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Solving puzzles about the casting method of bronze inscriptions of the Western Zhou Dynasty

Li Feng *

* Department of East Asian Languages and Cultures, Columbia University, New York, NY 10027.
Email: fl123@columbia.edu.

Abstract

This paper puts forward a new interpretation about the casting techniques of Western Zhou bronze inscriptions, especially those cast in raised grids. In fuller consideration of the various phenomena seen on the bronzes, this paper suggests a nine-step workflow in which transitional molds were employed to produce the real casting core with raised texts to be used for final casting. This new theory not only fully explains the production of long inscriptions with sunken texts and raised grids, but also explains the technical details behind a number of recently discovered special inscriptions.

Keywords: Bronze inscriptions–Western Zhou Dynasty; casting techniques; mold making

Introduction

The method of casting inscriptions is a difficult question in the study of Western Zhou bronzes. Past scholars including Shih (1955), Barnard (1976), Hayashi (1979) and Matsumaru (1990) have all conducted research on this issue to considerable depth. However, due primarily to their very complex process of production, the problem of casting of the bronze inscriptions has not been satisfactorily solved. Over the past three decades, as a number of important foundry sites were discovered and subjected to careful studies, we have gained new grounds to understand the process by which bronze vessels were manufactured. And several recently discovered bronzes have also provided us with new critical sources for studying the casting methods of their inscriptions. In a complete rethinking of the problem based on this new information, the overall view of this author is that we must at least hypothesize a number of ways by which bronze inscriptions were cast, not using any single method to try to explain all phenomena that we observed on the bronzes. Only by doing this, could we possibly achieve breakthrough on this difficult issue. On the basis of the information currently available to us and through systematic analysis, we can now with good reasons explain all phenomena that we see in bronze inscriptions, hence bringing this matter to a satisfactory conclusion.

The "insertion method" of casting bronze inscriptions

Generally speaking, character strokes of bronze inscriptions appear as intaglio grooves on the body wall of the bronzes (Figure 1), which means they were raised lines

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Figure 1 Western Zhou bronze inscriptions.
1. Inscription on the interior wall of the Forty-second Year Lai *Ding*; 2. Intaglio inscription on the Lai Bell.

on the casting molds, only by which they could be cast into intaglio inscriptions. Moreover, the majority of inscriptions are placed on the inside wall of bronzes (a few are on the outside, for instance, inscriptions on bells), so they must have been located on the inner mold before casting. However, there are also inscriptions which were cast as relief lines on the surface of bronzes, found either inside or outside of the bronze wall (JC6498, JC6424 and JC9850; see Figures 2:1, 2:2 and 2:3), as such they must have been made as intaglio lines on the molds. However, the number of such inscriptions is very small, and they must not have exceeded 1% of all inscriptions registered by the *Yin Zhou jinwen jicheng* 殷周金文集成 (Institute of Archaeology 1984-94; abbreviated as JC).

Figure 2 Inscriptions of raised strokes on Shang-Zhou Bronzes registered by *Yin Zhou jinwen jicheng*. 1. JC6498; 2. JC6424; 3. JC9850; 4. JC5677.

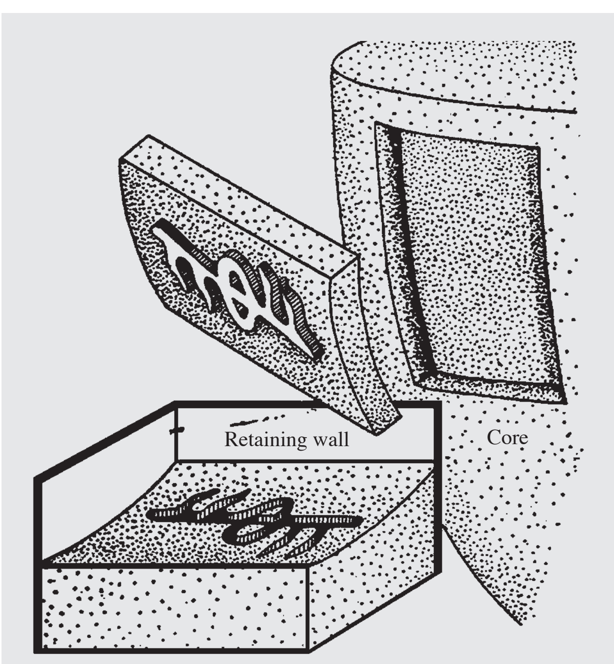

Figure 3 The "insertion method" illustration by Noel Barnard.

Regarding the method of casting these inscriptions, for instance, the inscription on the Lai bell, similar to most bell inscriptions, must have been engraved directly into the clay model of the bell in normal form; then it turned into mirror-reversed text in raised lines on the outer molds for casting. After casting, it reverted back to normal text of intaglio strokes on the surface of the bell. As for those inscriptions that appear as raised lines on the bronzes, whether on the interior (often appear inside the ring foot of *gu*-goblets) or exterior surface, they must have been engraved with a sharp tool directly into the inner or outer mold. But this required the engraver to execute it as mirror-reversed text, only by which could the normal text in raised lines be produced. Incidentally, quite often the engraver would mistake to incise normal characters if not the whole text; as a result, they could only produce mirror-reversed characters in relief lines (JC6498, see Figure 2:1). In a few cases, the text was engraved on the inner mold using double profile-lines; when cast, they became raised profile-lines on bronzes, for example, the Bird Father Gui *Zun*-wine vessel collected in the Shanghai Museum (JC5677, see Figure 2:4).

