A Preliminary Study on the Spherical Bombs (*Huolei*) of the Southern Song Dynasty, Unearthed in Chongqing¹

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Abstract: The military situation of the thirteenth century required that the Song and the Mongols construct a great number of defensive works, relying on the mountains or facing the rivers, in the mountainous Sichuan Province and Chongqing. In recent years, a special kind of explosive firearms, *huolei* 火雷 (bombs), was unearthed in the large-scale excavations of the site of Diaoyu Fortress 钓鱼城 in Hechuan District 合川 and the Baidicheng 白帝城 in Fengjie County 奉节, both of which were defensive works constructed in this mountainous area during the Southern Song dynasty. In addition, the ruins of kilns and the clay molds that were relevant to the casting of iron *huolei* have been discovered at the site of Baidicheng, indicating that these *huolei* might have been produced locally. The Southern Song iron *huolei* unearthed in Chongqing are the most direct evidence of the evolvement of gunpowder and firearms, and are of great significance to the history of science and technology, in particular the history of military technology.

Keywords: Chongqing, the Southern Song dynasty, *huolei* (bombs), firearms, history of weapons technology, history of science and technology

摘要: 13 世纪, 宋、蒙(元)双方出于战争需要, 在川渝地区依山就水修筑了大批山地城防设施。近年来在重庆地区的南宋山城遗址——合川钓鱼城遗址和奉节白帝城遗址

1 Editor's notes: This paper was written in Chinese, translated into English by Yu Yueyuan 俞月圆, and copyedited by Charlie Zaharoff. The excavation of the Fanjiayan relic site, where some of the iron *huolei* were unearthed, entered "China's Top 10 Archaeological New Discoveries in 2018" (Wang 2019). In this issue, we publish two articles on the discovery of iron *huolei*, with different emphases. The revised version of this article written by Yuan Dongshan and Hu Limin was received on April 14, 2019. The article written by Zhong Shaoyi 钟少异 was received on September 24, 2018.

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的大规模考古发掘中，都出土了一种特殊的爆炸性火器——火雷。这种火雷有铁质和陶质两类，铁火雷又有大小几种形制：陶火雷出土较少，现仅见于白帝城遗址。此外，白帝城遗址中还发现了与火雷冶铸有关的窑址和陶范，说明火雷可能为本地生产。重庆地区出土的这批南宋火雷是火药及火器演进史上最直接的证据，在军事技术史及科学技术史上具有非同凡响的意义。

关键词：重庆，南宋，火雷，火器，兵器技术史，科学技术史

Gunpowder, which is among the Four Great Inventions, “is the first chemical explosive that human beings ever mastered, and is the greatest scientific and technological achievement of China during the medieval period” (Pan 2016, 47–48).⁴ “It was first introduced to the Islamic countries, and therefrom to Europe” (Feng 1978, 40).⁵ The application of gunpowder in weapons technology has had an extensive and profound influence on the development of civilization throughout the world. Towards the end of the tenth century, the earliest gunpowder was compounded by Chinese military experts of the Northern Song dynasty following the formula that the alchemists had found. It was used to build firearms, ushering in a new era in the history of military technology in which firearms and cold weapons coexisted (Wang 1991, 1). If we take the crucial invention and renewal of firearms as marker events, the era can be further divided into four phases: the time when primitive firearms were invented and developed (the Song dynasty, 960–1279); the time when *chong 銃* (guns) were invented and refined (from the Yuan dynasty to the end of the Zhengde 正德 reign, Ming dynasty, 1279–1521); the time when *huosheng 火繩* (incendiary fuses) and guns were improved (from the beginning of the Jiajing 嘉靖 reign, Ming dynasty, to the end of the Ming dynasty, 1522–1644); and the period of erratic development of firearms in the Qing period before 1840 (Wang 1998, 95).

