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Sparks of Inquiry: Two Key Debates on Early Metalworking in China

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ABSTRACT

The origins of metalworking in Bronze Age China have long been a subject of interdisciplinary inquiry, drawing the attention of scholars in art history, archaeology, and the history of technology. This scholarly focus has developed against the backdrop of Southwest Asia's traditionally recognized (though debated) status as the primary metallurgical center of the Old World, where sheet-metal techniques such as hammering (forging) and annealing constituted foundational elements of its early metalworking traditions. Rather than reducing the distinctions between section-mold casting in early China and lost-wax casting in the broader ancient "West" (e.g., Southwest Asia and Europe) to a simplistic dichotomy, it is essential to emphasize that the early Chinese bronze industry was defined by its pronounced reliance on casting. Although lost-wax casting eventually appeared in early China, its verified use in the archaeological record postdates and remains far less prevalent than the region's long-established tradition of section-mold casting. The scarcity of archaeological attestations for lost-wax casting has thus fueled ongoing academic debate—not only concerning its technical application but, more fundamentally, its very existence as a distinct metalworking practice in pre-Han periods (prior to 202 BC). The debates over lost-wax casting and sheet-metal working in early China are closely tied to broader questions about the technological foundations of Bronze Age metalworking in the region. This paper critically engages with these debates, situating them within their wider historiographical context while evaluating their implications for current understandings of prehistoric metallurgical innovation and the emergence of Bronze Age society in China.

Keywords: Chinese Bronze Age; Metalworking; Origins; Lost-wax Casting; Sheet-Metal Techniques.

INTRODUCTION

"What is lost in universality will be gained in concreteness and specificity. Multilinear evolution, therefore, has no a priori scheme or laws."

Julian H. Steward (1955), p. 19

"In the ancient West, from Iran to Erin's Isle, we recognize a reasonably uniform sequence and analogous rhythms of technological events. It is from just such facts that the diffusionist theory draws its strongest proof. But any inclination we may feel to regard the Western development as more or less determined in the order of nature is discouraged by what we see in China."

William Watson (1971), p. 67

Julian H. Steward, in his influential theory of multilinear evolution, posits that cultural change does not conform to a predetermined schema or universal laws (Steward, 1955). In his understanding—and I concur—the pursuit of overarching patterns or unilinear sequences risks obscuring the intricate depth and specificity

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embedded in local knowledge systems and technological practices. Such a comprehension underscores the necessity of situating technological development within its distinct cultural and historical contexts. For a global technology like metallurgy, which encompasses metalworking as one of its key aspects in my discussion, the intertwined processes of transmission and adaptation—operating in tandem with evolutionary mechanisms—are pivotal to its global dissemination. More specifically, within the context of the Bronze Age Old World, these processes underpin what might be termed "(Afro-)Eurasianization." William Watson (1971, p. 67) highlights the relatively uniform sequence of technological developments observed in the ancient "West," from Iran to Ireland. He contends that this uniformity offers significant support for the diffusionist theory; however, he acknowledges that this perspective encounters formidable difficulties when confronted with the evidence from China (Figure 1 for the names of the provinces in the country). For instance, in the Chinese context, the marked emphasis on casting techniques—contrasting with the sheet-metal methods predominant in the West—presents a challenge, though not an outright refutation, to diffusionist frameworks and unilinear or universal evolutionist models, which posit a deterministic progression of technological development "in the order of nature" (Watson, 1971, p. 67). Notably, Watson seems to conflate diffusionary and evolutionary functions in his statement cited above, despite the theoretical compatibility between diffusionism and unilinear or universal evolutionism. It is crucial to acknowledge that technocultural homogenization can arise from diffusion processes, convergent evolution, or a combination of both. Therefore, whenever the opportunity arises, the conceptual framework employed in this paper seeks to transcend overly reductionist evolutionist and diffusionist paradigms. Nonetheless, Watson's point compels us to reconsider this complexity, necessitating a more nuanced examination of how diverse cultural practices shape technological trajectories across different contexts. It also calls for a specific inquiry into the case of early China, particularly concerning its Bronze Age development of metalworking. Central to this investigation is the question of whether bronze technology in China emerged from independent invention or derived from Western diffusion or stimulus. This paper offers a critical interdisciplinary analysis of two well-known debates surrounding this question, drawing on perspectives from art history, archaeology, and the history of technology to forge new insights into the metallurgical endeavors of Bronze Age China.

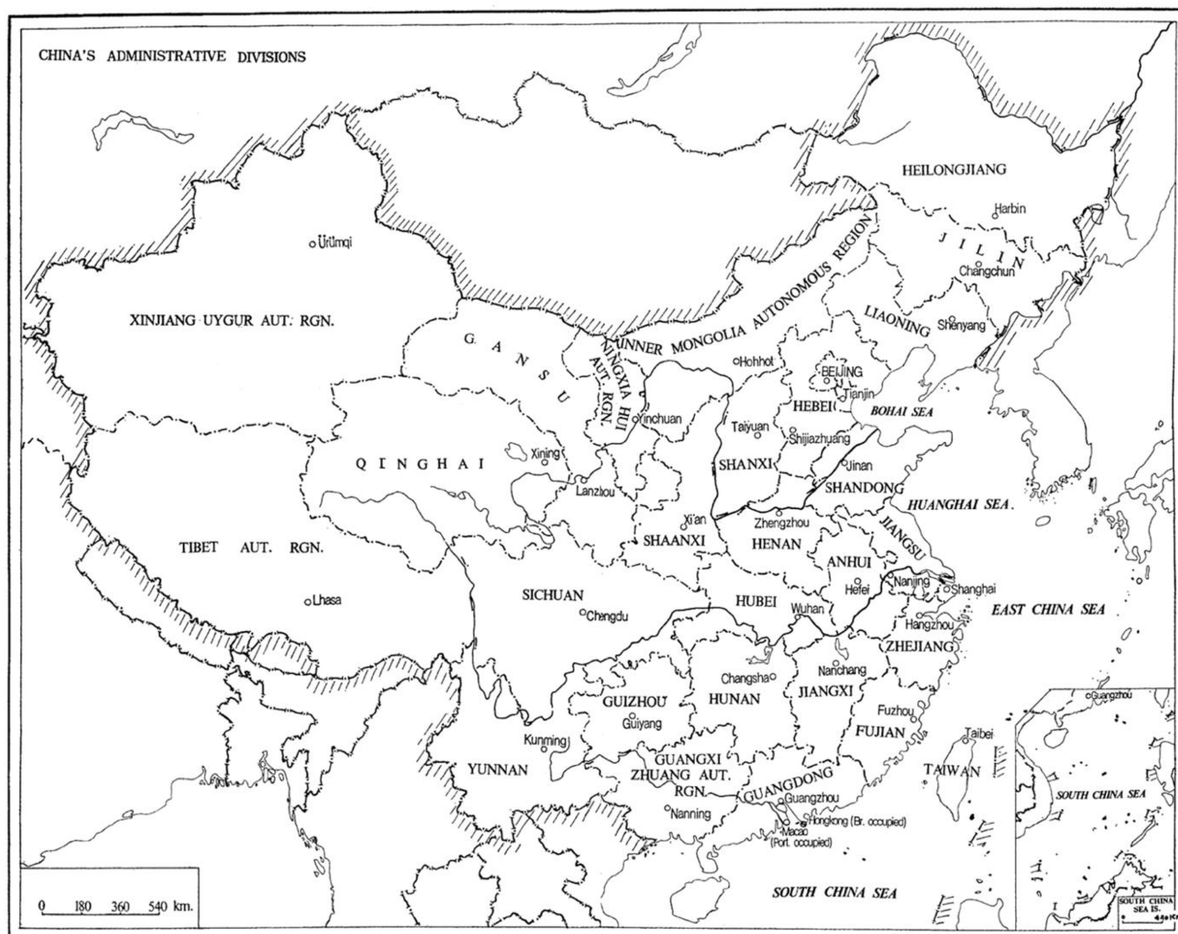

Figure 1. Map of China, around 1980, marking the names of provinces and certain geographical features (e.g., the Yellow River, which flows into the Bohai Sea, and the Yangzi River, which flows into the East China Sea). After Fong, ed., 1980, front flyleaf.

CRITICAL REVIEW AND DISCUSSION

The Lost-wax Debate

For many years, it was widely assumed that pre-Han 漢 (prior to 202 BC) Chinese ritual bronzes were generally fabricated by lost wax (e.g., Bushell, 1904, p. 61; Yetts, 1927, pp. 90-92), the most familiar form of investment casting (for discussions of the lost-wax process, see Hemingway, 2000, pp. 37-46; Mattusch, 1988, pp. 10-30; Mattusch, 1996, pp. 1-34). The schematic drawing in Figure 2 represents one of the straightforward forms of the lost-wax process. Lost wax in a similarly "direct" scheme was recorded by the thirteenth-century text *Dongtian Qingluji* 洞天清祿集 ("Compilation of Pure Earnings from the Cave Heaven," see Zhao, 1968) as the method for casting more "archaic" bronzes (Hua, 1985, p. 54; Zhou & Huang, 2015, p. 1630). During the late Imperial period (1368–1911 AD), lost wax was used to imitate or counterfeit the metalwork of Bronze Age China, a practice that extends to the modern era. With a permanent section-mold set in replicating the original design in wax, the so-called "indirect" lost-wax process could facilitate the serial production of wax models. Illustrated in Figure 3 in its typical scheme today, indirect lost wax used to be variously customized in pre-modern and modern China, and its Chinese use can be traced back considerably earlier. From the present-day perspective, lost wax is the most convenient way to reproduce the bronzes of early China. But would the choice of that process—or rather, processes—have seemed natural or even possible to the original producers of these early bronzes?

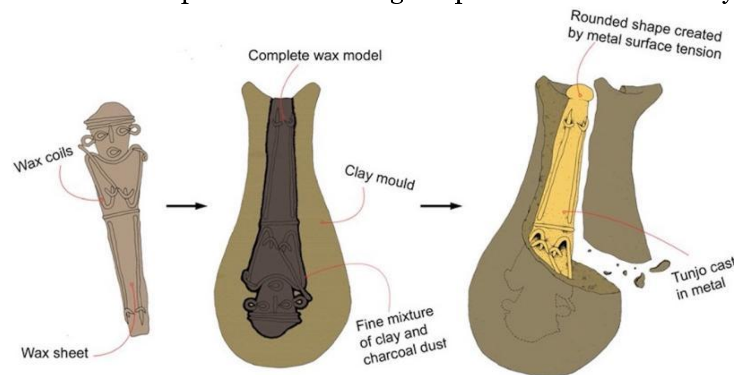

Figure 2. The direct lost-wax process in one of its simplest forms. Schematic drawing of the main steps in the manufacture of a South American tunjo: founders first shaped a wax model of that small figure (left). Clay, along with essential additives, was invested all around the model, and in this way an "investment mold" was built (middle). The wax was melted out of the baked mold, and the molten metal thereafter filled the cavity left by the wax; once the metal had gone hard, the roughcast product could have been brought to light (right). After Martinón-Torres & Uribe-Villegas, 2015, p. 379, Figure 1.