The instances discussed above are straightforwardly understandable, but the real problem is how those inscriptions that appear as normal texts in intaglio lines on the inside wall of bronze vessels were cast. Inscriptions in this category constitute the great majority of bronze inscriptions. Because these inscriptions must have appeared as mirror-reversed texts with raised character strokes on the inner mold, it is quite impossible (especially in cases of long text) for them to have been created directly using a method by which the background areas around the strokes were reduced in height. Instead, they must have been the product of a more complex method of manufacturing. Past scholars offered the explanation that inscriptions of this type were produced using the so-called "insertion method" as illustrated by Noel Barnard in this paper (Figure 3; see Barnard and Wan 1976). Barnard's illustration was reproduced by Edward L. Shaughnessy in his book (1991). Fenghan Zhu (1995) also introduced this method, but on a careful note he pointed out that it might be difficult to handle the work if the method were applied to casting inscriptions of long text. In short, "insertion method" is the general consensus currently held among the scholars.

In order to understand the "insertion method," we must first clarify the process by which the inner mold was formed. The general understanding is that the inner mold was originated out of the model – after the outer molds were partitioned and removed from the model, the craftsman would trim the model down in order to reduce its size, thus leaving an inner core with smooth surface, which is the inner mold (shave off all decors or appliqués that might have been built on the model). The depth of the layer trimmed off from the model was equal to the thickness of the wall of the intended bronze (for now let's ignore the shrinkage of the inner and outer molds when baked to dry). In other words, the process of making the inner mold is simultaneously the process to destroy the model. The method of making inscription is first to engrave the text into the surface of a separate clay sheet, resulting in intaglio strokes. This sheet can be separately called the "inscription modeler". Pressing soft clay into this sheet the craftsman can instantly produce an "inscription block," that is, a block of clay sheet that bears raised character strokes of a mirror-reversed text. Finally, carefully insert this inscription block into a hollow on the inner mold that was purposely excavated in advance, thus finishing a casting core that bears raised character strokes of a mirror-reversed text. When casting, it produces intaglio strokes of a normal text on the interior surface of the wanted bronze vessel.

Although the technical detail of the workflow discussed above remains largely speculative at this point, there are strong indications that it is indeed reliable. First, among the thousands of bronze vessels (including many similar pieces that have been unearthed in sets), no any two or more vessels are exactly identical; that is, there was no such thing as mass-production, a process in which a model would be used to produce multiple sets of molds. Second, the number of mold fragments hugely exceeds that of model fragments archaeologically unearthed. For instance, as many as thirty thousand clay mold pieces were unearthed from the foundry site in Xiaomintun in Anyang in 2000-2001, but fragments that can be identified as models are fewer than one hundred, leaving a huge gap between the two (Anyang 2006). Although these are not direct testimony of the process of making the inner mold, they strongly suggest that the model was for one-time use only, and after the outer molds were removed from it, the model was necessarily modified to form the inner mold (the casting core). Therefore, models rarely survived the process of bronze casting.

Figure 4 Inscribed clay object unearthed at Xiaomintun in Anyang (2001AGH2:2).

As for the making and use of "inscription block", we actually have direct archaeological evidence. Figure 4 shows a clay block that was unearthed at Xiaomintun in Anyang in 2001. The original report identified it as the inscription block originally placed on the core for casting a bronze, but the inscription is of a normal text in intaglio lines. Then, the inscription that was cast from it must have been of a mirror-reversed text that featured raised character strokes. However, if the initial purpose was to cast the inscription in raised lines, it could be done by directly engraving the inscription on the inner mold, and there was no need to use the "insertion method." Therefore, the real function of this inscribed object still needs further studies to reveal. The two clay blocks in Figure 5, unearthed from the foundry site at Beiyao in Luoyang in 1979, show mirror-reversed texts in raised lines (Archaeological Team of Luoyang 1983); they must have been real "inscription blocks". On the other hand, because of the complexity of the "insertion method," the ancient craftsmen could not always handle the technical details well, henceforth leaving traces on the cast bronze resulted from this process. For instance, the inscription on a *gui*-tureen (JC3126), because the inscription block was placed too low, it was cast higher than the surface of the finished bronze, appearing as a dark stamp on the rubbing (Figure 6:1). On the other hand, the inscriptions of a *zun*-

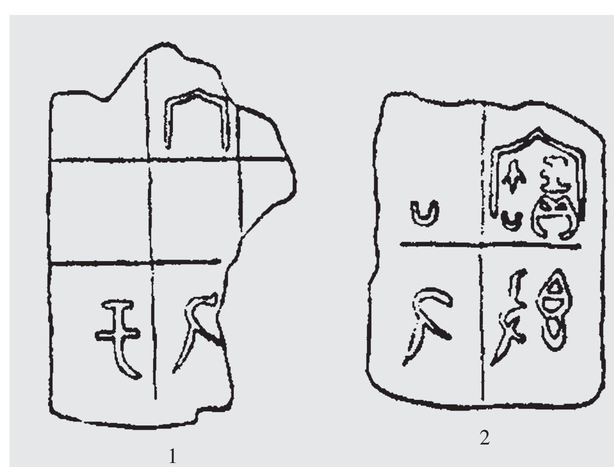

Figure 5 Inscription blocks from Western Zhou bronze foundry site at Beiyao in Luoyang.
1. H156:1; 2. T16 ④ :4.