During the Song dynasty, which saw the invention of primitive firearms, “the incendiary firearms, the explosive firearms, the tubular firearms, and the firearms that resembled a rocket successively came into being, thus setting a foundation for basic categories of ancient firearms in China” (Liu 2004, 37).⁶ Firearms of this time include “*huoyao jian 火药箭* (fire arrows) and *huoqiu 火球* (fire balls) of the Northern Song dynasty, and *huoqiu* with iron casing—iron *huopao 铁火炮* (iron gunpowder bombs)—and all kinds of *huoqiang 火枪* (fire lances) of the Southern Song dynasty,” which were gradually put into use in actual combat (Wang 1998, 103).⁷ At that point, fire and smoke started to spread over the battlefield, once the world of cold weapons.

4 “是人类第一次掌握的化学爆炸物，是中国在中世纪取得的一项最大的科技成就。”

5 “先传入伊斯兰教国家，然后再由伊斯兰教国家传入欧洲。”

6 “燃烧性火器、爆炸性火器、管形火器、火箭类火器相继出现，从而奠定了我国古代火器的基本门类。”

7 “有北宋时期的火药箭和火球、南宋时期创制的铁壳火球——铁火炮和各种火枪。”

Almost all previous research on primitive firearms of the Song dynasty is based on the analysis and interpretation of historical texts, the main reason being that remains of actual firearms are so few. In the thriving archaeological activity of recent years, however, a number of spherical *huolei* 火雷 (bomb) remains were discovered in the excavations of the defensive works constructed in mountainous areas of Chongqing during the Song-Mongol War. These provide precious tangible materials for the research on primitive firearms of the Song dynasty.

According to historical records of the thirteenth century, the contemporary military situation required the Song and the Mongols to construct more than eighty defensive works, relying on the mountains or facing the rivers, in the mountainous Sichuan Province and Chongqing. Now, after more than 700 years, preliminary research shows that over fifty historical sites of this kind in Sichuan and Chongqing still exist. In Chongqing, large-scale archaeological investigations have been carried out at Diaoyu Fortress 钓鱼城 in Hechuan District 合川, the city of Chongqing 重庆城, Baidicheng 白帝城 in Fengjie County 奉节, Tianshengcheng 天生城 in Wanzhou District 万州, Panshicheng 磐石城 in Yunyang County 云阳, Duogongcheng 多功城 in Yubei District 渝北, and Guilingcheng 龟陵城 in Fuling District 涪陵, among others (Figure 1), and much archaeological knowledge has been acquired, including the important discovery of remains related to the spherical *huolei*. Relevant findings mainly include spherical iron *huolei*, pottery *huolei*, furnaces for smelting, and clay molds. These were all unearthed at the sites of Diaoyu Fortress and Baidicheng; no similar items have been found at the other sites.

Figure 1: The sites of the defensive works constructed in the mountainous area of Chongqing during the Song-Mongol War (map developed based on Chen et al. 1988, 78).

1 The spherical *huolei* unearthed

Spherical *huolei* can be divided into iron *huolei* and pottery *huolei*, according to the material that they are made of. Iron *huolei* are found in greater number and are distributed across a wider area, while pottery *huolei* are very rare and have only been found in the ruins of Baidicheng.

1.1 The iron *huolei*

1.1.1 The site of the ancient tunnel in Diaoyu Fortress

An ancient tunnel was discovered outside the wall of Diaoyu Fortress, about 100 meters north of the Qisheng Gate 奇胜门, in 2005, and was excavated and cleared afterwards. Thirty-five meters of the tunnel have been excavated, consisting of the main channel, six short bypasses, and shafts (Figure 2). More than eighty pieces of arc-shaped fragments of ironware were discovered, and after the rust had been removed, they were identified as debris of iron *huolei* after explosion. The iron bomb D1: 6 is an arc-shaped fragment, which has a raised casting joint on the outside. It is 8.0 centimeters long, 7.0 centimeters tall, and its wall is 1.2 centimeters thick (Figure 3) (Yuan and Ding, forthcoming).

Figure 2: The top view and the sectional views of the ancient tunnel.

Figure 3: The fragments of the iron bomb (D1: 6) unearthed in the ancient tunnel.