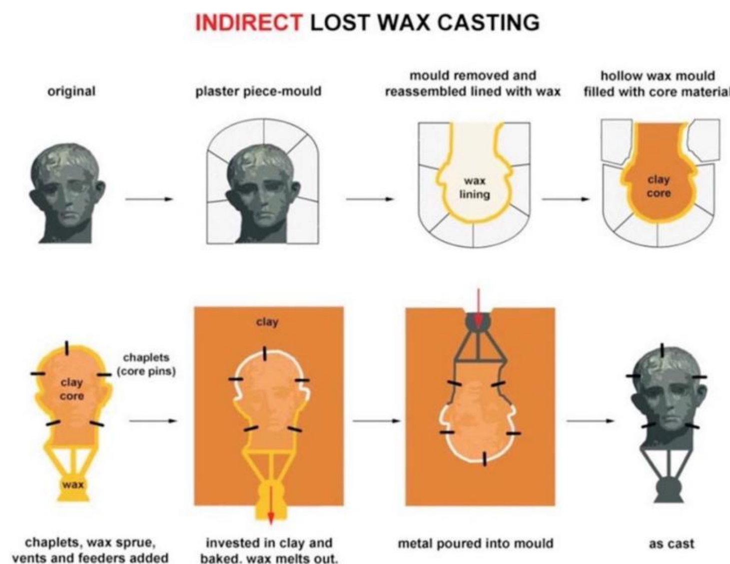

Figure 3. The indirect lost-wax process in one of its typical schemes today. The application of permanent sectional molds (the "master mold") could facilitate serial production of wax models. After Craddock, 2015, p. 73, Figure 23b (drawing by S. La Niece & A. Simpson © the British Museum).

The pre-1930s students of early Chinese bronzes, perhaps affected by anachronistic records in the received

texts and ethnography, believed almost without exception that the answer was "yes." As Stephen Bushell claimed, "Chinese bronzes have always, as far back as we have any record, been executed by the *cire perdue* [lost wax] process, and finished, when necessary, with the hammer, burin, and chisel" (Bushell, 1904, p. 61). Some scholars, though noting the section-mold cast marks on early Chinese bronzes, explained them away as part of the indirect lost wax process. For example, W. Perceval Yetts contended that the fitting of mold sections caused linear ridges in the wax model and finally on the cast metal, which he problematically called "seams" (Yetts, 1929, pp. 35-38; Yetts, 1935, p. 473).[1] In his crucial research on Anyang 安陽 foundry debris, Karlbeck (1935) argued that the sectional or multipiece molds there were used for the casting of bronzes, rather than the construction of wax models, as he observed scorch marks and occasional metal vestiges, as well as mortises and tenons from excavated mold fragment.[2] The possibility that the section-mold process had been used to cast Late Shang (i.e., the Anyang period, ca. 1200–ca. 1050 BC, with some scholars suggesting an earlier inception point in the thirteenth century BC) bronzes, raised earlier by Li Ji 李濟 (formerly romanized as Li Chi; see Li, 1931, p. 476), was thereby justified by Karlbeck (1935) with better empirical grounds and more cogent technical logic. Applying the section-mold theory that has developed since Li and Karlbeck proposed it, we can attempt to speculate about how a *ding* a couple of centuries earlier than Anyang may have been made (Figure 4, in the period of Erligang二里崗, sixteenth to fourteenth century BC). Though not among the weightiest pieces in the Chinese Bronze Age—it is far lighter than the Anyang Houmuwu后母戊 *ding*鼎 (currently weighing nearly 833 kilograms, Figure 5), for example—this ritual vessel was probably cast upside down, underpinned by the bulky clay core at the bottom. Before that, wet clay was compressed around the model with a desired form, dry-hardened, and peeled off in three fitted sections. Assisted by mortises and tenons, these mold pieces were thereafter rejoined around the core, ready to receive the pour of bronze. In the casting stage, the maker would have aimed to maintain an appropriate mold-core distance (e.g., by metal spacers) to achieve a consistent thickness of the vessel wall (cf. Bagley, 1990, pp. 9-10; Bagley, 2009, p. 44).

Figure 4. Bronze *ding*鼎 (H. 54 cm) in the Erligang二里崗 style (ca. 1400 BC) from Hubei Panlongcheng湖北盤龍城, cast by the section-mold process: clay core (1), clay mold sections (2), and completed bronze (3). After Fong, ed., 1980, p. 85, plate 5, and p. 72, Figure 16.

[1] For details about why Yetts's term (still popular with many scholars, especially those arguing against lost-wax use in Bronze Age China) is problematic, see Gettens, 1969, p. 23, pp. 60-67; Peng, 2023, pp. 7-9.

[2] This clearly dismissed the indirect lost-wax theory proposed by Yetts and his followers (e.g., Herrlee Creel, Herbert Maryon, and Harold Plenderleith). Though Karlbeck himself did not totally discard the direct lost-wax theory, he considered it "extremely unlikely." Karlbeck attested beyond doubt that Anyang bronzes were cast within mold pieces that fit well. It is hard to conceive of any reason for the investment mold to carry the mortises and tenons that Karlbeck clearly recognized. See Karlbeck, 1935, pp. 42-46; Creel, 1935, pp. 68-69; Maryon and Plenderleith, 1954, pp. 628-630.

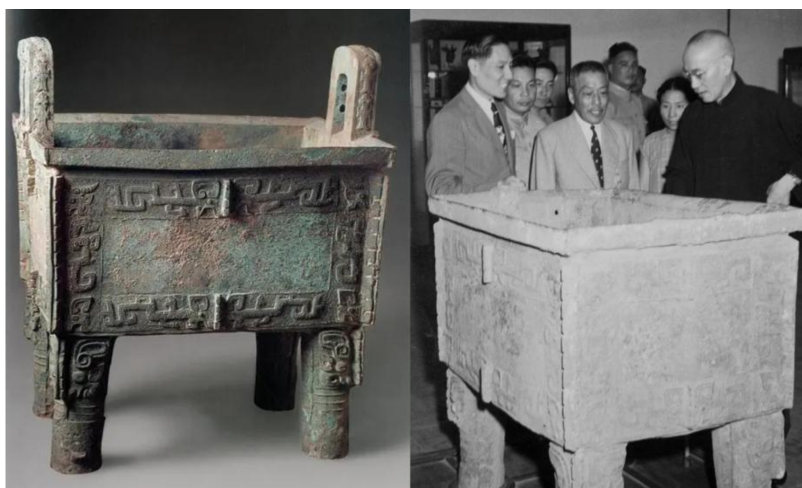

Figure 5. The Houmuwu *ding* (后母戊鼎; alternatively known as the Simuwu *ding* 司母戊鼎), a monumental ritual bronze vessel from Anyang (H. 133 cm; W. 832.84 kg; ca. 1200 BC), is shown in this historical photograph with Chiang Kai-shek (蔣介石, the balding figure) providing human scale. While imposing in its present condition, the vessel would have been even more massive originally, before three millennia of surface oxidation and corrosion. These images, made available through the courtesy of Amypaper, Meidosensei, and the National Museum of China, are sourced from: https://en.m.wikipedia.org/wiki/File:Houmuwu_Ding_or_Simuwu_Ding.jpg (accessed 16/09/2023); https://en.wikipedia.org/wiki/Houmuwu_ding#/media/File:Chiang_and_HouMuWu_Ding.jpg (accessed 16/09/2023).

Instead of working directly on hard metal, Central Plains participants in the early Chinese bronze industry (e.g., Erlitou二里頭, newly dated to ca. 1750–ca. 1520 BC, as well as Erligang and Anyang) were preoccupied with casting. In this respect, they differed significantly from metalworkers in the rest of Eurasia, such as Southwest Asia, the traditionally assumed primary center of Old-World metallurgy. The Anyang excavations starting in 1928 offered invaluable information on early Chinese foundry practices. In the following decades, researchers gradually reached a consensus that the use of lost wax was almost negligible in early China, whereas numerous Bronze Age metals were cast using the section-mold process. Similar to Wertime (1964, pp. 1257-1260), many scholars today still consider lost wax (Figures 2 and 3) the ultimate way of casting, or the standard of fine casting. To them, it was curious that the Chinese had used "backward" techniques (i.e., with sectional molds) to cast sophisticated bronzes (Figure 4). A few of them, such as Watson (1961), argued that lost wax was transmitted to China as early as metallurgy itself, only that its application had gone unnoticed.[3] More scholars, following Noel Barnard (1961), used this discovery to claim that Chinese metallurgy had arisen independently, free from any outside influence: the preservation of the "wrong" methods could not be understandable, it was argued, if the Chinese had learnt lost wax from outside.[4]

Up to that point, the lost-wax controversy had been entangled with the origins debate on Chinese metal technology that started notably with the renowned Karlgren-Loehr contention (Karlgren, 1945, pp. 112-144; Loehr, 1951, pp. 135-137). Barnard used to be confident about the utter nonexistence of lost wax throughout Bronze Age

[3] "It is very likely that the wax technique, so long known in the West, was conveyed to China along with the knowledge of metallurgy itself," wrote William Watson in 1961. Though his arguments on "Shang" (Anyang and earlier) lost wax is not based on evidence that is now widely acknowledged, Watson did affirm Orval Kalbeck's 1935 observation of Anyang sectional molds in casting bronzes directly: "This [Kalbeck's] argument appears to be conclusive, surprising as it is that the perfect, minute detail of the ornament of the bronze vessels could be produced by this means." Perhaps in Watson's mind, lost wax was not a technique that would necessarily revolutionize casting in every category, and "its use at Anyang may have been overlooked," a conjecture with no firm proof but worth exploring. Yet, like many scholars, Watson throughout his career seems to have taken lost wax as a synonym for fine casting: "*Cire perdue* casting was known in Western Asia by the early 3rd millennium BC. It spread to temperate Europe in the middle bronze age, and there, as in the Mediterranean civilizations, wax-casting became the method for all elaborate and artistically sophisticated work." See Karlbeck, 1935, pp. 39-60; Watson, 1961, pp. 79-80; Watson, 1971, pp. 76-77.

[4] For example, Noel Barnard used to be curious about why the Chinese kept casting impressive metalwork by the "direct casting into piece-moulds," since to him, "the 'finest castings' were achieved by means of the cire-perdue [lost-wax] process"; observing the "universal use of piece-mould systems up to Han times" with no revolutionary use of lost-wax, Barnard proclaimed that "bronze casting was almost certainly an art independently discovered in China." See Barnard, 1961, pp. 108-109. For related opinions, see Mitsukuni, 1954, pp. 5-8; Ho, 1975, pp. 75.

China: to him, there was no sign of the pre-Han section-mold tradition ever having been changed or even challenged by lost wax, a technique that in his view ought to have revolutionized the casting practice (Barnard, 1961, p. 105 & 108). That confidence must have been shattered by the unearthing of the *zun-pan* set from the tomb of Marquis Yi of Zeng (d. 433 BC) in the late 1970s and the follow-up discoveries of even earlier lost-wax castings in Eastern Zhou China (770–256 BC).[5] Since the early 2000s, surprisingly, Barnard's old view has been revived in Chinese academia (e.g., Wang, 2002; Zhou et al., 2006, 2009; Dong et al., 2008; Wang & Wang, 2014; Zhou & Huang, 2015), quickly attracting Western responses (e.g., Notis & Wang, 2017; Strahan, 2019; D. Xu, 2021). The tide of this view, which is still surging in both China and the West, is forceful but not unstoppable. In fact, the opinions that have emerged from it have been challenged by various scholars (e.g., Zhao, 2006; Zhang, 2007; Li et al., 2007; Hua, 2010) and recently subjected to systematic criticism (Peng, 2020, 2023). Now it is time to walk out of the doubting-lost-wax era and into the study of Bronze Age China, so "researchers can finally put aside previous disputes and move forward to more culturally significant questions" (S. Liu, 2022, p. 179). The verification of lost wax with its indicatively limited use, in a general sense, demonstrates that the arrival of that technique is not always earthshattering to metal casting. In the specific case of early China, it thoroughly disproves logically inadequate reasoning such as the following: if the Chinese had learnt about lost wax, they would have tossed out their lumbering methods, so they cannot have been aware of it and hence cannot have had any external connection in developing its metallurgy (cf. arguments with a comparable underlying rationale in Barnard, 1963; Barnard & Tamotsu, 1975).