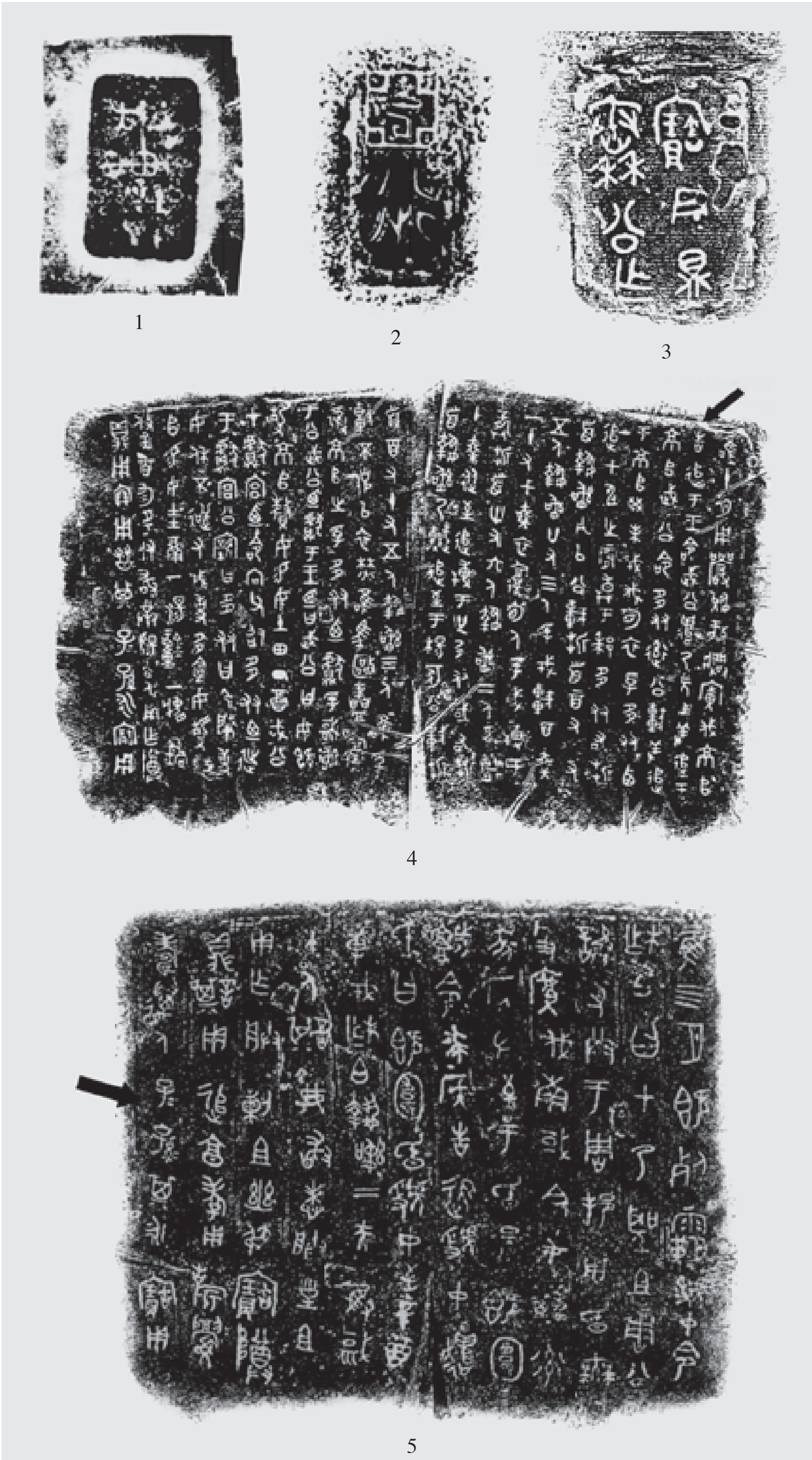

Figure 6 Indications of the use of inscription block on the surface of bronzes. 1. JC3126; 2. Qingong *Ding* no. 3; 3. JC5685; 4. Duoyou *Ding*; 5. Zhabo *Ding*.

wine vessel (JC5685) and the Qingong *Ding* no. 3 in the Shanghai Museum, because the inscription blocks were placed too high (which is more common), formed shallow dented areas on the surfaces of the finished bronzes, showing white seams on the rubbings (Figures 6:2 and 6:3).

A close examination reveals that even some long inscriptions were cast using the "insertion method". For example, a white line appears clearly above the inscription area on the rubbing of the Duoyou *Ding* (Figure 6:4). On the Zhabo *Ding*, this line appears white above the inscription, but to the left of the inscription, it turned into a black edge line (Figure 6:5, arrow), which can be easily overlooked by a casual observer. Because the inscription block was placed too low on the left side, resulting in a step raised from the surface of the finished bronze, which appears black on the rubbing. In contrast, the upper side of the inscription block was placed too high, so it was cast sunken into the surface of the finished bronze, showing a white seam on the rubbing. Among the newly discovered Shan 单 family bronzes from Meixian, six of the Forty-third Year Lai 逨 *Din*g were cast using three separate inscription blocks, while the other four were cast using a single inscription block. Most typically the inscription of no. 2 *ding* was formed by a set of three inscription blocks, the intervals between which were taken up by two irregular ridges (Figure 7). This was the result of filling the gaps between the inscription blocks with soft clay – for the difficulty of leveling the clay fills exactly with the inscription blocks on the two sides, and the infeasibility of smoothening the larger areas up without damaging the characters that already stood in relief strokes – the craftsman had no choice but to leave finger-impressed tracks between the inscription blocks, cast as ridges on the surface of the bronze.

The above examples suggest that the casting of most of the Shang and Zhou period bronzes with intaglio character strokes on their interior surfaces indeed adopted the method of inserting inscription blocks; the question can thus be solved in bronze studies. However, were all the bronzes with intaglio inscriptions on their interior surfaces from the Shang and Zhou period uniformly cast with the “insertion method”? Certainly not.