The ancient tunnel in Diaoyu Fortress was cut in 1259, when Möngke Khan led an army to conquer the place. This is an example of fighting a war with *ditu* 地突 (tunnels).⁸ The Mongol troops dug the tunnel to attack the fortress while the Song troops defended it using iron *huolei*. Attacking with the help of tunnels was a common practice for the Mongols. In Friar Giovanni DiPlano Carpini's *The Story of the Mongols Whom We Call the Tartars*, it says that "they tunnel under it [the fort] and approach it armed from underground. Once they have entered at one place they set fire to it so that it burns while they fight the men of the fort in another area" (Carpini [n.d.] 2017, 76). *Jin shi* 金史 (History of Jin) records a similar incident. In 1232, when the Mongol troops attacked Kaifeng 開封,

the [Mongol] soldiers impaled the cow hide [to provide themselves a shelter] and thereby approached the city wall. In the wall, the Mongols made niches that are large enough to hold people; the defenders on top of the wall could do nothing to stop them. Someone [from Jin] suggested tying *zhentian lei* 震天雷 (literally "thunder-crash bomb") to iron ropes and lowering them down. The bombs would be detonated when they reached the

8 Some other examples include: "An army of about fifty to sixty thousand troops led by Wang Xun 王尋 and Wang Yi 王邑 arrived. They set up camps besieging the city of Kunyang 昆陽 with dozens of rows. . . . The whole field was covered with flags, and the dust was blown about, touching the clouds. The drumbeats could be heard from dozens of *li* 里 away. [The attackers] were either digging *ditu* or building *chongche* 衝車 (battering-rams) to hit the city wall" ("尋、邑兵已五六萬到，遂環昆陽城作營，且圍之數十重……旗幟蔽野，塵燄連雲，金鼓之聲數十里。或為地突，或為衝車撞城。" Liu et al. [178] 2000, 4), and "In the twelfth month of the second year of Taihe 太和 [228] in the lunar calendar, Zhuge Liang 諸葛亮 besieged Chencang 陳倉. . . . He further dug *ditu*, in the hope that his soldiers would be able to jump out of the tunnel inside the city, but [Hao] Zhao 郝昭 dug into the ground inside the city and intercepted the digging" ("太和二年十二月，諸葛亮圍陳倉……亮又為地突，欲踴出於城裡，昭又於城內穿地橫截之。" Sima et al. [1084] 1956, 2249–2250).

place where the enemies had dug the holes. Both the human bodies and the cow hide were devastated and left no traces at all. (Tuotuo [1344] 1975, 2496–2497)⁹

This quotation reveals that the idea employed by the Song soldiers to repel the Mongols' *ditu* attack was consistent with a prevalent strategy of the time.

1.1.2 The garden area at the site of Fanjiayan in Diaoyu Fortress

In 2013, a fragment from the explosion of an iron *huolei* (Figure 4) was unearthed during the excavation of pool H1 in the garden area of the site of Fanjiayan 范家堰 and was given the title H1 ⑦: 4. Its structure of mouth, body, and bottom, as well as the traces of casting, were complete and clear, so it is regarded as a restorable vessel from an archaeological perspective. The diameter at its mouth is 1.4 centimeters, the diameter of the bomb is 10.7 centimeters, and its wall is 0.7–1.3 centimeters thick. It stands at 10.4 centimeters tall. Judging from the casting joint, it can be deduced that the bomb was cast using a horizontally divided mold. The bomb is rather small and without a protruding tubular thick “lip” where the fuse touches off the bomb; rather, at this spot there is a little circular opening whose diameter is less than 1 centimeter.

Figure 4: The iron bomb 2013HDFH1 ⑦: 4 unearthed in the garden area at the site of Fanjiayan in Diaoyu Fortress.