The attempt to use the purported Chinese neglect of lost wax to claim an indigenous origin for metallurgy[6] has undoubtedly failed. Yet that failure does not mean that metallurgy was *not* locally initiated in China; it says nothing one way or the other. The professed dualism in casting—sectional molds in China versus lost wax in the West—is nearly an academic cliché (e.g., see Zhou et al., 2007, p. 42),[7] but is it in touch with reality? Admittedly, in the western (and potentially southern) spheres of Eurasia, lost wax can be traced back to the first half of the fourth millennium BC, perhaps even earlier, as evidenced by the considerable copper alloy castings from the Levantine hoard of Nahal Mishmar (Figure 6),[8] among others.[9] However, against the narrative of sectional molds by Barnard ("prior to 1500 B.C., Western achievements in direct casting in piece-mould assemblies were rudimentary in the extreme," in Barnard, 1963, p. 227),[10] we have a better-grounded alternative: the time when the section-mold process was first being mastered by the Chinese, it had long reached sophistication in Southwest Asia; otherwise it would not have been used for royal castings during the First Dynasty of Ur (ca. 2600 BC).[11]

[5] Later Barnard changed his mind and became interested in the route and agency for the transmission of lost wax and other methods of investment casting to Eastern Zhou China (770–256 BC). See Barnard, 1996, pp. 1-94.

[6] In Barnard's generation, this way of thinking was also popular among Chinese-born scholars. For example, in a 1971 letter to He Bingdi 何炳棣 (Ho Ping-ti), Zheng Dekun鄭德坤 (Cheng Te-k'un) averred, "The complete absence of smithy methods, cire-perdue [lost-wax], and even so elementary a technique as annealing can only mean that the Shang bronze work had indigenous origins." See Ho, 1975, p. 203.

[7] In numerous other essays one can find this oversimplified and essentially misleading belief, which is either directly expressed or, more frequently, internalized as part of the logic underpinning the arguments.

[8] Among the 429 objects discovered from Nahal Mishmar ("Cave of the Treasure"), 416 pieces are in metal, involving crowns, wand-like standards, and massed mace heads. Most of the casting surfaces were carefully polished, making it hard to determine the method of manufacture; the only unpolished mace head, for example, carries no sectional or piece-mold cast marks but a diagnostic trace left by the "sprue," vindicating the use of lost wax, which is also indicated by some compellingly intricate shapes from the cache (e.g., Figure 6: left). See Bar-Adon, ed., 1980, p. 116; Lapérouse, 2016, p. 3188.

[9] For a comprehensive but somewhat outdated (especially in terms of dating) review of early lost-wax global history, see Hunt, 1980, pp. 63-79. For more recent proposals of early Eurasian lost-wax castings, some regrettably requiring further discernment, see Mille, Bessenval, and Bourgarit, 2004, pp. 264-271; Bourgarit and Mille, 2007, pp. 54-60; Weeks, 2008, pp. 335-345; Davey, 2009, pp. 147-154. The reader is advised to be cautious of certain rash judgments in the last thesis (for a critique of one of them, see Peng, 2020, pp. 150-151).

[10] Asserting that *cire-perdue* or lost wax casting was introduced to China sometime between 200 BC and 600 AD, Barnard emphasized sectional molds as the exclusive way of shaping all previous Chinese castings, in stark contrast to the "Western" cases: for instance, the "sectional mould casting" was in "restricted use" in Mesopotamia, Barnard proclaimed, whereas "in the Chinese scene it was a case of Hobson's choice." See Barnard, 1961, pp. 108-109; Barnard, 1990, p. 278.

[11] At Ur, for example, the "three- or four-pieced moulds were in regular use," an application with no intervention of wax; though two experts conjectured that those Ur objects "cast in piece-moulds" (e.g., "a little gold monkey surmounting a bronze pin [PG 755]," "the electrum onager on 'Queen Shubad's' [RT 800: Pu-abi] rein-ring," and "the silver bull on the king's rein-ring [RT 789]") may initially have been "modelled in wax," there is no justification for the proposed wax use. See Maryon and Plenderleith, 1954, p. 626. The royal use of sectional molds was also persistent in Mesopotamia, suggested by the cast statue of the king Naram-Sin of Akkad (r. ca. 2254–2218 BC) and many other examples centuries later than Shubad (i.e., Puabi). For

Section-mold mastery, assumed by many to be a hallmark of "Chinese" metalworking—and therefore critical to Barnard's (1961) argument[12] on the metallurgical independence of China from the start—is far from unique. Beyond various Old-World regions outside China (e.g., Southwest Asia), the precolonial New World also yields traditions adept at sectional molds: for instance, linear cast marks have been noted from some Inca-style (1438–1533 AD) metals, among others, sometimes even exhibiting mold divisions numbering as many as nineteen (Figure 7).[13] Further examination of the potential origins of section-mold casting in China will be undertaken in the concluding remarks of this paper, adding a nuanced layer of complexity to this topic.

Figure 6. One of the lost-wax cast "standards" (H. 27.5 cm), along with many mace heads and other metal artifacts, from the cave of Nahal Mishmar, Israel. Site dated no later than 3500 BC, probably in the last quarter of the fifth millennium BC. Photographs after Moorey, 1988, p. 177, plate 3; the illustrations of a lost-wax standard viewed from different angles are drawn by the author's team.

Figure 7. Inca-style silver figurine as a man carrying cobs of maize, Peru, H. 7.9 cm; ca. 1450–ca. 1550 BC. "Each of the mold parts identified through examination of the flash lines on the figure has been given a number. Nineteen mold pieces were assembled to cast the figure. The position of the mold joins is indicated by a thin

details, see Moorey, 1982, pp. 13-38; Moorey, 1994, pp. 269-273. To me, the method of making the Erlitou vessels (e.g., Figures 8–10) in the Central Plains of China is essentially not far away from the Mesopotamian casting with three/four-piece sectional molds witnessed at Ur and other sites (e.g., Tell al-'Ubaid), but nearly one millennium younger. For a supporting argument, see Bagley, 1987, pp. 16-17.

[12] Though correctly embracing Kalbeck's section-mold theory, Barnard garbled the casting of Chinese bronzes in an extremely cumbersome and unrealistic manner (a so-called "sectionalism"). As an insightful critic of Barnard, Wilma Fairbank points out that "the number of horizontal mould sections" in Barnard's scheme "often seems excessive, and the widespread use of detachable insertions seems overcomplicated." See Barnard, 1961, pp. 112-168; Fairbank, 1962, p. 180.

[13] A silver casting representing a maize-cob holder has raised ridges on its surface, believed by Heather Lechtman to be "the flashes of metal that had seeped out along the mold seams." After close examination, Lechtman inferred that the entire figurine was cast within a nineteen-piece mold. See Lechtman, 1988, pp. 352-353.

double line in the drawings." Object in the collection of American Museum of Natural History, New York (acc. T-86/1); photograph courtesy of Michael Notis; drawing by S. Whitney Powell, after Lechtman, 1988, p. 353, Figure 30.18, with notes adapted or cited from Figures. 30.16 and 30.18 of the same source.

The Sheet-metal Debate

Rather than the dichotomy between section-mold casting in early China versus lost wax in its far west, "What sets the Chinese metal industry apart is its reliance on casting to make objects that elsewhere were made by hammering" (Bagley, 1987, p. 17). Some may feel this observation a bit sweeping, since metal traditions with a casting focus, though exceptional, were not completely absent. However, in terms of casting scale or dominance,[14] Bronze Age China is without peer, even if we extend our search to the pre-Columbian New World.[15] In vessel production, for example, scarcely any Erlitou-like ventures of exclusive casting were attempted with those relatively simple shapes not challenging at all for hammers (e.g., Figures 8–10, and 11: 1). By hammering, an economically far more "frugal"[16] method than casting, a workpiece can be made exceedingly thin. To make a vessel, metalsmiths outside China frequently chose to cast only the hard-to-hammer parts, whose challenging shape invited lost-wax attempts (Peng, 2018, p. 109). Illustrating this subtle intricacy is a Greek krater of the fourth century BC (Figure 12) that skillfully combined extensive hammering and sensational casting: the vast handles, base, and three-dimensional statuettes sitting on the vase shoulder are among the select parts cast in shape, probably with the lost-wax method (Barr-Sharrar, 1982, pp. 13–19; for details, see Barr-Sharrar, 2008). The rest of the krater was mostly hammered, including multiple forms of visual complexity, such as in the repoussé motifs of the neck (walking animals), within the handle volutes (human faces), and in the frieze of the body (multi-figured scene, see Barr-Sharrar, 2012, notes 20, 21, & 23)—"the egg-shaped body itself was raised by hammering a bronze disk to a height of 76.6 cm" (Houser, 2011, paragraph 7). As a result, with an imposing height of about ninety centimeters and a surprising weight of merely forty kilograms,[17] this Greek krater turns out to be around one third shorter than the Chinese *ding* in Figure 5 but more than 95% lighter.[18] This compelling difference indicates the substantially distinctive traditions of metalworking, but is it sufficiently revealing of divergence in metallurgical origins?

[14] E.g., the Anyang Houmuwu *ding* (Figure 5) stands unparalleled in scale among all known Bronze Age metal artifacts from contemporaneous civilizations. With a retained weight of approximately 833 kilograms—and likely greater in its original form—this monumental vessel exemplifies near-complete cast construction. Significantly, the present archaeological records suggest that no preserved Chinese ritual vessel, either preceding it or contemporary with it, was crafted through hammering into shape.

[15] Though an exhaustive search is impossible, to my knowledge, one of the examples closest to China is the Isthmo-Colombian region in Intermediate America. According to Heather Lechtman, "the metalworking traditions of Andean and Intermediate Area artisans were almost diametrically opposed, that the Andean metalworkers were exquisite forgers of metal and the Intermediate Area artisans superb founders" (Lechtman, 1988, p. 346). As specified by Hosler, "In Colombia, metal was treated as a liquid and objects were cast in open molds, in one- or two-piece molds or by the lost-wax method. Bells, cast using the lost-wax method, occur in Colombia and Costa Rica by 100 C.E." (Hosler, 2014, pp. 334-335). Though casting was the most routine method in Intermediate American metalworking, what was cast in shape there were often personal ornaments and small artworks, far from the Bronze Age Chinese massiveness in casting. In addition, a non-trivial portion of Isthmo-Colombian metal pieces were also hammered and joined, similarly a far cry from the case of Bronze Age China. For further details, see Jones and King, 2002; Falchetti, 2008, pp. 39-74.

[16] In the sense of saving metal and fuel but not necessarily the masterful input.

[17] For more details of the Derveni Krater's scale and dimensions, see Barr-Sharrar, 1982.

[18] In comparison, the Anyang Houmuwu *ding* is 133 centimeters high, about six centimeters thick on average, and weighs 832.84 kilograms. See the website of Yinxu Museum殷墟博物館, Anyang: http://www.ayyx.com/Photos/Show/523 (accessed 19/05/2023).