The difficulty of applying the “insertion method”

As discussed above, inscriptions that appear as intaglio lines on the exterior of bronzes (mostly on bells, but sometimes also found on the rims of *li*-cauldrons) could be done by directly engraving characters on the initial model of the intended bronze. Inscriptions that appear as relief lines on the bronzes, whether on interior or exterior, could be directly incised into the molds. There is no need for the “insertion method” in such cases. Even among inscriptions that were cast as intaglio lines on the interior surfaces of bronzes, many of them simply could not have been produced by the “insertion method.”

The famous Ling *Fangyi* (JC9901) currently collected in the Freer Gallery in Washington DC has 185 characters each on its vessel and lid. Particularly the inscription on the lid, not only was it placed on a surface that bends in the middle, but it takes up almost the entire interior surface of the lid (Figure 8). It is difficult to cast such inscription using the “insertion method” which can only be applied to flat surface. Another typical case is the Ran 䣄 *Fangding* in the collection of the Asian Art Museum of San Francisco. Each line of the inscription begins halfway on the wall of a longer side of the bronze and goes down from there, turning 90° to continue onto the bottom of the bronze (Figure 9). The inscription on the Ling *Fangzun* (JC6016), collected in the Palace Museum in Taipei, similarly starts on a side wall of the vessel; after covering its bottom, the inscription continues onto the opposite wall of the bronze. The full length of the inscription area can thus be divided into three sections with the folding lines between them leaving two white tracks on the rubbing (Figures 10 and 11). Another example is the Da *Gui* (JC4299) which has 106 characters that take up the entire interior surface of its lid. What is even more is that the inscribed surface of the lid undulates in the formation of concentric waves, and so does the inscription that rises and falls following the waves (Figure 12). These inscriptions certainly could not have been produced using the “insertion method.”

Moreover, there are many bronzes with intaglio inscriptions that were cast into grids, for instance, the Xiao Ke *Ding* (JC2797). Such grids are usually raised from the surface of the bronze but the inscriptions in them were cast sunken. Interestingly, sometimes the inscribed characters are not necessarily restricted by the grids, but can intrude the raised gridlines (Figure 13). On the Forty-second Year Lai *Ding* no. 1, we can even see that spacers were frequently placed on the crosses and regularly break the gridlines running between the characters (Figure 14). The method by which such featured inscriptions were manufactured must have been much more complex than the “insertion method,” and this matter deserves further investigation.

The phenomena analyzed above suggest that the “insertion method” can only explain the casting of rather

Figure 7 Ridges between inscription blocks on the interior wall of the Forty-third Year Lai *Ding* no. 2.

Figure 8 Inscription on the lid of the Ling *Fangyi*.

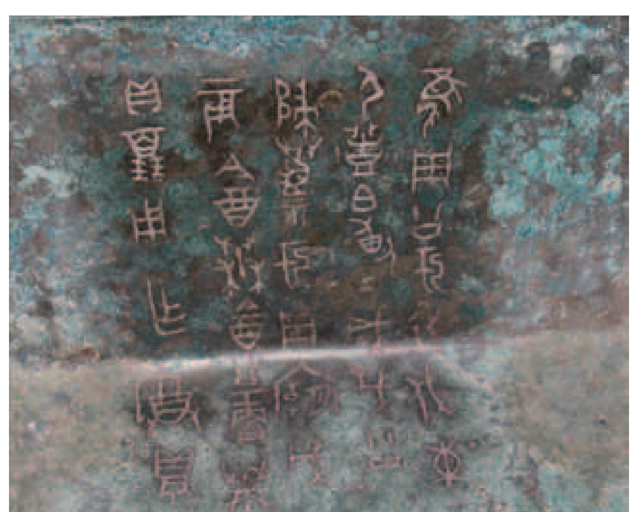

Figure 9 Inscription on the interior wall of the Ran *Fangding*.

Figure 10 Ling *Fangzun*.

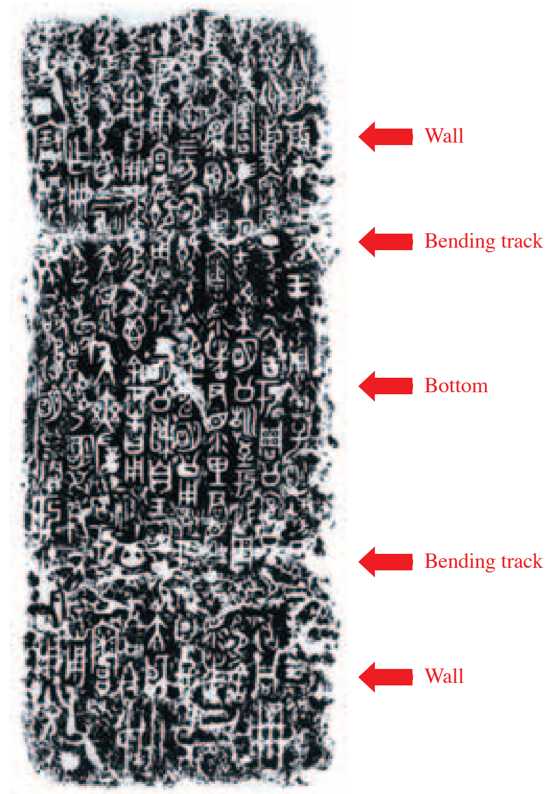

Figure 11 Inscription on the Ling *Fangzun*.

Figure 12 Inscription on the lid of the Da *Gui*.

Figure 13 Inscription on the Xiao Ke *Ding*.

ordinary inscriptions, but it cannot be used to explain inscriptions with more complex features. Therefore, scholars in the past have experimented other ways to explain the casting of inscriptions on Western Zhou bronzes. For instance, Professor Matsumaru (1990) proposed the "leather method," suggesting that at least a certain number of bronzes were cast by first carving inscriptions on thick leather, which then was pressed on soft clay that was mounted on the inner core. This way, the craftsman not only could easily produce characters raised from the surface of the core ready for casting, but he could also align the characters well over angular surfaces of the bronzes. Matsumaru's hypothesis was questioned by Kuang-Yuan Chang (1991); however, Chang himself was unable to provide another solution to the problem. In sum, this is a difficult question that has yet to be solved in bronze studies.