1.1.3 The government office area at the site of Fanjiayan in Diaoyu Fortress

In 2017, an iron bomb (H27②: 12) was unearthed as pool H27 in the government office area of the site of Fanjiayan was being cleared. The bomb has an incomplete mouth, a spherical body that is hollow inside, and a casting joint that surrounds its middle part. With corrosion on its surface, the bomb is 11.0 centimeters in diameter and 0.8–1.0 centimeter thick. The remaining part of the bomb is 9.7 centimeters tall (Figure 5).

9 “（蒙軍）大兵又為牛皮洞，直至城下，掘城為龕，間可容人，則城上不可奈何矣。（金）人有獻策者，以鐵繩懸‘震天雷’者，順城而下，至掘處火發，人與牛皮皆碎迸無跡。”

Figure 5: The iron bomb 2017HDFH27 ②: 12 unearthed in the government office area of the site of Fanjiayan in Diaoyu Fortress.

1.1.4 The excavation area of Miaoping at the site of Baidicheng

In 2015, the Archaeological Team of the Department of Anthropology, Sun Yat-sen University, cleared and excavated a pool in the excavation area of Miaoping 庙坪 at the site of Baidicheng, Fengjie County, where two iron *huolei* were unearthed (Figure 6). Resembling a melon-shaped modern grenade, bomb S1①: 9 has a small gourd-shaped flared mouth, a round middle part, and an incomplete bottom, measuring 13.7 centimeters in diameter. Bomb S1①: 8 is incomplete in its upper part, hemispherical in its lower part, and appears a little pointed on the bottom. Its diameter is 14.0 centimeters (Wang, forthcoming).

Figure 6: Left: The iron bomb S1①: 9. Right: The iron *huolei* S1①: 8 and S1①: 9 unearthed in the excavation area of Miaoping at the site of Baidicheng.

1.1.5 The excavation area of Fanjiatai at the site of Baidicheng

Pit H1 lies in the southeast of the excavation area of Fanjiatai 樊家台 at the site of Baidicheng. The pit, which was cleared in 2007, is in the immediate vicinity of the city wall. Sixteen perfectly preserved iron *huolei* were unearthed there. Including another one that was discovered in the barbican of Huangdiantai 皇殿台, there are altogether seventeen iron *huolei*, none of which were detonated (Figure 7). Five pieces of charcoal and one piece of animal bone that were unearthed in the pit have been tested in the Beta Analytic Testing Laboratory in Florida. The radiocarbon ages of the charcoal and the bones were determined to be 800 ± 30 BP, 830 ± 30 BP, and 850 ± 30 BP, respectively, and the calibrated results of their calendar ages are 1184–1275, 1160–1264, and 1152–1260, respectively, which correspond to the middle and late Southern Song dynasty. According to the stratigraphic sequence, other relics that were discovered, the results of radiocarbon dating, and an analysis of the historical context, it can be speculated that what was found in the pit may have been buried by the defending troops of Kuizhou 夔州 before they surrendered, in the year 1278 or sometime earlier (Sun, forthcoming). Metallographic examination shows that all the iron *huolei* unearthed are made of white cast iron. These *huolei* are either large or small, with an obvious difference between their mouths—on larger ones, the protrusion at the mouth is not evident, while the smaller ones have small tubular mouths.

Figure 7: The iron bombs unearthed in H1 pit, Fanjiatai.

1.2 The pottery *huolei*

Only four pottery *huolei* have been discovered at the ruins of Baidicheng. One of the four, 2000FBT203⑥: 11, is restorable. It has a contracted mouth, a round lip, a short neck, a protruding abdomen, and a flat bottom. The bomb is made of clay and appears grey. The diameter at its mouth is 4.6 centimeters; the diameter of the abdomen is 17 centimeters; the diameter of its bottom is 12 centimeters; and it stands at 14.5 centimeters tall (Figure 8).

Figure 8: The pottery bomb 2000FBT203⑥: 11.