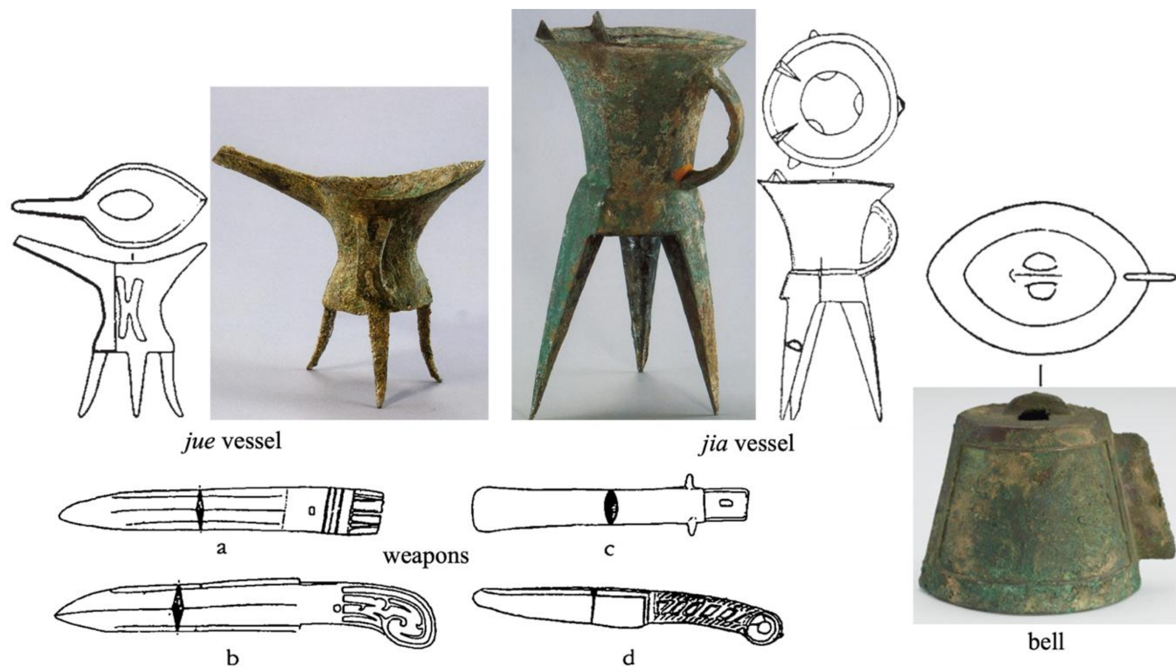

Figure 8. Representative examples of bronze artifacts excavated from Yanshi Erlitou偃師二里頭, Henan河南 province (not to scale), the second quarter of the second millennium BC: *jue*爵, weapons (a and b: *ge*戈 blades; c: axe blade; d: ring-pommeled knife), *jia*斝 and bell. Drawings adapted from Bai, 2003, p. 161 & 163, Figures. 7.2, 11.1, and 11.5; Bagley, 1999, p. 161, Figure 3.12. Images of the *jue* and *jia* vessels after Zhongguo Qingtongqi Quanji Bianji Weiyuanhui, 1996, plates 4 and 14; photograph of the bell courtesy of the Smithsonian Institute, Washington, DC: https://music.si.edu/story/sync-ancient-chinese-bronze-bells-smithsonian (accessed 08/01/2022).

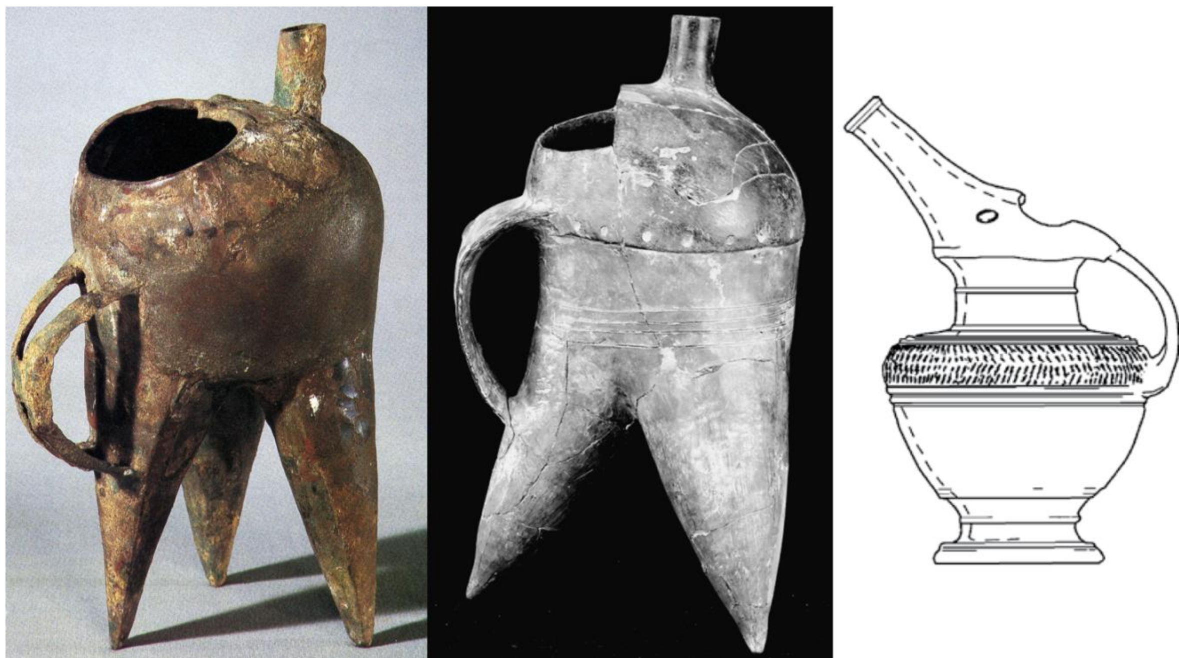

Figure 9. Bronze *he*盉 (left) and its pottery counterparts with three legs (middle) or ring foot (right) unearthed from Erlitou二里頭, ca. 16th century BC. After Zhongguo Qingtongqi Quanji Bianji Weiyuanhui, 1996, plate 19; Li, 2018, p. 209, Figure 5.15: right; Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo, 2014, p. 1003, Figure 6-4-3-4-2B-9.

Figure 10. Bronze *ding*鼎 tripods (1 and 2) discovered from Erlitou二里頭 and an Erlitou clay mold fragment (3) carrying the same style of linear patterns seen from the vessels, ca. 16th century BC. The surface decoration of *ding* 1, in Loehr Style I, is unfolded in drawing after Bagley, 1999, p. 162, Figure 3.13: c; photographs after Zhongguo Qingtongqi Quanji, 1996, plate 1; Li, 2018, p. 203, Figure 5.11: left and bottom right images.

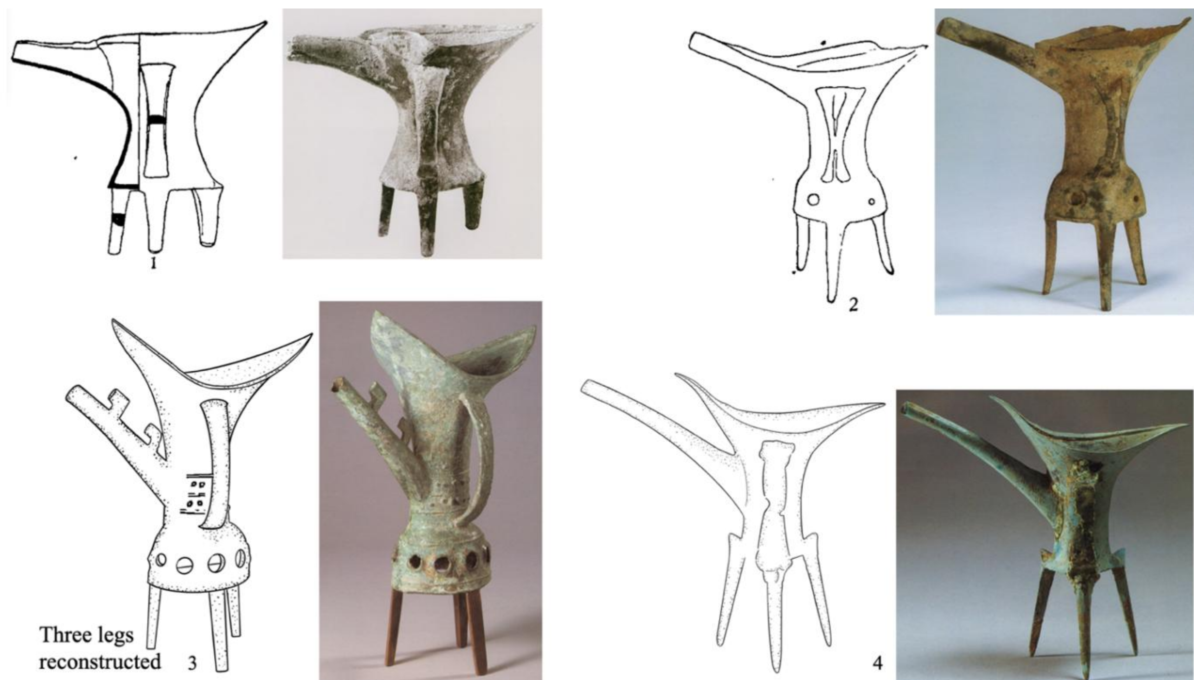

Figure 11. Early specimens of bronze *jue* 爵 (or its variant *jiao*角) in the Central Plains of China, not to scale: 1 excavated from Erlitou VIIIT22③: 6. H. 12 cm; 2 said to be unearthed from Shangqiu商丘 of Henan province, H. 19.7 cm; 3 exhibited in the Shanghai Museum, H. 20.6 cm (no leg extant); 4 said to be unearthed from Luoning洛寧 of Henan province, H. 21 cm. Photographs after Zhongguo Qingtongqi Quanji Bianji Weiyuanhui, 1996, plates 3, 9, 12 and 11. No. 1 and 2 illustrations after Du, 1994, p. 265, Figure 2: 1; p. 266, Figure 3: 2; No. 3 and 4 illustrations drawn by the author's team.

Figure 12. The Derveni Krater excavated from a cist tomb at Derveni (near Thessaloniki, northern Greece) in, the fourth century BC. H. 90.5 cm; W. 40 kg; bronze with about 15% tin. Object photograph after Barr-Sharrar, 2012, p. 2, Figure 1; detail on the right adapted from Barr-Sharrar, 1982, p. 14, full-page image.

Best presenting what we may call Bronze Age "Chinese-ness" in metalworking, the rectangular *ding* in Figure 5 is characteristic in its merciless use of metal under highly organized management that made the noted extravagance possible. When looking at Anyang bronzes like that monumental piece, Li Ji inferred that their zoomorphic decoration might have come from a die-out woodcutting tradition established by some northern Asiatic groups of forest-dwelling animal hunters in southern Siberia and eastern Mongolia, the same assumed source or inspiration for the rectangular vessel shapes.[19] A clever guess at explaining the well-carved animal motifs and plank-like walls in such bronzes, Li's hypothesis turns out to be empirically unsupported by archaeology. True, rectangles and squares were among woodcarvers' favored shapes, but was the same not also true of section-mold designers? Such a form is presumably not difficult for potters to create. The Anyang zoomorphic motifs similarly show no conclusive evidence of woodcarving derivation, while current scholarship increasingly interprets them as potentially representing an artistic innovation originating among Central Plains artisans, possibly incorporating selective elements from adjacent cultural traditions. The *taotie*饕餮 animal motif prominently featured on Anyang ritual bronzes—such as the principal mask design in the decorative registers of Figure 5—has been most persuasively interpreted (e.g., Bagley, 1993, pp. 6–26; Bagley, 2008a, pp. 43–68) as elaborating from a simpler pair-eye configuration dating to the Erligang period, which looks more rudimentary than the pattern shown in Figure 4 (left). Recent archaeological discoveries, especially the large stone reliefs (Figure 13) embedded in the walls of the palace platform at Shimao石峁 in Shenmu神木, Shaanxi province (ca. 2200–ca. 1800 BC), nevertheless highlight the pressing need to reevaluate the factors that may have inspired the origins of the *taotie* in Chinese metalwork (idea inspired by Falkenhausen, 2024). Whatsoever, the development of pre-Zhou ritual bronzes (before ca. 1050 BC) was illustrated by Max Loehr in a sequence of five styles, linking thread-relief ornaments like those seen on the Erligang-style *ding* (Figure 4, Loehr Style I) or earlier to the

[19] In addition, Li Ji speculated that some Anyang ornaments (e.g., the universal pattern of zigzag, or in his words, "the interlocking of reclined S-shaped pattern") had evolved a long way from the art of Middle Neolithic Yangshao culture; the "round type" of Anyang bronzes was thought by Li to retain the pottery shapes of Late Neolithic Longshan culture. For the ideas of Li Ji, see Li, 1977, pp. 961-987; Li, 1957. For J. G. Andersson's theory of the "Western" origin of Yangshao painted pottery and a recent critical review of him and Li Ji, see Andersson, 1923, pp. 1-68; Andersson, 1943, pp. 7-304; Peng, 2021, pp. 515-548.

zoomorphic images in the Anyang *ding* (Figure 5) with evidence of intermediaries.[20] Less clear-cut than the bronze decoration is the shape of the cast vessels, which shows a mash-up complexity: the rectangular quadrupeds were either created by section-mold casters or inspired by domestic potters (e.g., see Figure 14; also see Xu, 2022, p. 175, the middle image); a variety of rounded vessel types (e.g., tripods and ring-foot utensils) are rooted in the East Coast of Neolithic China (Keightley, 1987, pp. 91-128) or nearby; and a few curious designs are still not fully understood. Regarded by Loehr (1953, p. 44) and another art historian of his generation as the "earliest example [of] the first style of ornamental bronze in China" (Davidson, 1937, p. 51) at the time they wrote, a *he*盉 vessel formerly in the Berlin Museum, along with a few comparable pieces, carries intelligible thread-relief ornament but an intriguing shape (Figure 15): the bulbous legs are derived from Neolithic Chinese pottery, while the other features, as Robert Bagley maintains, appear to resemble a jug from the Qijia齊家 culture (ca. 2300–ca. 1500 BC, Figure 16)—the prototype of which was "made from several pieces of metal that were hammered to shape and then joined by crimping and riveting" (Bagley, 2014, pp. 38-39).