A new explanation about the method of casting bronze inscriptions

In order to solve this problem, we must seriously rethink the whole process through which a bronze was cast, particularly the method by which the inner mold was shaped. It can be said in general that the Western Zhou craftsmen should have worked with the material that they normally used (clay mixed with very fine sand), and by properly adjusting the workflow design they should have been able to complete complex casting assignments of various kinds. The key concept here is "Fake mold" – a fake mold is a transitional mold that was created for the purpose of producing the wanted mold, necessitated by the casting process programmed in certain ways. The reason that it is called "Fake mold" is because it is the product of the programmed casting process, but not the real mold used in casting.

In fact, in his early work Noel Barnard already raised questions about the casting method of the relief gridlines on bronzes and tried to solve them through experiment. He hypothesized first incising grids on a flat clay sheet of a proper size; when it is pressed on a second soft clay sheet it could produce relief gridlines. Carving inscriptions into the grids and impressing them onto a third clay block, the craftsmen could produce an inscription block with raised character strokes and sunken grids. Inserting this inscription block into the inner mold, the craftsman could cast inscriptions of intaglio characters in raised gridlines (Barnard and Wan 1976). Minao Hayashi pointed out that this hypothesis cannot explain the real purpose of the raised grids; in the cases of long inscriptions, it would be very difficult to manipulate the soft clay sheet to insert it on the inner core without causing damages to the characters that are raised from its surface (1979: 8–12). Hayashi's solution was to first carve grids onto a hemispherical model; when impressed with soft clay, an "inscription matrix" bearing raised gridlines can be shaped. From this clay matrix, one can further create an inner core with intaglio gridlines and raised characters

Figure 14 Inscription on the Forty-second Year Lai *Ding* no. 1 (attention to the spacers on the intersections of the gridlines).

(1979: 19-20). Hayashi's method is a step further than Barnard's, but the workflow designed by Hayashi has many problems. For instance, the initial hemispherical model was first used to produce the "inscription matrix"; then, it was reduced in size and three legs were set up on it before the making of outer molds. At the last step, decors were directly carved onto the outer molds ready for casting. This way, there is no chance to create an initial model (same as the wanted bronze), and consequently there is no chance to create the outer molds shaped by the model that bears decors. Archaeological excavation has already yielded many clay models that bear decors. They suggest that in the Shang and Zhou periods the craftsmen indeed did make the initial model, and then from this model he produced outer molds that were impressed with ornaments. The casting process reconstructed by Hayashi has internal contradictions.

Based on what we know to date about the bronze casting process, and considering also some newly discovered inscribed vessels, I have reconstructed the workflow for casting bronzes with long inscriptions in raised grids. Below, I will use the body shape of the Song *Ding* (JC2827; note that the Song *Ding* does not have raised grids) collected in the Palace Museum in Beijing as an example to demonstrate this workflow (Figure 15). If the craftsmen of the Western Zhou period could comply with this workflow design, and if they could execute accurately every step of the work, they should be able to produce bronzes with long inscriptions and raised gridlines. In short, the method of casting long inscriptions with raised gridlines has been a difficult question in bronze studies. If we can clarify this hard issue, the various complex phenomena seen on bronzes can all be subsequently solved.

Step 1: Make model. In order to cast a bronze like the Song *Ding*, an initial clay model (A) shaped exactly like the wanted Song *Ding* must be produced first. This clay model is solid, surface bearing two rings of raised