2 The kiln and the clay molds

2.1 The kiln

In 2003, kiln 2003FBY1 was cleared during the excavation of the Baidicheng ruins. The kiln is located in the east on the gentle slope near the foot of Baidi Hill 白帝山, facing the Caotang River 草堂河 in the east. The shape and structure of kiln Y1 are rarely seen. The eastern and the northern parts of the kiln are severely damaged. The remnant is close to a long rectangle in shape, with its base sitting lower in the northeast and higher in the southwest. The remnant is 502 centimeters in length, 174 centimeters in width, 36–140 centimeters in height, and consists of a combustion chamber, fire channels, a kiln floor, insulating walls, flue channels, and so on (Figure 9).

Figure 9: The top view and the sectional views of kiln 2003FBSY1.

The major part of the combustion chamber has been destroyed, and the remaining part has an irregular shape, with an inclined arc wall and a dome. Three fire channels still exist, of which the northern one and the middle one are well preserved, while the southern one is incomplete. In all three channels, there is a thick layer of kiln sweat on the wall, and the drips are obvious (Figure 10). On the kiln floor, which connects the fire channels and the flue channels, three long passages were built by putting black bricks upright. Each of the passages is 26 to 30 centimeters wide, and the gap between two passages is around 24 centimeters. The three passages have complex structures, with holes both in the horizontal side and the vertical side. Viewed from above, each passage has six holes that are rounded rectangles in shape. The length of them is around 33 centimeters and the width about 18 centimeters. The holes run from the remaining part of the kiln's top to the bottom of the kiln floor. Viewed from the left, four circular holes, each about 18 centimeters in diameter, still exist, and directly connect the fire channels and the flue channels. The insulating walls were built by putting black bricks upright. Four layers of the walls remain, together with three vertical flue channels, whose sections are close to circles (Figure 11).

Figure 10: The kiln sweat in the combustion chamber.

Figure 11: The kiln floor.

2.2 The clay mold

In 1994, when the plan to protect the cultural relics in the Three Gorges Area was being formulated, a dozen or so clay molds were discovered in Miaoping at Baidicheng by scholars from Jilin University in their archaeological investigation. The body of the molds contains rough sand and appears black-brown, while both the inner surface and outer surface of the mold are red-brown. The molds, whose diameters are around 15 centimeters, have relatively thick walls. They may have something to do with the casting of iron *huolei*. The color of their inner surface reveals no trace of these molds having ever been used (Figure 12).

Figure 12: The clay molds.

As the kiln and the molds are so unique in shape and structure, and are unprecedented in the archaeological excavation of the Three Gorges Area, they sparked our interest as soon as they were discovered. Constrained by the fact that no actual spherical *huolei* had been found at that time, we previously failed to make the connection between the two.

3 The surviving spherical *huolei*

In the Yuan and Ming dynasties, tubular firearms developed rapidly. As fireguns and cannons became increasingly powerful, spherical *huolei* almost disappeared. Some archaeological discoveries, however, have provided surviving examples of spherical *huolei*.

For example, iron *huolei* were discovered in the ruins of barracks of the Ming dynasty in Huoyan Hill 火焰山, which is located to the southeast of Shiyao Village 石窑村, Sihai Town 四海镇, in the Yanqing District 延庆 of Beijing. They are similar in shape to those discovered in Chongqing, but were cast in a different way—using a vertically divided mold (Figure 13) (Beijing Cultural Relics Institute et al. 2010, 301–312).

Figure 13: The iron *huolei* unearthed in the ruins of barracks in Huoyan Hill.

Among the defensive weapons employed by the troops on the Ming Great Wall, there was one called *shi pao* 石炮 (stone bomb), which was actually made by filling gunpowder into hollow stone missiles. In making *shi pao*, fieldstones were chipped into a shape resembling a circular truncated cone, and one side of the cone would be made hollow. Gunpowder would then be filled in and the fuse would be installed. After the fuse had been ignited, *shi pao*, which could help the defenders to effectively eliminate the dead angles at the foot of the Great Wall, would be released through the embrasure that was used to drop the stone missile. With a sound like a crash of thunder, the broken stones would fly in all directions, and enemies within an area of about ten square meters would be either killed or injured (Gao and Lin 2011).

