left the age of cold weapons and entered a period of coexistence between cold weapons and firearms.⁴ The iron *huopao* is one of the most significant inventions of this time.

The earliest record of iron *huopao* in ancient historical literature appears in *Xinsi qi Qi lu* 辛巳泣蘄錄 (Records of defending Qizhou in the year of Xinsi) by Zhao Yurong

3 For data on the Southern Song iron *huopao* unearthed in Chongqing, see Yuan and Hu 2019. This citation is omitted hereinafter.

4 For systematic knowledge concerning the history of early gunpowder and firearms in China, see Needham 1986; Cheng and Zhong 1990; Wang 1991; Zhong 1995; Zhong 2015; Pan 2016.

趙與裕 of the Southern Song dynasty. In the fourteenth year of Jiading 嘉定 reign (1221) in the Southern Song dynasty, the Jin troops employed a large number of iron *huopao* during their attack on Qizhou 蘄州, which was then under the control of the Southern Song. “In shape they are like gourds, but with a small mouth. They are made with pig iron, about two *cun* 寸 in diameter, and they cause the city wall to shake” (Zhao [1230] 1935, 23).⁵ Zhao Yurong personally participated in the war, and the book is the record of his first-hand experience. The Song soldiers defending Qizhou did not have this kind of weapon at first; later on, this new style of firearm quickly spread and was produced and consumed in large quantities by the Song troops as well. In the Song-Jin wars, Mongol-Jin wars, Mongol-Song wars, and during the Yuan attack on Japan, the iron *huopao* was heavily used, leaving abundant accounts in ancient literature. During the Song and Yuan dynasties, these bombs with iron casing were either fired by trebuchets or hurled by soldiers. According to *Jingding Jiankang zhi* 景定建康志 (Gazetteer of Jiankang during Jingding reign), which was finished during the reign of Jingding 景定 (1260–1264), the iron casings of the bombs weighed three *jin* 斤, five *jin*, six *jin*, seven *jin*, or ten *jin* (Zhou [1261] 1989, 18–24) (one *jin* in the Song dynasty equals approximately 633 grams today, see Anonymous 1994, 18). The casings could be large or small, and the quantity of the gunpowder filled in the casings varied.

In 1954, while doing research concerning the history of gunpowder and firearms, Feng Jiasheng 馮家昇 drew a diagram of the four types of iron *huopao* based on historical accounts (Figure 1) (Feng 1954, 33). Later on, Feng’s diagram was frequently cited by researchers, some of whom even modified it to be three-dimensional (see Figure 2 for an example). The first type is *hewan shi* 合碗式 (in the shape of two enclosed bowls, see Figure 1.1), which is based on the account of He Mengchun 何孟春 from the Ming dynasty: “. . . on top of Xi’an’s city wall, there is an old stockpile of iron *huopao*. They were called *zhentian lei*, and were like two enclosed bowls with a hole at the top, just big enough to put your finger in” (He [1528] 1997, 153).⁶ Feng took this comparison to two enclosed bowls further by arguing that each half of the casing was cast individually, taking as supporting evidence the fact that “to make shells, sixteenth and seventeenth-century Europeans also made two halves of the casing first; then they

5 “其形如匏狀而口小，用生鐵鑄成，厚有二寸，（爆炸）震動城壁。” The English translation is borrowed from Andrade 2016, 42, with minor revisions. Here the original Chinese text reads “*hou you ercun*” 厚有二寸 (about two *cun* thick). The “*hou*” 厚 (thick[ness]) here probably refers to the maximum width of the bomb horizontally, if we take the straight line connecting its mouth and bottom as the vertical. This can be confirmed by the actual Southern Song iron *huopao* unearthed in Chongqing.

6 “西安城上舊貯鐵火砲曰震天雷者，狀如合碗，頂一孔，僅容指。” The author is grateful to the anonymous reviewer for noting the source cited here. See also He [n.d.] 1938, 11. The English translation is based on Andrade 2016, 46.

filled in the gunpowder, and put the two halves together” (Feng 1954, 38–39).⁷ Now we know that each of the Southern Song iron *huopao* unearthed in Chongqing was cast as a whole, rather than assembled as two halves. However, there is indeed a casting joint in the middle part of the shell’s casing, which might imply that the casing was produced by putting two halves together. This was probably what He Mengchun had in mind when he described the *huopao* as “like two enclosed bowls,” rather than shells assembled out of two individually cast halves, as Feng argued.