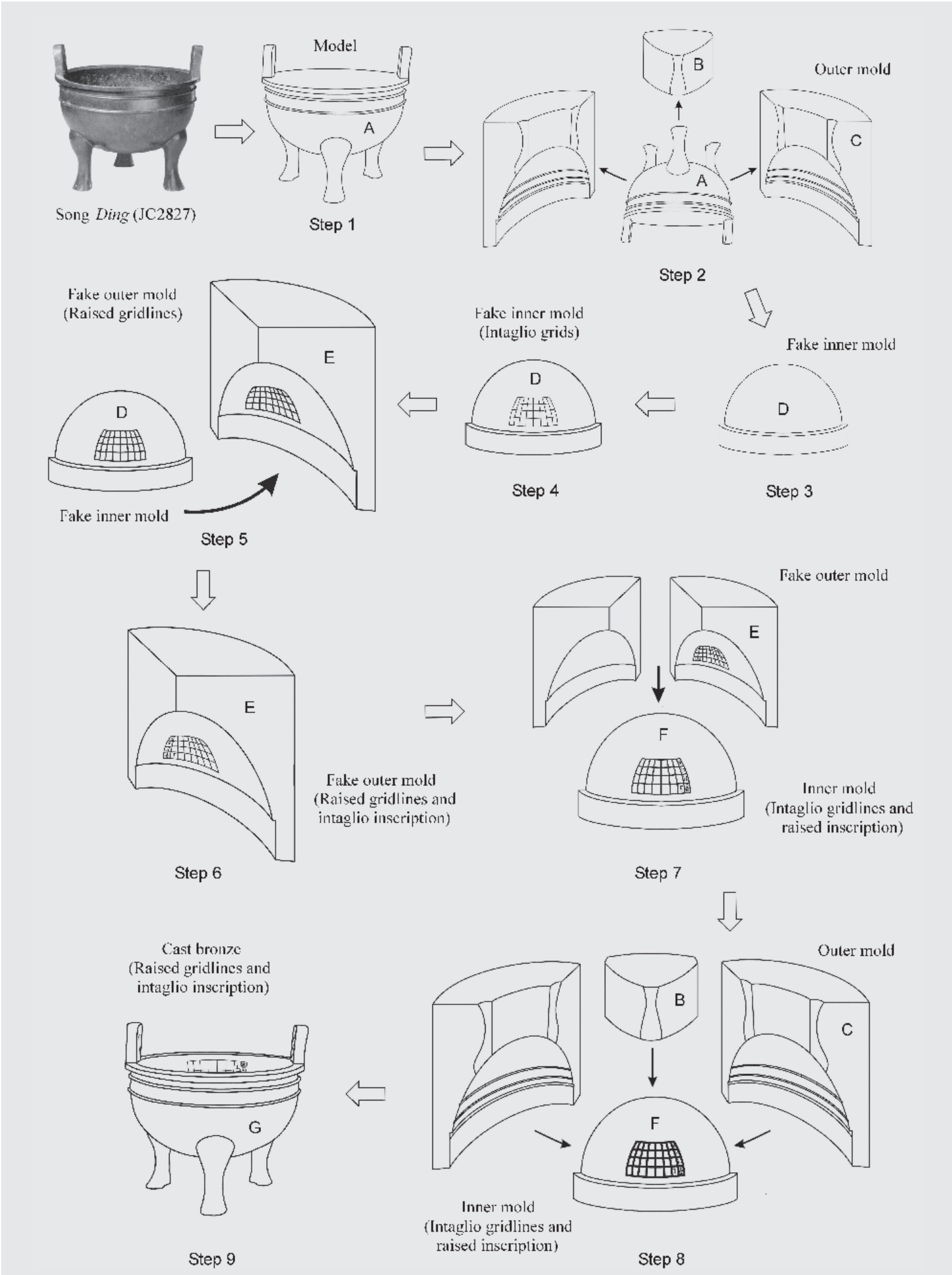

Figure 15 Workflow for casting inscriptions on Western Zhou bronzes.

bowstring designs, and is of the same size as the cast bronze. If the cast bronze has decors, they must be carved on the clay model.

Step 2: Impression of outer and bottom molds. Overturn the model *ding* in 180° . First fill the space between the three legs with soft clay and cut it along the three legs into a triangular bottom mold (B), impressed on which is the bottom curve of the *ding* (after removal, as is often the case, incise tracks on the mold to form thickening belts, the purpose of which is to strengthen the bottom of the bronze). Then apply soft clay from outside and cut and remove it to form three pieces of outer molds (C). The fine surface of the outer molds is impressed with the body curve of the model *ding* and with whatever decors that were carved on it. The outer molds also include the height of the base that would be placed under the mouth of the *ding* during casting; usually it is also the height of the *ding*'s ears.

Step 3: Make "Fake inner mold". Remove the three legs from the model *ding* to leave only a hemispherical body. Trim to reduce it to a certain depth (which is equal to the thickness of the wall of the casting), and obtain a solid hemispherical body smaller in size than the initial model. This is the "Fake inner mold" (D) that will not be used in actual casting.

Step 4: Incise gridlines. On the surface of the "Fake inner mold" incise gridlines. The purpose of the grids is to effectively overcome the curve of the inner wall of the bronze, so that the inscription text can align well in both vertical and horizontal directions over an angular surface, critical to the casting of long text inscriptions. However, some short inscriptions were also produced by this method. There are also cases where the gridlines were corrected and re-incised. For instance, the Shan Wufu 单五父 *Fanghu*-square vase among the Shan Family bronzes unearthed in Meixian, because the original gridlines were placed oblique and the lowest row of the grids was also too narrow, this led the craftsmen to re-incise the gridlines before the "Fake inner mold" was impressed to make the "Fake outer molds" on which characters were engraved (Figure 16).

Step 5: Make "Fake outer molds". Apply soft clay onto the "Fake inner mold" (D), and cut and remove it when dry. This process creates the "Fake outer molds" (E), the surface curve of which matches that of the inner surface of the wanted bronze *ding*. But it is smaller than that of the real outer molds (B+C), the gap between them being the thickness of the wall of the cast *ding* ("Fake outer molds" are similar to the "core box" used to shape the sand core in modern industrial casting). The "Fake outer molds" bear grids, but they are formed by lines that are raised from the surface of the molds.

Step 6: Engrave characters. Engrave characters into the grids of the "Fake outer molds (E)", which would then bear intaglio inscription and raised gridlines. Because the characters were carved later than the grids, sometimes they could break the gridlines or a single character could take up two grids.

Figure 16 Inscription on the Shan Wufu *Fanghu*-square vase with gridlines corrected.

Step 7: Make the inner mold. Assemble the "Fake outer molds" and turn them over (which should have 3-4 pieces) to form a hemispherical space with a round bottom. Fill soft clay into this space to form the real inner mold (F) which is similar to the "Fake inner mold," but now bears raised characters and intaglio gridlines.

Step 8: Assemble the molds for real casting. Set up the real outer molds (B+C) around the real inner mold (F), matching the joints between them and readying them for casting. In order to effectively distance the outer molds from the inner mold, for otherwise this could lead to holes on the casting if the two touched each other, at this point spacers would be applied. In the inscription area, the spacers are usually placed between the lines of the inscription, forming regular distribution patterns. The latter phenomenon has been considered criterion for authenticating ancient bronzes (Matsumaru 1980). However, the spaces between characters are also the areas where the gridlines run, and this leads to the situation that spaces are purposely placed on the crosses of the gridlines as on the Forty-second Year Lai *Ding* no. 1 (Figure 14). Because the gridlines are intaglio lines on the mold, the spacers could be conveniently placed at their crosses, and would break the gridlines when cast. But sometimes there could be a situation that the raised gridlines continue onto the surface of the spacers on the cast bronze.