4 Research on the spherical *huolei*

4.1 A preliminary discussion concerning the remains of spherical *huolei*

1. The spherical *huolei* unearthed are many in number and with a wide distribution. Furthermore, there are both complete *huolei* that have not been used and fragments left by explosions. These objects can therefore convey comprehensive historical information related to spherical *huolei*.

In an overall analysis of the more than twenty iron *huolei* unearthed, three conclusions can be made about their structural features: (1) the casing of these bombs, which is made of white cast iron, is thicker than one centimeter and is very hard; (2) the inner cavity of the bombs can hold a large quantity of gunpowder; (3) the diameters at the mouth of the bombs are small, making it easier to seal off, and the bombs are touched off with fuses. In addition, the iron *huolei* have another three characteristics: (1) the bombs' bodies resemble a ball in shape. The smaller ones have small tubular mouths, while on larger ones, the protrusion at the mouth is not evident; (2) all the bombs were cast using a horizontally divided mold, and each of them has a raised casting joint, which is very obvious, in the middle part; (3) as for the effect of explosions, in detonations, the bombs either lost their mouths and bottoms, or were broken into two or three pieces.

The fact that iron *huolei* have a fairly hard, over one centimeter thick white cast iron casing that could nonetheless be broken into pieces by the explosion suggests that the gunpowder filling these bombs was indeed powerful, with great deterrent effect and the capacity to inflict significant damage. Meanwhile, their globular shape could help to ensure that the bombs were accurately hurled, either by manpower or by machine, and increase the probability that they hit their target. It is important that the bombs were detonated by fuses, which were not only safe, fast, and efficient, but also could delay the explosion, thus making military actions more effective.

2. The pottery *huolei* are to some extent similar to the iron *huolei*, the fundamental difference between the two being that for the former pottery rather than iron was used to make their casings. As pottery casings are easy to break, they might not have required as much gunpowder. As such, there were usually many other objects packed inside the pottery *huolei*, for example, chips of porcelain, pieces of iron, lime, poisonous substances, and iron caltrops, intending to injure and kill the soldiers and horses of the enemy. As they were convenient to manufacture and cost less, it could have been a cost-effective option in long-lasting warfare to choose pottery casing for the bombs. Since the casings of pottery *huolei* are comparatively easy to break, there might have been two ways to actually use the bombs in a battle—one is to detonate the bombs after putting them on the ground or on the surface of water under some cover, or burying

them under the ground; the other is to hurl the bombs within a short distance and let them explode before they reach the ground.

3. The clay mold, whose inner space is ball-shaped, can be divided into an upper part and a lower part and has a hole in it. As the mold has the same shape, the same casting joint between the upper part and the lower part, and the same characteristics of the mouth, we can come to the conclusion that this is the outer mold to cast iron *huolei*. There is not a single trace of burning, indicating that the molds have not been used after being fired. The kilns are very rare in their shape and structure, and it is certain that they were not used for smelting and casting, or for baking bricks and tiles. Taking the clay mold that was discovered into consideration, it can be assumed that the kiln was specially used to fire the clay mold. The discovery of clay molds and kilns demonstrates that the iron casings of the iron *huolei* were built locally; fortresses built in the mountainous area during the Song-Mongol (Yuan) War must have had workshops to make firearms, and must have been competent to produce firearms independently.