Figure 1: The diagram of four types of iron *huopao*, drawn by Feng Jiasheng. 1: *Hewan shi*. 2: *Guanzi shi*. 3: *Hulu shi*. 4: *Yuanti shi*.

Figure 2: The diagram of iron *huopao*, adapted from Feng Jiasheng's drawing.

7 “欧洲十六七世纪时的炮弹也是先把两半壳制成，装上火药，然后合拢起来的。”

The second type is *guanzi shi* 罐子式 (in the shape of a jar, see Figure 1.2). The name comes from “Chizhan Hexi zhuan” 赤盞合喜傳 (Biography of Chizhan Hexi) in *Jinshi* 金史 (History of Jin): “One of the weapons deployed by the defenders is *zhentian lei*, which is an iron jar filled with gunpowder. When it is lit, the bomb is shot off and explodes. It goes off like a crash of thunder, and can be heard at a distance of over a hundred *li* 里, burning an expanse of land of more than half a *mu* 畝. When hit, even iron armor is pierced through” (Tuotuo et al. [1344] 1975, 2496–2497).⁸ This type of bomb is very close to those of the Southern Song unearthed in Chongqing.

The third type is *hulu shi* 葫蘆式 (in the shape of a gourd, see Figure 1.3). This name comes from a passage of Zhao Yurong’s *Xinsi qi Qi lu*, finished in the Southern Song dynasty: “in shape they are like gourds, but with a small mouth.” Gourds can be wasp-waisted, but they can also be pear-shaped or elliptic. In Feng’s diagram, this type of bomb appears wasp-waisted, but objects of this shape are absent among the iron *huopao* of the Southern Song dynasty unearthed in Chongqing. On the other hand, if we interpret “in shape they are like gourds” to mean the bombs are like pear-shaped gourds or elliptic gourds, then bombs of the third type will be very similar to those of *guanzi shi*, as well as those of the Southern Song unearthed in Chongqing. It seems that the phrases “iron jar” and “in shape they are like gourds” in historical accounts are referring to the same form; varying understandings have resulted from the fact that the real thing was unavailable to scholars until recently.

The fourth type is *yuantishi* 圓體式 (in the shape of a ball, see Figure 1.4). Feng did not provide supporting evidence from historical accounts; this category was probably a speculative one based upon modern shells and bombs. Closest to this category are a few of the Southern Song iron *huopao* unearthed in Chongqing that are relatively short and wide in diameter. In fact, they should be classified under the “iron jar” shape described in historical books.

So there are both similarities and differences between the four shapes in Feng’s diagram and the Southern Song iron *huopao* unearthed in Chongqing. This is due to the limitation of analysis based on written records and verbal descriptions only—one should never expect to reach an accurate conclusion in this way. Above we have limited our discussion to the appearance and the shape of iron *huopao*; as for the properties, strength, and manufacturing technology of iron *huopao* and the gunpowder that they are filled with, it is impossible to conduct any research that is concrete and accurate without real relics.

With the Southern Song iron *huopao* unearthed in Chongqing, we are now for the first time able to see these important ancient firearms as they really were. Discovered

8 “其守城之具有火砲名震天雷者，鐵罐盛藥，以火點之，砲起火發，其聲如雷，聞百里外，所熱圍半畝之上，火點著甲鐵皆透。” The English translation is borrowed from Andrade 2016, 46, with minor revisions.

using scientific archaeological excavation techniques, this series of findings is rich and reliable. We not only have vessels that are intact or almost intact, but also pieces or fragments left by explosions and gunpowder remains in the belly of some of the vessels. We have found a clay mold which perhaps was used to cast the shell's iron casing as well as a kiln that might have had something to do with the manufacture of this weapon. In addition, extremely rich historical information is contained in the condition of these buried vessels, in various traces that are attached to the vessels, and in the connection between the site and the vessels or between vessels. This batch of findings makes it possible for scholars to conduct solid, concrete, and deep research on the iron *huopao*, including its casting technology and the technology behind the gunpowder it used. In particular, it is now possible to do technical detection and analysis and run analog simulations so as to accurately learn about the technical performance and explosive power of the bombs, as well as the technology and craft of making such weapons. Only through research methods as solid, concrete, and deep as these can we correctly understand and reveal what level of development early gunpowder and firearms in China had reached. It is certain that this kind of research requires interdisciplinary cooperation. We believe that as these Southern Song iron *huopao* become known to all, and as interdisciplinary research makes progress, scholars will be able to probe deeper in their research into the history of the invention of gunpowder and firearms.⁹