Step 9: Casting. Pour the bronze liquid into the molds and cast a bronze which bears raised gridlines and intaglio characters.

The workflow described above needs to be verified by archaeology in the future, through especially the identification of "Fake inner mold" and "Fake outer molds" among the remains from bronze foundry sites of the Western Zhou period, or by the discovery of more clay inscription blocks. However, even on bronzes that we currently have, the careful observer can still recover

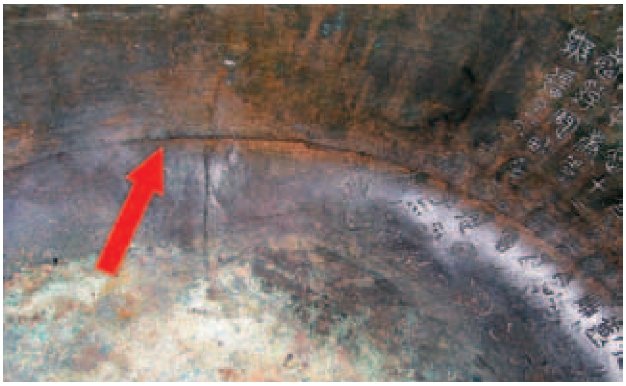

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Figure 17 Extension of gridlines from the lower-left corner of the inscription on the Forty-second Year Lai *Ding* no. 1.
1. Reference line; 2. Gridlines.

some important clues. For example, on the Forty-second Year Lai *Ding* no. 1, the raised gridlines extend far beyond the inscription area from its lower-left corner and were executed in a very disordered fashion (Figure 17:2). Slightly above it, a single raised gridline goes so far as to make a complete circle near the bottom of the *ding*-tripod. Judging from its strong and very smooth track raised from the surface of the bronze, it is impossible that it be a natural crack that might have occurred on the inner mold during casting, but is the extension of perhaps a special gridline that makes up the grids (Figure 17:1). I suspect that this was the reference line that was incised in order to determine the accurate orientation of the grids that were subsequently engraved. Thanks to the existence of this reference line, other horizontal gridlines can run in exact parallel, altogether paralleling the rim circle of the *ding*-tripod. Furthermore, because it is intruded by the characters of the inscription, similar to other gridlines on the same bronze, there seems little doubt that it was created in or even before the step in which the grids were incised, and had been maintained throughout the casting process, showing up clearly on the inner surface of the finished bronze. The existence of this reference line proves the existence of a complete "Fake inner mold (D; instead of a clay inscription block)"; it also confirms that our reconstruction of the workflow discussed above is largely accurate. The inner mold that bore raised inscription in use for casting the Forty-second Year Lai *Ding* no. 1 must have been created from the "Fake outer mold (E)" which was in turn shaped by the "Fake inner mold" that bore the reference line and the grids; therefore, the finished bronze also bears this reference line.

Of course the application of the above workflow design was not restricted to casting long inscriptions with raised gridlines. In a simplified way, it could also be used to cast inscriptions like those on the Ling *Fangzun* or the Da *Gui* that occupy a large area of the bronze surface but were cast with no grids. Even in the case of casting inscriptions in gridlines, as a modification of the work design, the craftsmen could simply produce an inscription block from the "Fake outer molds" and insert this block back onto the "Fake inner mold (D)" used directly for casting. One half of the long inscription on the famous Da Ke *Ding* (JC2836), currently collected in the Shanghai Museum, was produced precisely by this method.

Explaining a few special inscriptions

There are also some other complex phenomena that occur in bronzes inscriptions and puzzled scholars past and present, leading to misunderstandings. These problems must be clarified now.

The first case is the Chugong Jia 楚公冢 Bell, unearthed in 1998 from cache 98 no. 5 at Shaochen Village in Zhouyuan, dating to the late Western Zhou period (Luo 1999). It is a bronze bell cast in the Chu State in the south, bearing a total of 16 characters in two columns, but for some unknown reason it was found in the Zhou core area (Figure 18:1). Different from other bells (include the four Chugong Jia Bells in traditional collections, JC0042-0045), this bell shows a ridge (which is indeed the casting seam) running at the middle of its central *zheng* panel, and the characters are distributed on the two sides of the central ridge. In other words, the characters were located on two separate outer molds before casting. 15 of the 16 characters are of intaglio lines, but the last character *yong*

1 2 3

Figure 18 Re-engraved inscriptions on Western Zhou bronzes.
1–2. Chugong Jia Bell; 3. Guoji *Gui*.

用 is raised from the surface. A closer look reveals also slightly raised gridlines that are more visible along the left column of the characters; on the right they are visible only in the areas around the last character (Figure 18:2). The phenomenon we see on the Chugong Jia Bell on which relief and intaglio characters coexist, coupled by the use of raised gridlines, is very rare among inscriptions on bells. In general, bell inscriptions were directly incised on the bell model, and some long inscriptions continue from the central *zheng* panel onto the two edges of the bell. When molds were detached from the model, inscriptions of raised and mirror-reversed characters were produced, which then would then revert to intaglio characters on the finished bell. Based on the above new understanding of the method for casting long inscriptions with raised gridlines, we can reconstruct the process by which the Chugong Jia Bell was cast as below:

First, apply soft clay to the bell model and cut and detach after dry to form the molds, each side having two pieces split in the center of the *zheng* panel. Then, incise gridlines that can contain two lines of characters onto the *zheng* of the bell model, and take impressions from it with a first clay block which would come to bear raised gridlines, into which characters were carved. Press and detach clay from it to form a second clay block which would bear raised characters and intaglio gridlines. Finally cut this block in half and insert the two halves into the two front molds along their opposing edges. This way the finished Chugong Jia Bell would necessarily bear intaglio characters in raised grids. But, perhaps because the craftsmen forgot to carve the last character *yong* when he engraved other characters onto the first clay sheet, or perhaps because the very character was damaged in the process when the second clay sheet(s) bearing raised characters were inserted into the outer molds, the craftsman simply carved the character directly on the block that was already inserted into the molds. When cast, it became the only raised character in the entire inscription. Incidentally the similar situation is found on the Guoji 虢季 *Gui*-tureen (M2001:86) unearthed in the cemetery of the Guo State in Sanmenxia (Henan Provincial 1999). On this *gui*-tureen, seven characters were cast between three raised lines. Although they are intaglio characters in main, for instance, the upper part of the character *ji* 季 , the two strokes of *yǒng* 永 , and most part of the character *yòng* 用 are all in raised lines (Figure 18:3). All of these were produced at the last step of the workflow and were results of makeup carving.

Another example is the Da Ke *Ding* in the Shanghai Museum (JC2836), which bears what Noel Barnard once called the “skeleton line graphs” (Figure 19, see Barnard and Cheung 2000). The long inscription on the Da Ke *Ding* was divided in two parts, the one on the right being cast into grids and showing also the seam lines of the inscription block. Undoubtedly it was a product of the “insertion method”. However, underneath the characters are hidden some other characters in raised lines. For instance, under the character *sheng* 聖 is found the raised character *wang* 王 ; under *zai* 在 is another character *zai* 在 ; under *jing* 巠 is the character *xiao* 孝 (Figure 20). This phenomenon has puzzled past scholars, and it can be well explained in the context of the workflow reconstructed above – such should be characters that were engraved together with the grids on the “Fake inner mold (D)” in Step 4, for the purpose of reminding the craftsmen of what characters should be engraved in these grids in a future step. For unknown reasons the engraver in the later step (Step 6) did not follow the original plan to carve

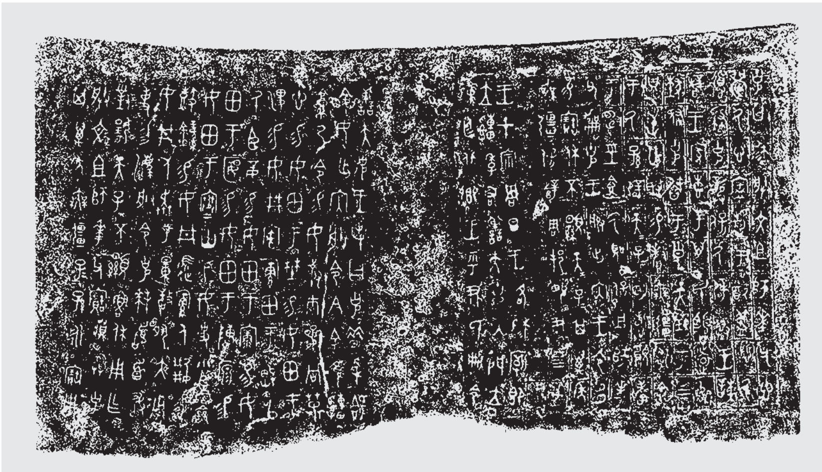

Figure 19 Inscription on the Da Ke *Ding*.

Figure 20 “Skeleton line graphs” on the Da Ke *Ding*.

these characters, but instead he carved a new text, hence giving rise to this unusual phenomenon that intaglio characters overlap raised characters.

In recent years, from the standpoint of casting technology of inscriptions, the most important discovery is the Jing Shi Xun 京师畯 *Zun* that was reported by Xueqin Li in his article (2010). The inscription is composed of 26 characters in six columns, which are separated from each other by vertical raised gridlines (Figure 21), similar to the guidelines found on the Guoji *Gui* mentioned above. However, this inscription is composed of neither intaglio characters nor raised characters; instead, it is composed of intaglio characters the strokes of which are demarcated with raised profile lines. Similar inscriptions have been known in the past, dating mostly to the late Shang and the early Western Zhou periods, but such a long inscription composed of raised profile lines is really rare. It must have been produced using a method significantly different from that which produced inscriptions composed merely of raised profile lines (Figure 2:4), which were carved directly on the inner mold. Hayashi once collected examples of such inscriptions and considered that they were resulted from a process in which the impressed raised characters were re-carved into intaglio lines (1979:23–36). This was a reasonable explanation. Putting it into the workflow proposed in the present paper, the method by which it was produced is as follows: First, carve intaglio profile lines into the intaglio guidelines on the “Fake inner mold” in Step 4. Then, in Step 5, on the “Fake outer molds (E)” it became raised profiles lines after impressed. Finally, in Step 6, the engraver carved the interior of the strokes down along the profile lines, and this created intaglio characters edged by the raised profile lines. Carefully examining the rubbing of the Jing Shi Xun *Zun*, one can discover that the profile lines are very clear in some areas but are less clear in others, or the profile lines on one side of the stroke is not clear. This is precisely the result of re-carving; that is, in the process of re-carving some of the profile lines were trimmed off. There are also characters, for instance, in the lower part of the character *han* in the first line, or the character *gong* at the end of the second line, the intaglio strokes are blocked out by the raised profile lines. These are indeed the places where the second engraver loyally followed the strokes produced by the first engraver, as he truthfully left out the stroke overlaps in raised lines created by the first engraver.

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Figure 21 Inscription on the Jing Shi Xun *Zun*.

Postscript

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