4.2 The nomenclature

As Professor Pan Jixing 潘吉星 pointed out in his *Zhongguo huoyao shi* 中国火药史 (The History of Gunpowder in China), the development of gunpowder and explosive firearms in the Song dynasty can be divided into two phases. The first is the Northern Song dynasty, when firearms, ignited by iron awls, were filled with gunpowder paste, and the casings were soft, made of sackcloth or papers that were pasted together. In *Wujing zongyao* 武經總要 (Collection of the most important military techniques) and *Songshi* 宋史 (The history of Song), these firearms are called *huopao* 火砲 (literally “fire bomb”), *huoqiu* 火球 (literally “fire ball”), *shoupao* 手砲 (literally “hand bomb”), and so on. The second phase is the Southern Song dynasty, when firearms, fired by fuses, were filled with granular gunpowder that was high-nitrate, and the casings were hard ones made of iron or pottery. *Jinshi* 金史 (The history of Jin) and *Xinsi qi Qi lu* 辛巳泣蘄錄 (Records of defending Qizhou in the year of Xinsi) called them *tie huopao* 铁火砲 (literally “iron fire bomb”), *zhentian lei*, *huipao* 灰砲 (literally “ash bomb”), and so on (Pan 2016, 297–304). The evolution of explosive firearms during the Song dynasties resembles the transition from explosive packages to bombs, which immensely increased the deterrent effect and killing power of firearms. Through a comparison between the date and features of the spherical *huolei* and the historical records, the author believes that the spherical iron *huolei* are what is meant by *tie huopao* and *zhentian lei*, while *huipao* refers to the pottery *huolei*.

4.3 The spherical *huolei*'s production and its application in warfare

In historical literature, there are two records concerning the production of iron *huolei* in

the late Southern Song period. The first one occurs when Li Zengbo 李曾伯, the Military Commissioner of Jing Hunan Circuit 荊湖南路, was investigating the armaments of the Jingjiang 靜江 Prefecture (today's Guilin 桂林, Guangxi Province) in the fifth year of the Baoyou 寶祐 reign (1257) of Emperor Lizong 理宗:

As for the weapons used for gunpowder warfare, there are usually hundreds of thousands of iron *huopao* in Jingzhou 荊州 and the Huai 淮 River region. When I was in Jingzhou, one thousand to two thousand *huopao* could be produced within a month. For allocation to Xiang 襄 or Ying 郢, each time ten thousand or twenty thousand pieces would be transported. Now in Jingjiang, however, the iron *huopao*, both large and small, add up to only eighty-five. For fire arrows, there are ninety-five, and fire guns are only one hundred and five. These are not enough for a thousand soldiers to fight a single battle. (Li [n.d.] 2016, 52)¹⁰

The second record testifies to the fact that between the first year of the Kaiqing 開慶 reign (1259) and the second year of the Jingding 景定 reign (1261), Ma Guangzu 馬光祖, the Prefect of Jiankang 建康 Prefecture, “produced and added to the stockpile the weapons used for gunpowder warfare, 63,754 pieces in total. . . . For casings of the iron bombs, there were 4 ten-*jin* cases, 8 seven-*jin* cases, 100 six-*jin* cases, 13,104 five-*jin* cases, and 22,044 three-*jin* cases. . . .” (*Songyuan fangzhi congkan* 1990, 1981).¹¹ According to the sources, Jingzhou produced one thousand to two thousand pieces of iron *huopao* each month and had a stock of more than a hundred thousand. Meanwhile, Jiankang Prefecture produced more than sixty thousand firearms within two years, among which the casings of iron bombs reached over thirty-five thousand, which is more than one thousand per month. That is a considerable output. Moreover, as fighting a single battle would consume almost one hundred firearms, if there had not been a strong productive force as a guarantee, firearms including iron *huopao* could hardly have been relied upon in a war. From this point, we can assume that during the Song-Mongol (Yuan) Wars, in the fortresses built in the mountainous area, iron *huolei* must have been produced in very large numbers.

According to the historical records, the iron *huolei* were frequently used in wars, appearing in the battle of Qizhou 蘄州 between the Song and the Jin, the battle of Hezhong 河中 and the battle of Kaifeng 開封 between the Mongols and the Jin, the battle of Xiangyang 襄陽, the battle of Jingjiang, and the naval battle of Yashan 崖山 between the Song and the Mongols, and in the warfare between the Mongols and European countries or Japan. In some of the battles, the iron *huolei* even played a

10 “於火攻之具，則荊淮之鐵火砲動十數萬支。臣在荊州，一月製造一二千支，如撥付襄郢，皆一二萬支。今靜江見在鐵火砲，大小止有八十五支而已。如火箭則有九十五支，火槍則止有一百五箇。據此不足為千百人一番出軍之用。”