2

The discovery of these Southern Song iron *huopao* in Chongqing is significant for studying the history of war and military history as well. At first, when gunpowder was employed in ancient wars, it was used to start a fire; all the earliest firearms were incendiary. Later on, explosive firearms with casings made of paper or pottery were invented. It took another step to invent explosive bombs with iron casings, which is what the iron *huopao* represent. The invention and adoption of iron *huopao* mark the beginning of explosive weapons playing an important role in warfare. All the iron *huopao* unearthed in Chongqing were discovered in the Diaoyu Fortress and Baidicheng, two sites of ancient battlefields of the Mongol-Song War, and especially Baidicheng, where "the scourge of God" was snapped and where Möngke Khan died. All the iron

⁹ Previously there were some amateur collectors who claimed to have possessed iron *huopao* (*zhentian lei*) of the Song or Yuan dynasties, but as there was no reliable sample (for instance, relics unearthed in professional archaeological excavations) to be compared against, there was no way to determine whether their possessions were genuine or not. There are also counterfeiters who passed on baseless rumors. Now, after the discovery of actual Southern Song iron *huopao* in Chongqing, we can take these findings as a standard for comparison, and decide whether the collectors' so-called iron *huopao* or *zhentian lei* are real antiques.

huopao unearthed here were left by the fierce war between the Song and the Mongols, and thus they provide important historical information and physical evidence for us to study that dramatic war.

For example, historical sources and scholars disagree about details concerning the death of Möngke Khan in 1259 during the fight at Diaoyu Fortress between the Song and the Mongols. According to “Diaoyucheng ji” 釣魚城記 (Record of the Diaoyu Fortress), in the first year of Kaiqing 開慶 reign in the Southern Song dynasty (1259), Möngke Khan led an army to attack the Song’s Diaoyu Fortress. To spy on the Song’s city defense, he ordered a watchtower to be built. In turn, the Song soldiers in the fort fired *paoshi* 砲石 (projectiles) at the tower using trebuchets. Möngke Khan “was caught in the shock of *paofeng* 砲風 and thus fell ill. [The Mongol army] withdrew. . . . Möngke Khan passed away when the troops arrived at Wentangxia 溫湯峽 in Jinjian Mountain 金劍山.”¹⁰ The author believes that this historical record in “Diaoyucheng ji” deserves much attention, as now the remains of complete iron *huopao*, and more importantly, a large number of fragments, were discovered at the site of Diaoyu Fortress. In the Southern Song and Yuan dynasties, *paofeng* is prevalently used to describe the shock wave of an explosion produced by gunpowder or firearms. For example, in “Paohuo” 砲禍 (Accidents caused by gunpowder) in *Guixin zazhi* 癸辛雜識 (Miscellaneous records of the year of Guixin), written by Zhou Mi 周密 in the seventeenth year of Zhiyuan 至元 reign in the Yuan dynasty (1280), an explosion took place in the gunpowder warehouse in Weiyang 維揚: “the huge noise like a landslide or tsunami made the whole city terrified. . . . When it was settled, the defending troop, which had over a hundred soldiers, as well as all the buildings, were either smashed into pieces or carried to more than ten *li* away by *paofeng*” (Zhou [1290] 1922, 14).¹¹ Here again, *paofeng* is used to describe the shock wave of an explosion. Now we are