Regrettably, the Qijia-style jug (Figure 16) is not in metal, but it is arguably a ceramic skeuomorph of hammered metal. Bagley speculates that the gibbous cover of the original "was hammered to shape and attached to the body by crimping," the tubiform spout "rolled from sheet metal and attached with solder or an adhesive," and the handle "riveted to a rectangular tab hammered out from the edge of the cover" (Bagley, 1987, p. 15). Although these serial traits, at first glance, nearly yell that they survived from an earlier sheet-metal tradition, the tubular spout and rivet-like nodules seem to have equipped earlier pottery *he* in broader regions of China during the late third millennium BC (for details, see Du, 1992, pp. 1-12, and pp. 20-25). Would it be surprising if some of the assumed remnants of hammered features (e.g., "rivets") turned out to be purely ornamental? Or did vessels shaped by beaten metal indeed appear in Late Neolithic China, but they were hard to come by for some reason? So far, the earliest metal *he* was unearthed at Erlitou from around the sixteenth century BC (Figure 9: left). From the same epoch, scholars have also found a few *ding* and *jia*斝 tripods as well as a number of *jue*爵 pitchers (e.g., see Figures 8, 10, and 11: 1). If we exclude undetermined or fragmentary finds,[21] such Erlitou specimens are the earliest well-preserved metal vessels in China. Section-mold cast in a single pour,[22] these bronzes carry controversial characteristics that are possibly indicative of an earlier metalworking tradition.[23] Yet observations along these lines are far from conclusive. In fact, the "rivet-heads" first proposed by Margit Bylin-Althin (1946) as an explanation of the coupled protuberances on the Qijia-style pottery handle (Figure 16) may be misleading.[24]

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[20] It must be emphasized that the surface ornament was selected by Loehr to present his five styles of bronzes for descriptive convenience. As observed by Robert Bagley, readers who deem Loehr's paper to be "a study of surface decoration alone" often overlook this point; Loehr's décor sequence, as "a schematic way of describing," is not solely based on the surface decoration, but rather on the "total effect" of the whole vessel. For example, a major rationale for Loehr when it came to distinguishing his Style I bronzes was their "quite obviously primitive" shapes, such as that for a *he* vessel (Figure 15: left). In addition, focusing on the artistic invention of bronzes, the five styles refer to their stylistic inception rather than perpetuation. For details, see Loehr, 1953, pp. 42-53; Bagley, 2008b, pp. 64-70.

[21] E.g., the Dengfeng Wangchenggang登封王城崗 and Xinmi Xinzhai新密新砦 shards said to be from bronze containers, as well as similar copper-based remnants from Xichuan Xiawanggang淅川下王崗 and the southern Shanxi site of Linfen Taosi臨汾陶寺. See Bai, 2002, p. 31; Zhang, 2017, p. 55. For the milieus yielding such metal vessel fragments, see An and Li, 1983, pp. 8-20; Zhao et al., 2004, pp. 4-20; Gao, 2009; Gao and He, 2014, p. 92.

[22] For example, the mold for an Erlitou *ding* (Figure 10: 1) probably has two or three vertical subdivisions, judging by the corresponding traces of ridges that run down. A further piece of the mold was probably withdrawn from the bottom of the tripod model. Hence, in total, there were presumably three or four sections of mold and an appropriately applied clay core. Admittedly, the specific casting process of this *ding* tripod is still debated. For details, see Su et al., 1995, p. 98; Liu et al., 2013, p. 196; Miyamoto, 2019, pp. 95-102.

[23] As suggested, the domed shape of the *he* jug's upper part is familiar in the wrought-metal traditions, and the tubular spout seems to imitate a prototype rolled from hammered sheet. The outer portion of the broad everted rim of the flimsy *ding* (Figure 10: 1 and 2) seems to imitate the inward-folded verge that might be envisaged in a container hammered in shape. Likewise, the rim of the *jue* pitcher (e.g., Figure 8: top left, and Figure 11) steps up to some degree, as though it had been beaten out and forced inward to give an even edge. As noted by Bagley, "several of the *jue* and *jia* have stumps or prongs on the rim that do not originate in pottery and that do not seem to make sense as remnants of a casting process either." See Bagley, 2014, p. 39; Fong, ed., 1980, p. 74 and 104. For similar views, see Fitzgerald-Huber, 1983, p. 207; Hwang, 2014, pp. 601-602 and pp. 607-616.

[24] In this essay, Margit Bylin-Althin insightfully suggested that Qijia was neither "pre-metallic" nor "pre-Yang-Shao" (i.e., pre-Majiayao馬家窯), against the excavator J. G. Andersson's understanding, mainly based on what she argued was the Qijia ceramic skeuomorph of metalwork— "The imitation of metal is striking in the pot reproduced in Pl. 22, Figure 5 (the same object shown in Figure 16, author's note). The long handle of this vessel has (...) two 'rivet-heads.' The same 'rivet-heads' appear also on the spout. Even the kidney-shaped opening in the superstructure, the extremely high neck and the body with its

Noel Barnard (1980) has offered a critical review that has weakened the credibility of Bylin-Althin's proposal and the derived insights,[25] and some of his critiques, such as his point that "rounded protuberances do not necessarily imply rivets," make sense. In this regard, we even need to reconsider certain counter-intuitive points made by Barnard, such as the representational use of initially "decorative" paired protuberances ("rivets") in denoting "animal-heads" (Barnard, 1980, p. 12), which finds Qijia-associated supporting evidence emerging continuously (e.g., for a newly acquired example in the Harvard Art Museums, see Figure 17: left; this vessel top is more like an anthropomorphic face,[26] but zoomorphic heads in the same fashion also exist[27]), among others in early China.[28] In light of the likely ways of viewing a decorated vessel in prehistory (e.g., Figure 17: right),[29] Barnard's proposal is of particular interest.

Figure 13. Image (above) and rubbing (below) of the No. 11 stone carving from the Shimao石峁 site in Shenmu神木, Shaanxi province (ca. 2200–ca. 1800 BC). After Sun et al., 2020, p. 42, Figure 16.

bulbous belly and narrow foot part must have been influenced by metal models." See Bylin-Althin, 1946, pp. 465-466. Cf. Andersson, 1943, pp. 7-304, with appendix. Perhaps because of Bylin-Althin's accurate prediction about the existing metallurgy and relatively young age of Qijia, readers may have believed that all her ideas were similarly correct.

[25] This is a critical response to Bylin-Althin's (1946) proposal, later echoed or supported by several scholars, such as An (1956, p. 46), Fitzgerald-Huber (1983, pp. 177-216), and Bagley (1987, pp. 15-140). Cf. Barnard, 1990, pp. 271-298.

[26] For a comparable example of a human face, see Zauho Kankokai, ed., 1982, p. 149, plate 130.

[27] According to Zou Heng鄒衡, the so-called *jiyi*雞彝 ("cock-shaped pots") in received texts (e.g., *Li Ji*禮記, "The Classic of Rites") originally referred to such *he* and their prototype *gui*鬶 vessels because of the formal likeness. See Zou, 1980, p. 149. Later, Lu Chi-Chang呂琪昌 likened the design of the *he* vessel to the bird motif in the East Coast of prehistoric China with the long vessel spout representing the bird beak and the paired dots portraying its eyes. Though a concrete bird face has been noted on some examples (one of a Late Neolithic piece even has feather-like patterns "fully decorating the lid"), Lu's argument may go too far, since the representation of birds is still too limited in the corpus of preserved specimens. For relevant details, see Lu, 2007, pp. 200-203; Wu, 1985, pp. 30-41; Jia et al., 1983, p. 43. Ranging from one to more than ten in number, the rounded protuberances on the *gui* and *he* vessels may have been intended for ornamental purposes at first. The paired dots, in my opinion, may sometimes have been used to enliven the vessel and attract viewers' attention in the function of eyes, which seem to have eventually been incorporated with more concrete patterns for representational use. For a comparable discussion on the origins and stylistic evolution of the *taotie* motif in early Chinese bronzes, see Bagley (2015, pp. 157–174). While Bagley's argument remains highly influential, the discovery of Shimao's impressive stone reliefs (ca. 2200– ca. 1800 BC, see Figure 13) introduces new evidence that invites a reconsideration of established interpretations regarding the cultural and artistic foundations of *taotie* in early Chinese bronze art. (A detailed discussion of the *taotie* motif, however, lies beyond the scope of this footnote.)

[28] For illustrations of this observation in pottery and metalwork from the Erlitou to the Anyang period, see Du, 1992, pp. 15-16, and p. 24: Figures 9–10, 14.

[29] For discussions, see Gu, 1977, pp. 67-71; Shang, 2016, p. 30.

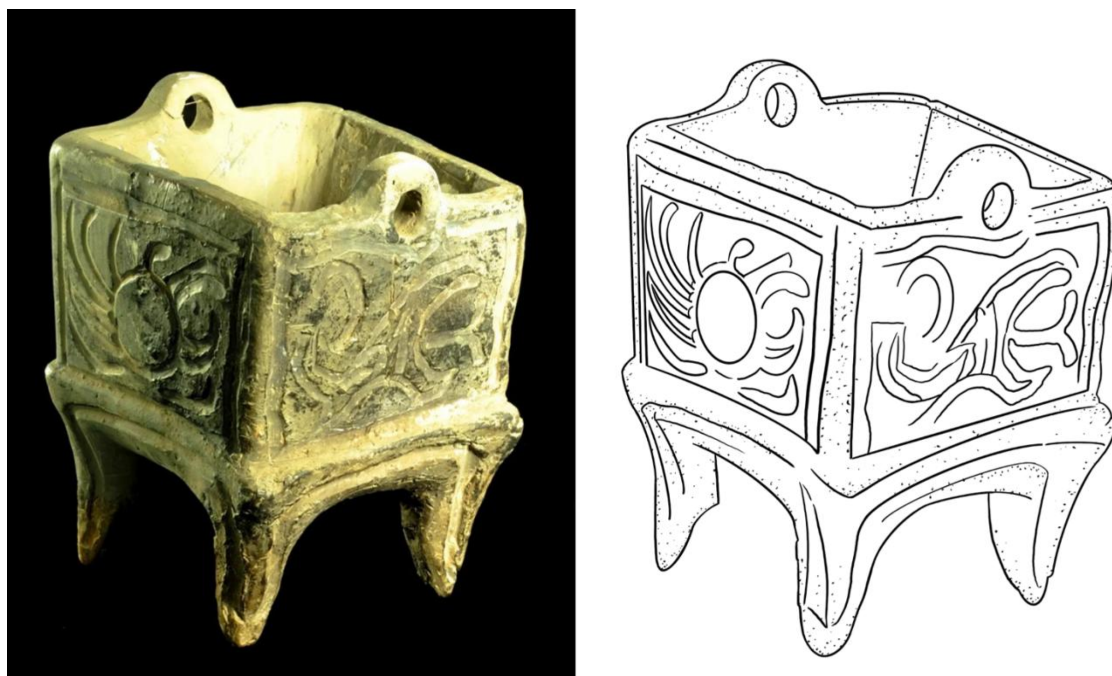

Figure 14. Rectangular pottery *ding*鼎 vessel with surface decoration unearthed from Yanshi Erlitou偃師二里頭, Henan province, H.9.5 cm, Erlitou Phase III (ca. 1610–ca. 1560 BC). Object in the collection of the Erlitou Site Museum of the Xia Capital 二里頭夏都遺址博物館, after Q. Liu, 2022, p. 503, Figure 4.2: 2; drawing by the author's team.