11 “又創造添修火攻器具共六萬三千七百五十四件……鐵砲殼十斤重四支，七斤重八支，六斤重一百支，五斤重一萬三千一百四支，三斤重二萬二千四十四支……”

game-changing role. The pottery *huolei*, on the other hand, was mentioned in one case:

The government army then changed to use *huipao*. They chose some earthen jars that were extremely thin and brittle, and filled them with poison, lime, and caltrops. During the battle, the *huipao* were used to attack the enemy's ships. As the ash spread like smog, the enemies would be unable to open their eyes. [The enemies] wanted to copy that from the government army; however, in their territory there were no kiln workers, so they failed to build *huipao*, and suffered a crushing defeat. (Lu [ca. 1194] 1979, 2)¹²

4.4 The iron *huolei* and the death of Möngke Khan

The death of Möngke, or Emperor Xianzong 憲宗 of the Yuan dynasty, is still controversial, and there are many different explanations of its cause. According to *Wanli Hezhou zhi* 合州志 (Gazetteer of Hezhou), "Emperor Xianzong 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" (*Hezhou zhi* [1788] 1992, 280).¹³ Previously, *paofeng* was believed to be caused by stone missiles. The patriotic poem writer and scholar Zhou Mi 周密, who lived during the time of the Song-Yuan transition, also used the term *paofeng* in his record in *Guixin zazhi* 癸辛雜識 (Miscellaneous records of the year of Guixin) to describe the gunpowder warehouse explosion of Yangzhou in 1280: "The accident that happened in the gunpowder warehouse in Weiyang 維揚 [now Yangzhou], which took place in the year of Gengchen 庚辰 (1280) during the Zhiyuan 至元 reign, was extremely serious. . . . 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] 1988, 16).¹⁴ From the sources, we can deduce that *paofeng* must have referred to the shock wave of an explosion. With knowledge about the spherical iron *huolei* discovered at the site of Diaoyu Fortress, we can infer that Möngke Khan might have been injured by firearms similar to the iron *huolei* and died thereafter. The discovery of the spherical iron *huolei* thus provides a new perspective on the academic controversy around the death of Möngke Khan.

5 Concluding remarks

The Southern Song spherical *huolei* unearthed at Diaoyu Fortress and Baidicheng are

12 "官軍乃更作灰砲，用極脆薄瓦罐，置毒藥、石灰、鐵蒺藜於其中，臨陣以擊賊船，灰飛如煙霧，賊兵不能開目。欲效官軍為之，則賊地無窟戶，不能造也，遂大敗。"

13 "憲宗為砲風所震，因成疾……次過金劍山溫湯峽而崩。"

14 "至元庚辰歲，維揚砲庫之變為尤酷……則守兵百人皆糜碎無餘，櫓棟悉寸裂，或為砲風扇至十餘里外。"

relatively mature explosive firearms appearing during the development of primitive firearms in China. It requires various technologies such as iron smelting and casting, gunpowder production, and fuse-making to make them. These objects are significant in deepening our understanding of the time, production, and application of primitive firearms. The repeated discovery of explosive firearms proves that these weapons were not individual cases; rather, there had been a complete system of production, and these firearms were widely used during the war. These advanced military weapons might have played a crucial role in some battles, thus affecting the whole process of war.

The Southern Song spherical *huolei* unearthed at Diaoyu Fortress and Baidicheng are abundant and well-preserved, and the time at which they were produced can be clearly determined. As actual primitive firearms rarely seen throughout China or elsewhere in the world, these *huolei* have filled gaps left by related archaeological discoveries, thus providing very valuable materials for research on the history of science and technology and the history of military technology in particular. As precious evidence of the early phase at which firearms and cold weapons coexisted during medieval times, and as important physical objects that support the argument for the Four Great Inventions, the iron *huolei* are academically significant and historically valuable.

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