10 “為砲風所震，因成疾，班師……過金劍山溫湯峽而殂。” The earliest existing text of “Diaoyucheng ji” that we know of can be found in Wanli *Hezhou zhi* 合州志 (Gazetteer of Hezhou, block-printed edition of 1579, stored in the National Archives of Japan), whose facsimile edition was included in *Riben cang Zhongguo hanjian difangzhi congkan* 日本藏中国罕见地方志丛刊 (Selection of rare Chinese historical gazetteers in Japan) and *Xijian Zhongguo difangzhi congkan* 稀见中国地方志丛刊 (Selection of rare historical gazetteers in China)—the author is grateful to the anonymous reviewer for pointing this out. The article was later included in “Zhifang dian: Chongqing Fu bu” 職方典·重慶府部 (Local official’s records of Chongqing Prefect) of *Gujin tushu jicheng* 古今圖書集成 (Imperially approved synthesis of books and illustrations past and present), which was compiled during Kangxi reign, in “Guji: Chongqing Fu” 古跡·重慶府 (The ancient sites of Chongqing Prefect), chapter 50 of *Sichuan tongshi* 四川通史 (A complete history of Sichuan Province), compiled in the thirteenth year of Yongzheng reign (1735), and into “Yiwen buyi” 藝文補遺 (Supplementary passages), chapter 12 of *Hezhou zhi*, compiled in the fifty-third year of Qianlong reign (1788). It was concluded as written by an author from the late Song or the early Yuan dynasty. See Department of History, Southwest China Teacher’s College 1962, 58.

11 “大聲如山崩海嘯，傾城駭恐，……事定按視，則守兵百人皆糜碎，楹棟悉寸裂，或為砲風扇至十餘里外。”

sure that in the battle of Diaoyu Fortress, iron *huopao* were employed by the Song troops. Among the *paoshi* that they fired using trebuchets there were both ordinary stone shells and iron *huopao*, explosive bombs with iron casings. The shock wave of an explosion produced by the iron *huopao* could not have been as powerful as that produced by the explosion of a firearms warehouse, yet within a small perimeter its shock wave carried fragments of the shells, which flew in all directions and could thus be lethal. It is very likely that Möngke was injured in this way. In its account of the iron *huopao* explosion, the above-cited “Chizhan Hexi zhuan” in *Jinshi* stated that “it burn[s] an expanse of land of more than half a *mu* 亩” (所焚園半畝之上), which means that the explosion could cause major damage across an area of more than half a *mu*, and that “When hit, even iron armor is pierced through” (火點著甲鐵皆透), which means that the bomb fragments from explosions could impale iron armor. Also, according to “Ma Xi zhuan” 馬壑傳 (Biography of Ma Xi) in *Songshi* 宋史 (History of the Song), in the fourteenth year of Zhiyuan reign (1277), the Yuan army attacked Jingjiang 靜江 (nowadays Guilin 桂林, Guangxi Province). When the city fell, the surviving Song soldiers in the city’s gate tower still had a huge iron *huopao*: “The bomb was detonated. The noise was like a tremendous thunderclap, shaking the walls and ground, and the smoke billowed up to the sky. Many of the troops [outside] were startled to death. When the fire was extinguished they went in to see. There were just ashes, not a trace left” (Tuotuo et al. [1345] 1977, 13270).¹² All the historical records above can prove that some of the iron *huopao* at the time were already extremely powerful; it is thus reasonable to postulate that Möngke was injured by one.

Another research question on which the unearthed iron *huopao* can shed light is whether the Mongols employed iron *huopao* in the battle of Diaoyu Fortress. While relevant historical documents have been lacking, the actual iron *huopao* discovered at the site of Diaoyu Fortress, and especially the large quantities of fragments left by explosions, provide new physical evidence. First of all, it was the Jin people who invented iron *huopao* and first put them into frequent use. After the Jin had been conquered by the Mongols and the Song, the Mongol army, which made up the major part of the Mongol-Song allied forces, must have acquired more craftsmen and weapons from the Jin, and must have mastered the technology well enough to produce iron *huopao*. If so, it would be very likely that the Mongol army employed iron *huopao* in the battle of Diaoyu Fortress. Secondly, only a few decades after the battle, in 1274 and 1281, Kublai, Emperor Shizu of the Yuan dynasty, twice dispatched his troops to attack Japan by sea, and iron *huopao* were employed by the Yuan army during the

12 “燃之，聲如雷霆，震城土皆崩，煙氣漲天外，兵多驚死者，火熄入視之，灰燼無遺矣。”