Figure 15. Unprovenanced bronze *he*盉 vessels carrying the surface decoration of Loehr Style I, respectively in the former collection of Berlin Museum (left: H. 31.7 cm) and the Brundage Collection, Asian Art Museum of San Francisco (acc. B60B53; right: H. 22.9 cm), ca. 15th century BC. After Davidson, 1937, p. 33, Figure 6; Bagley, 1990, p. 10, Figure 7.

Figure 16. Pottery *he* 盉 vessel of Qijia 齊家 type in the collection of Shanghai Museum, obtained by J. G. Andersson in Gansu Lanzhou 甘肅蘭州. H. 27 cm; ca. 2300–ca. 1500 BC. The detailed depiction of the vessel was drawn by the author's team. Photograph courtesy of Zhangzhugang under the Creative Commons Attribution-Share Alike 3.0 Unported license: https://en.wikipedia.org/wiki/File:Black_Pottery_He_Ewer.jpg (accessed 23/09/2023).

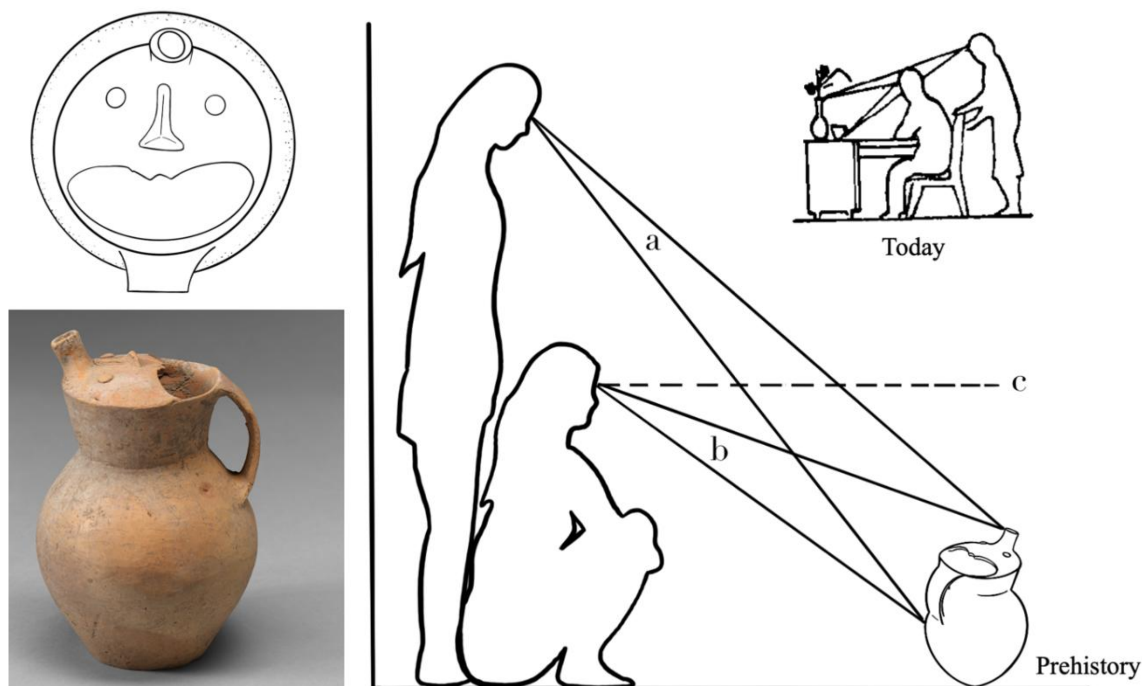

Figure 17. The difference in viewing objects in prehistory and today, taking a Qijia 齊家-style *he* 盉 (H. 18.4 cm; Diam. 12.3 cm; ca. 2300–ca. 1500 BC) as a prehistoric example: a as the visionary span when standing; b as the visionary span when squatting. Diagram adapted from Gu, 1977, p. 68, Figure 3. Photograph of the Qijia-style *he* courtesy of the Harvard Art Museums/Arthur M. Sackler Museum (acc. 2006.170.60), Partial gift of the Walter C. Sedgwick Foundation and partial purchase through the Ernest B. and Helen Pratt Dane Fund for Asian Art: https://harvardartmuseums.org/collections/object/182444 (accessed 23/10/2023). The anthropomorphic top of this Qijia-style spouted jug, easily captured by prehistoric viewers, is illustrated on the top left by the author's team.

Some of the traits that intuitively seem to be left over from hammered metal may have originated in pottery, due to the similar effects of pressing, folding, and joining clay sheets—for instance, the tubular spout could be rolled up from metal, but a creative potter may have come up with similar ideas in processing flexible pieces of muddy clay (e.g., an inspiring modern case is the making of the renowned Yixing宜興 teapots). In fact, some of the pottery characteristics taken by Bylin-Althin to be reminiscent of metalwork, such as an "extremely high neck" and "bulbous belly" (e.g., Figure 16) in addition to an oddly unsymmetrical upper part of the vessel, can be likewise found in pottery *gui*鬶 (Figure 18, note that the single protuberance on this Dawenkou大汶口 artifact may be misunderstood as a "rivet-head"). This pottery is a ceramic type long rooted in the East Coast of Neolithic China, often thought to be unaffected by metal in its Dawenkou cultural stage (ca. 4300–ca. 2500 BC) surrounding Shandong province or the not-far-off periods to its south.[30] Another of Bylin-Althin's inaccuracies that seems to have ensnared other scholars is his reading of pottery like the Qijia-style *he* (Figure 16) as "a direct imitation of metal ware."[31] Due to this cognitive or descriptive inaccuracy, Barnard's corresponding criticism, which looks mechanical at first sight, deserves scholarly acceptance at least partially. Yet it is crucial to stress that skeuomorphism is not necessarily point-to-point copying, and not every vestigial feature of a skeuomorph must stay functional or remain in an accurate place (=symbolically functionary), as demanded by Barnard.[32] Treated as part of the "fossil record" instead, several pottery skeuomorphs comparable to that of Qijia have been propounded by Bagley from Xichuan Xiawanggang淅川下王崗 and Shanghai Maqiao上海馬橋 with wider distribution in the period of "Late Longshan"[33] (this phase of Longshan龍山 period or "horizon" is often dated to ca. 2300–ca. 1800 BC): "Somewhere in north China around 2000 BCE smiths were hammering vessels from sheet metal," Bagley infers, "by the time of the third stratum at Erlitou these [sheet-metal] techniques had been given up in favor of casting" (Bagley, 2014, p. 39; Bagley, 1987, p. 16). The reason for the archaeologically smithed-vessel absence, according to Bagley, is likely due to (1) insufficient production capacity when hammering is used compared with casting, and (2) the vulnerability of flimsy sheet-metal vessels to corrosion.[34] By acknowledging such possibilities, we may extend our search deeper into the third millennium BC, even though it is unclear whether a sheet-metal tradition in vessel making really existed in prehistoric China.[35]

For Bagley's sheet-metal hypothesis, a provocative clue comes from *jue*, the vessel type most frequently encountered at Erlitou (e.g., Figure 8: top left, and Figure 11: 1). Far exceeding the excavated sum of the rest of the contemporaneous bronze vessels in quantity, the Erlitou *jue* carries an irregular shape that has little chance of having been first invented by section-mold casters. With no widely agreed-on prototype in pre-Erlitou ceramics of East Asia, the *jue* vessel of unmistakable prestige at the Erlitou site shares a curious similarity with a hammered design from Shahdad of southwestern Iran (Figure 19: 2), a likely BMAC ("Bactria–Margiana Archaeological Complex," ca. 2400/2250–ca. 1950/1700 BC[36]) offshoot from Central Asia.[37] Interestingly, another common Shahdad type of sheet-metal ware (Figure 19: 1) displays a more conspicuous resemblance to *gu*觚, a ritual vessel

[30] The *gui* is considered to have originated either in Shandong province or the areas around Lake Tai. For details, see Shao, 1980, pp. 86-89; Gao and Shao, 1981, pp. 428-459; Huang, 1997, pp. 59-62.

[31] For direct citations in this paragraph so far, see Bylin-Althin, 1946, p. 427, pp. 465-466.

[32] When scrutinizing some of the argued ceramic skeuomorphs of hammered metalwork, Barnard found the "curiously restricted use of 'rivets' in the pottery vessels. When these protuberances appear on handles they are limited to the upper area of the handle terminals and there is nothing to hold the lower handle terminals to the vessel body! Rivets would surely have to be employed at both terminals!" (Barnard, 1980, p. 12). Similar critiques can be found throughout Barnard's (1980) essay. Though carrying similar doubt about the "rivet-heads" proposed by Margit Bylin-Althin, the "direct imitation"—another of Bylin-Althin's (1946) suggestions, refuted by Barnard—is not the only way for skeuomorphism to make sense, and not everything in pottery must be exactly in a position corresponding to its technical counterpart in metal.

[33] Bagley, 1987, p. 16 and 46, notes 13-14. For more examples, see Hwang, 2014, p. 646, plate 3.

[34] "Hammering makes thinner walls than casting and thus uses metal more sparingly, so it is the technique of choice for metalworkers with limited metal supplies" (Bagley, 2014, p. 39).

[35] Though some of the assumed smithed traits (e.g., the imitation of rivets) are still questionable, if a hammering tradition did exist, it may not necessarily have been a short-lived one. Because of the two potential reasons summarized by Bagley, the total number of hammered vessels cannot be significant even with a substantial span of production. On the other hand, it begs the question of why only in China we find such an awkward undocumented status if a hammering tradition of vessel production did exist in prehistory. Regardless, concrete proof of this speculated sheet-metal tradition is still absent, despite long-term attempts to find it.

[36] For two different dating schemes of BMAC (ca. 2400–ca. 1950 BC versus ca. 2250–ca. 1700 BC), compare Vidale, 2017, p. 8; Lyonnet and Dubova, 2021, p. 20.

[37] For relevant details, see Hakémi, 1972; Amiet, 1974, pp. 97-110; Hiebert and Lamberg-Karlovsky, 1992, pp. 1-15; Hiebert, 1994, pp. 372-387; Hakémi, ed., 1997, pp. 121-138; Potts, 2008, pp. 165-194; Eskandari et al., 2021, pp. 31-46.

of remarkable significance in early Bronze Age China.[38] Presenting these comparisons, Fitzgerald-Huber (1995, p. 63) argues that "the *conjunction* of these two vessel types in *both* traditions makes the case for possible Bactrian influence less easy to dismiss," before securing further cultural parallels between BMAC and the Central Plains of China.[39] Hammering technology was never entirely absent from prehistoric China, after all, and its early use is evidenced at Qijia; we might even be able to trace it back earlier in northwest China.[40] The region around Beijing in the northern frontier of the Chinese Central Plains testifies to the mastery of sophisticated hammering in processing meteoritic-iron-bladed weapons no later than the fourteenth century BC,[41] and recently two much earlier knives made entirely of meteoritic iron (ca. 3000 BC; hammering would have been necessary to shape and sharpen them) have been found in northern Xinjiang,[42] though somewhat distant from the Central Plains. When it comes to the proposal of a pre-Erlitou tradition of fashioning sheet-metal vessels, these clues are far from sufficient but technically suggestive. We should, however, be aware that such a sheet-metal tradition, if it exists, does not theoretically exclude the use of casting in the manufacture of simple-shaped tools or weapons that require better solidity.[43] In fact, both casting and hammering were in the ordinary toolkit of Steppe metalworkers, and both techniques were familiar to the makers of Qijia metalware and their associates. Would any further (in the technological sense, rather than strictly chronological) attempts have been made to hammer vessels in shape within broader China before the lavish metal expenditure by the Erlitou casters?

To return to the intercultural comparison noted by Fitzgerald-Huber, we once again reach a tricky complication: though no metal *gu* has been unearthed at Erlitou, ceramic pieces have been found frequently,[44] and earlier *gu*-shaped designs were widespread in the Neolithic East Coast and Central Plains of China (Figure 20).[45] Likewise, potential candidates for the *jue* model have been suggested in such an indigenous context: the earliest ceramic *jue* in its acknowledged form is discovered from the phase of Erlitou I (ca. 1750–ca. 1680 BC) or II (ca. 1680–ca. 1610 BC), somewhat earlier than their first metal counterparts known from Erlitou III (ca. 1610–ca. 1560 BC) in the archaeological record.[46] Among these Erlitou I or II ceramic *jue*, a white pottery from Dengfeng Yucun 登封玉村 (Figure 21: 1) appears to many scholars to be the most primitive.[47] Zou Heng 鄒衡

[38] E.g., compare Lamberg-Karlovsky and Hiebert, 1992, p. 137, Figure 1, and Zhongguo Qingtongqi Quanji Bianji Weiyuanhui, 1997, plates 103-128.

[39] For details, see Fitzgerald-Huber, 1995, pp. 52-65.

[40] E.g., there is a hammered awl assigned to the Machang 馬廠 culture (ca. 2300–ca. 2000 BC), and potentially earlier than that, the controversial cast tin-bronze knife excavated from Dongxiang Linjia 東鄉林家, Gansu (ca. 2800 BC?), is also said to have received light hammering: the Machang awl (found at Jiuquan Zhaobitan 酒泉照壁灘, Gansu) "was shaped by hot forging and was cold locally worked"; the Linjia knife (assigned to the Majiayao culture) "was processed by slight cold forging or grinding." In addition, "Both casting and forging methods were used in manufacturing Qijia artifacts. Knives and awls were usually made by forging." See Sun and Han, 2000, pp. 176-177.

[41] According to the earliest known record in East Asia, the evidence for the use of hardened meteoritic iron comes from Pinggu Liujiahe 平谷劉家河 of Beijing, and around 370 kilometers to its southwest, Gaocheng Taixi 藁城台西 of Hebei province. Both sites, from roughly the same time in the northern frontiers of early China, yielded bronze *yue* 鉞-axes with meteoritic iron blades. Chemical studies have confirmed that both blades are high in nickel, an element commonly associated with meteorite iron. Metallographic examination has also verified that the Taixi iron blade was shaped by hammering. For technical details, see Li, 1976, pp. 17-34; Zhang and Zhang, 1990, pp. 66-71. Worldwide these two early "Chinese"-related weapons seem unremarkable in age or craftsmanship. However, in design, they are compelling for the smart combination of potentially harder meteoritic iron (after hammering) and less brittle bronze as a distinctive bimetallic arm. For later comparable examples in early Bronze Age China, see Gettens et al., 1971.

[42] For details, see Alifujiang, 2023, pp. 3-17; Zhang et al., 2023, pp. 88-94 and 175.

[43] Just like the opposite case: throughout the casting-dominant Chinese Bronze Age hammering was always possible to improve the hardness or sharpness of similar utensils. See Bagley, 1987, pp. 46-47, note 16.

[44] E.g., see Zhongguo Kexueyuan Kaogu Yanjiusuo Luoyang Fajuedui, 1961, p. 83 and 85; Xu, 2022, pp. 118.

[45] For the charted linages of two *gu* 觚 variants that can be tracked back to the Dawenkou culture, see Zou, 1980, p. 148, Figure 8. For a scope focusing on Longshan-Erlitou span in the Central Plains, see Lu, 2007, pp. 214-216. For further details, see Wang and Zhang, 2004, pp. 286-365; Su, 2019, pp. 47-49; Han, 2011, pp. 59-64.

[46] For details, see Du, 1994, pp. 263-298; Du, 1990, pp. 519-530. Digging for decades at the Erlitou site and comprehensively reviewing unearthed materials from the Erlitou period, Zheng Guang 鄭光 sees no clear proof of ceramic *jue* prior to Erlitou II, and suggests that those assigned to Erlitou I should be reconsidered and instead dated to Erlitou II. See Zheng, 1995, p. 6. For discussions of the Erlitou chronology, see Liu and Chen, 2012, p. 266; Qiu et al., 1983, pp. 923-928; Qiu et al., 2006, p. 323, and pp. 326-332; Zhang et al., 2007, pp. 74-89; Qiu, 2015, p. 101; H. Xu, 2021, Chapter 3, Part 1.

[47] See Han et al., 1954, p. 22 (Figures 9 and 10), and pp. 23-24.

considers the Yucun *jue* as deriving from a *gui* subtype like the piece from the Shandong Longshan山東龍山 (ca. 2300–ca. 1800 BC) site of Weifang Yaoguanzhuang濰坊姚官莊 in the East Coast of North China (Figure 22: 7).[48] Elizabeth Childs-Johnson proposes two other Late Neolithic candidates for the *jue* prototype, one from the site Beiyinyangying北陰陽營 near Lake Tai, and the other from the site Sanliqiao三里橋 in western Henan (respectively Figure 22: 6 and 2).[49] Comparable pieces to the Sanliqiao specimen have been revealed from a variety of Henan Longshan河南龍山 (ca. 2300–ca. 1800 BC) sites, which are collectively termed "proto *jue*" by Du Jinpeng杜金鵬 (Figure 22: 1–5).[50] Yet virtually all Childs-Johnson's and Du's examples of native "prototypes" are set apart from the *jue* vessels (Figure 21) by the absence of a slender pouring channel or tubular spout, and Zou's proposed Yaoguanzhuang *gui* (Figure 22: 7), with an elongated pouring channel, is far too stout in its entire shape. In my eyes, two containers from the Henan Longshan sites of Dengfeng Wangchenggang登封王城崗 and Yuzhou Wadian禹州瓦店 (e.g., Figure 22: 8–9) are the closest local specimens in form and age to the earliest *jue* known to us (Figure 21).

Figure 18. White pottery *gui*鬹 vessel of Dawenkou大汶口 type (left), its folded rim and elongated pouring channel (middle), and the decorative protuberance on the front of the vessel body (right). H. 33 cm; ca. 4300–ca. 2500 BC. Image courtesy of the collection of the National Palace Museum in Taipei (acc. 贈瓷 000445N000000000): https://digitalarchive.npm.gov.tw/Antique/Content?uid=43475&Dept=U (accessed 23/10/2023).

[48] Zou, 1980, p. 164. For contextual information on the *gui* subtype ("Subtype II") noted by Zou from the site, see Zheng, 1963, pp. 347-350 (for a "Subtype I" *gui* specimen carrying a great number of round nodes through its body, see plate 1.1). For a similar view taking the *gui* as the prototype of *jue*, see Tang, 1979, pp. 46-47.

[49] Childs-Johnson, 2003 (?), p. 2, Figure 1. For contextual information, see Zhao, 1958, pp. 7-23, with affiliated 16 plates (Childs-Johnson's assumed prototype for *jue* in plate 13.1); Zhongguo Kexueyuan Kaogu Yanjiusuo, 1959, pp. 98-115 (Childs-Johnson's assumed prototype for *jue* in Figure 66).

[50] These sites include, but are not limited to, Mengjin Xiaopangou孟津小潘溝, Tangyin Baiying湯陰白營, Luoyang Wangwan洛陽王灣, and Shangcai Shilipu上蔡十里鋪. See Du, 1990, p. 527.

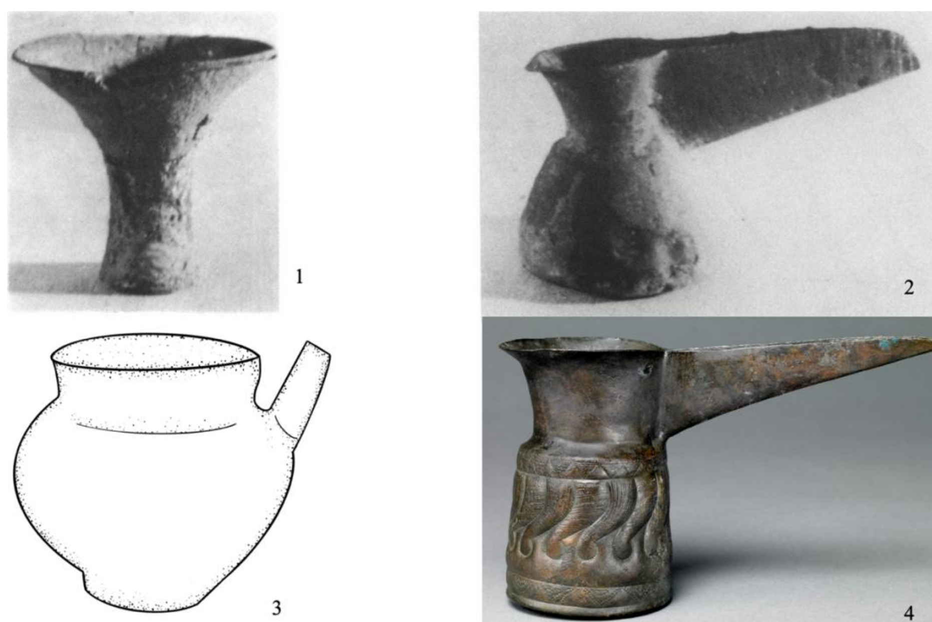

Figure 19. Hammered vessels in copper/copper-alloy from the BMAC-affected site of Shahdad in southwestern Iran, not to scale (1: drinking vessel, H. 10.4 cm; 2: pouring vessel, H. 13.3 cm; 3: spouted vessel: H. 13.7 cm. Perhaps ca. 2400/2250–ca.1950/1700 BC) or nearby (4: pouring vessel, H. 13.5 cm, from Tepe Gilweran, western Iran, ca. 2750–ca. 2250 BC). Images 1, 2 and 4 after Fitzgerald-Huber, 1995, p. 61, Figure 12b; p. 60, Figure 12a; The British Museum (acc.128600): https://www.britishmuseum.org/collection/object/W_1936-0613-200 (accessed 24/10/2023); No. 3 vessel drawn by the author's team, after Hwang, 2014, p, 602, Figure 1.3.