By “many of the troops [outside] were startled to death,” the author was talking about the Yuan soldiers besieging the city’s tower, who were actually killed by the shock wave of the explosion. The English translation is borrowed from Andrade 2016, 51, with revisions.

confrontation. Takezaki Suenaga, a Japanese samurai who fought in the battle, had someone draw *Mōko Shūrai Ekotoba* 蒙古襲来絵詞 (Scrolls of the Mongol invasion of Japan) afterwards to record the situation. In the scroll, there is a scene of the iron *huopao* exploding high above (Figure 3), which provides a piece of circumstantial evidence to support that it was possible for the Mongol army to have used iron *huopao* during the battle of Diaoyu Fortress. Thirdly, up till now, all the iron *huopao* and their fragments and incomplete pieces have been discovered within the fortress, some of which were found in a pool at the site of a Southern Song government office (Figures 4-5).¹³ Probably not all of them were left by the Song army; rather, some of the findings were probably from the Mongol army who attacked the city. According to *Xinsi qi Qi lu* by Zhao Yurong of the Southern Song dynasty, in 1221, when the Jin army invaded Qizhou, which was at that time under Song control, they used trebuchets to fire iron *huopao* into the city, and some of the bombs even hit the headquarters of the magistrate, or the roof of the author's bedroom (Zhao [1230] 1935, 20-23). This seems to agree with the claim that some of the iron *huopao* discovered at the site of Diaoyu Fortress, the incomplete pieces and fragments in particular, were left from the explosion after the Mongol attackers shot the bombs into the city. Based on the analysis above, the author believes that the Southern Song iron *huopao* unearthed in Chongqing must have been left by both sides of the Mongol-Song war. During the battle of Diaoyu Fortress, and in the Mongol-Song war generally, this new weapon was employed not only by the Song troops but also by the Mongol troops. Paying special attention to all the relevant information, a deeper exploration should be conducted in the future so as to find evidence that is more definitive.

Figure 3: The explosion of iron *huopao*, depicted in *Mōko Shūrai Ekotoba*.

13 As the site is impressive in size, and the buildings are well organized and with delicate details (Figure 5), it is probably the remains of a government office. After analyzing various evidence, archaeologists who participated in the excavation decided that this is the site of the government of Diaoyu Fortress during the Southern Song dynasty.

Figure 4: The incomplete iron *huopao* (left) and a fragment of an iron *huopao* (right) unearthed in a pool at the site of the government office of the Southern Song dynasty. According to *Xinsi qi Qi lu*, written by Zhao Yurong of the Southern Song dynasty, we can deduce that in 1221, when the Jin troops attacked Qizhou, some of the iron *huopao* that they shot into the city did not explode, or there might have been incomplete explosions. This incomplete iron *huopao* unearthed in the Diaoyu Fortress in the picture lost its mouth only, which is probably the result of an incomplete explosion, which is very common for bombs of modern times as well. Photo taken by Zhong Shaoyi 钟少异 on July 24, 2018.

Figure 5: A pool at the site of the Southern Song government office in the Diaoyu Fortress. Photo taken by Zhong Shaoyi on July 22, 2018.

All the preliminary conclusions above are newly acquired through the important relics recently unearthed in Chongqing, whose usefulness no doubt extends far beyond the few personal thoughts presented in this paper. In particular, as interdisciplinary research makes progress in the future—as research on technology and research on history become more deeply integrated—it is absolutely foreseeable that abundant new findings will be brought forth from this excavation.

Lastly, a few words concerning nomenclature. Mr. Yuan Dongshan 袁东山, who is in charge of the excavation, refers to the Southern Song iron *huopao* unearthed in Chongqing as *qiuxing huolei* 球形火雷 (spherical bombs)—a choice of words which reflects the professionalism and prudence of an archaeologist. Comparing these Southern Song iron *huopao* to the numerous records in the historical literature (the materials quoted above will suffice), we can come to the clear conclusion that these are actually iron *huopao* or *zhentian lei* of that time. According to the principle of *wucong yuanming* 物从原名 (using the original name of the object) in assigning names to ancient vessels, we can feel certain that the term for these bombs should be iron *huopao* (also called *zhentian lei*).

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