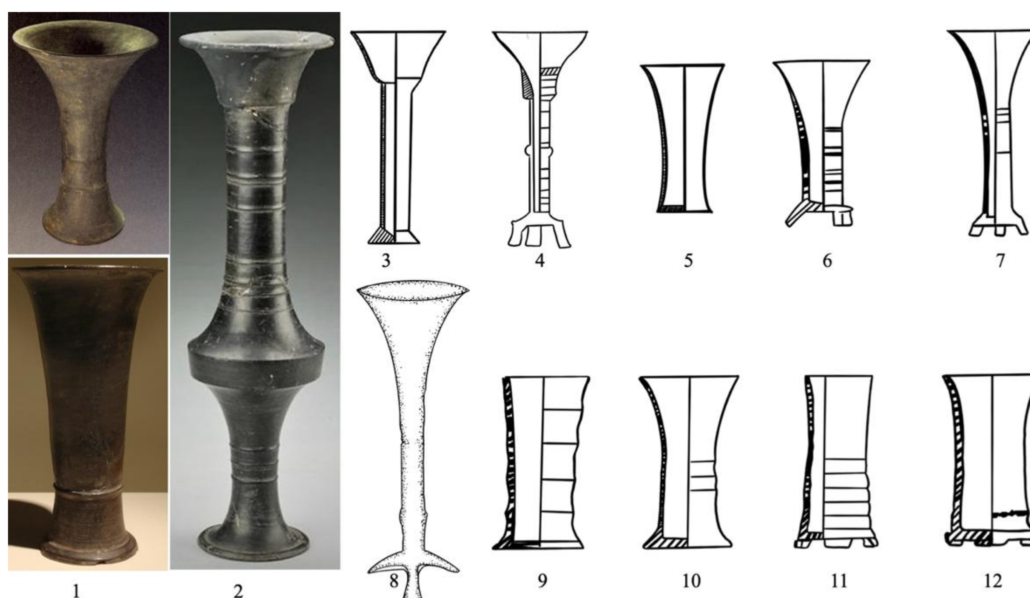

Figure 20. Erlitou pottery *gu*觚 vessels (1: with slender and stout variants) and their potential prototypes in the Central Plains (2: from Yuzhou Wadian禹州瓦店, Henan Longshan culture) and East Coast (3–8 from various sites of Dawenkou大汶口 culture; 9–12 from the Qingdun青墩 and Songze崧澤cultures) within present-day China. Objects not to scale. Photographs 1–2 respectively after Xu, 2022, p. 118, lower right image; https://commons.wikimedia.org/wiki/File:CMOC_Treasures_of_Ancient_China_exhibit_-_pottery_gu.jpg (accessed 05/11/2023), public domain, under the Creative Commons Attribution-Share Alike 2.5 Generic license; https://www.chnmus.net/sitesources/hnsbwy/page_pc/bwzl/yyhxzzjd/cpsx/article2a35acdb504f4100a5576317d 3095af2.html (accessed 05/11/2023; image courtesy of Henan Provincial Museum). Objects 3–7 and 9–12 were redrawn by the author's team, after Wang & Zhang, 2004, p. 84, Figure 1.2-1: 16–21; p. 179, Figure 2.2-3: 21–24. Object 8 was drawn by the author's team, after an unusual *gu*-shaped tripod excavated from Pixian Sihugongshe Dadunzi邳縣四戶公社大墩子, Jiangsu province.

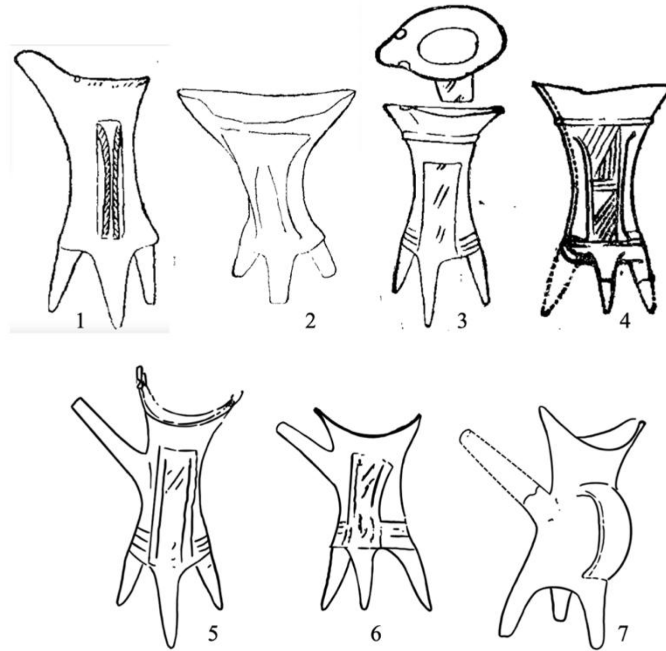

Figure 21. Early specimens of pottery *jue* 爵 (or its variant *jiao* 角) vessels in the Central Plains of China, not to scale: 1 from Dengfeng Yucun登封玉村; 2 and 7 from Luoyang Dongmagou洛陽東馬溝; 3–6 from various tombs of the Erlitou site (respectively VI M3: 1, III M5: 2, VI M1: 4, and IX M20: 10). All sites in Henan province. After Du, 1990, p. 520, Figure 2: 1–2; p. 521, Figure 3: 1–2; p. 523, Figure 1–2, 4. No. 5–7 illustrations retouched by the author's team.

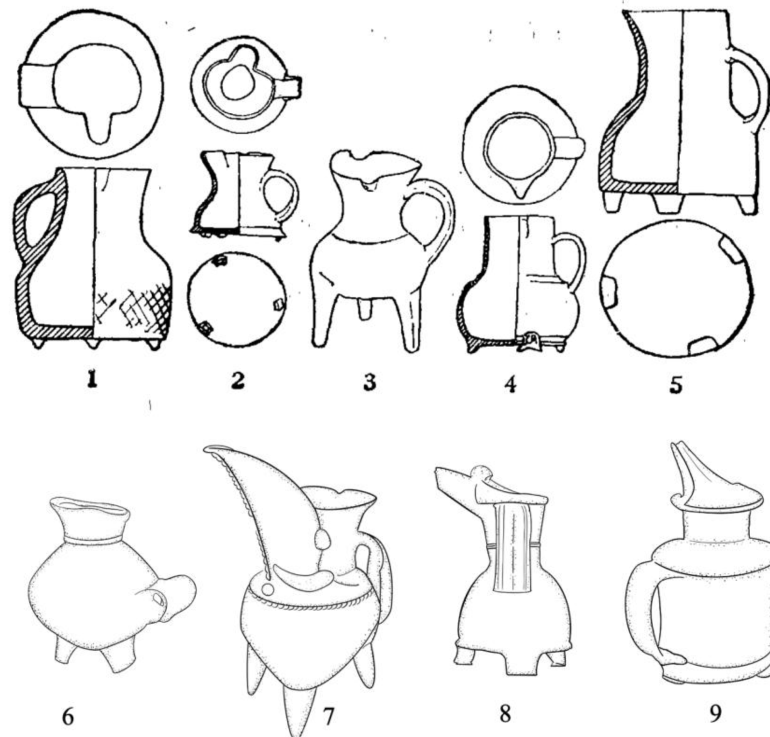

Figure 22. Variously proposed pottery types as potentially local prototypes of the *jue*爵 vessels, not to scale: 1–5, and 8–9 from sites of Henan Longshan河南龍山 culture (respectively Luoyang Wangwan洛陽王灣, Shaanxian Sanliqiao陝縣三里橋, Mengjin Xiaopangou孟津小潘溝, Shangcai Shilipu上蔡十里鋪, Tangyin Baiying湯陰白營, Dengfeng Wangchenggang登封王城崗 and Yuzhou Wadian禹州瓦店); 6 from the Beiyinyangying北陰陽營 culture, Jiangsu province; 7 from Weifang Yaoguanzhuang濰坊姚官莊, Shandong Longshan山東龍山 culture. Except for object 6 (fourth millennium BC), the rest of the vessels are earlier than Erlitou by only a few centuries. No. 1–5 objects after Du, 1990, p. 527, Figure 12. No. 6–9 objects drawn by the author's team, after Zhao, 1958, affiliated plate 13: 1; Zheng, 1963, affiliated plate 1: 2; Hwang, 2014, p. 645, plate 2: 12 and 14.

Regardless, even for *jue* alone, many questions remain: Did artisans in China need a foreign prototype or inspiration like the BMAC pouring vessel (Figure 19: 2) to design the unusual *jue* form, or were local resources (e.g., Figure 22) adequate for a manageable integration? If the Yucun *jue* (Figure 21: 1) and similar bronzes around the Erlitou period (Figure 8: top left, and Figure 11: 1–2) could be justified by an indigenous synthesis, what about the subtype or variant of *jue* with a tubular spout arising no later than Erlitou I or II (Figure 21: 5–7; for their bronze counterparts, see Figure 11: 3–4, perhaps a bit later)? Was the spouted design affected by a sheet-metal tradition, or was it developed entirely by local potters, considering the presence of such a spout in earlier ceramics of the East Coast and Central Plains?[51] More broadly, if every feature of the first known metalwork at Erlitou can be attributed to internal developments in pottery, how are we to understand the curious "coincidence" that when the earliest bronze vessels appear in the Chinese archaeological record, BMAC somehow holds the hammered counterparts of certain prevailing shapes? In addition, how can we explain the cultural parallels that Fitzgerald-Huber notes between BMAC and China (the Central Plains and elsewhere) around the centuries of the Erlitou epoch, such as the visually close crosses (compare Figure 23, and Figure 24: 1b, 2, and 3) and stars (compare Figure 24: 1a and Figure 25) in their ornamental vocabularies?[52] Do such relatively simple decorations belong to the category of so-called "universal motifs" that appear independently in unconnected cultures,[53] or do they, along with the *jue* and *gu* at issue, point to "cultural transmission"? If evidence confirms the latter possibility, we must evaluate whether the record supports Fitzgerald-Huber's (1995, p. 52) view of unidirectional diffusion "from Bactria," or instead demonstrates more complex technocultural exchanges (e.g., through reciprocal transfer or pan-regional networks). This requires identifying the relevant cultural groups, production centers, and their sociopolitical and economic contexts in order to properly reconstruct the metallurgical formation of Bronze Age China—provided that its origins trace to external diffusion or stimulus.

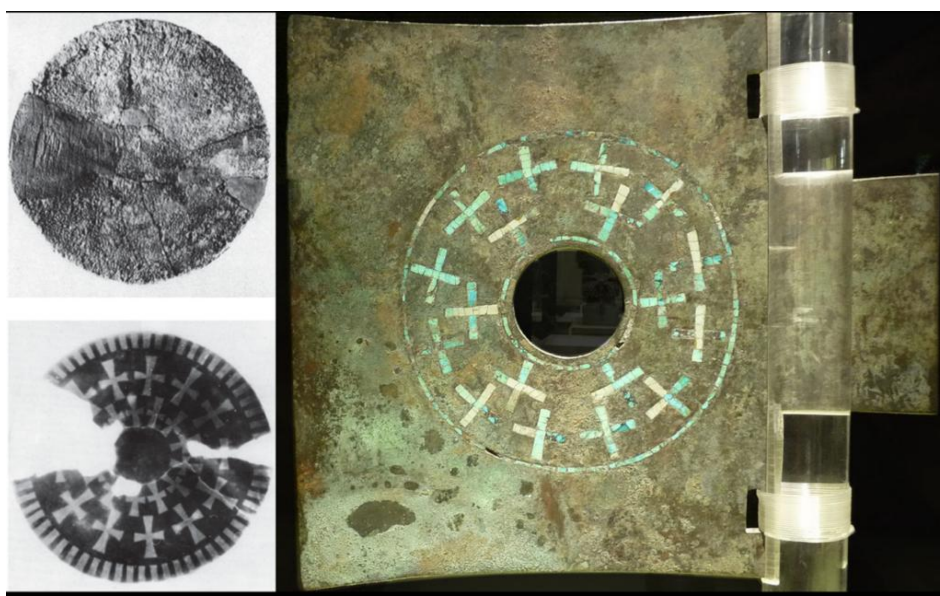

Figure 23. Erlitou mirror (left, Dia. 17 cm, Erlitou III; with X-ray photograph) and unprovenanced *yue*鉞 axe in the Shanghai Museum (right, W. 33 cm): both bronzes carry stylistically similar decorative crosses of turquoise inlay. After Hwang, 2014, p. 622, Figure 13: left; https://zh.wikipedia.org/zh-hk/File:Yue_(weapon)_inlaid_with_cross_pattern._Shanghai_Museum.jpg (accessed 05/11/2023), image in the public domain under the Creative Commons Attribution-Share Alike 4.0 International, 3.0 Unported, 2.5 Generic, 2.0 Generic and 1.0 Generic license, courtesy of H. Sondaz and Shanghai Museum.

[51] Ceramics with a tubular spout have been seen not only from Shandong (by the Dawenkou大汶口 period, ca. 4300–ca. 2500 BC) but also from multiple cultures in the southern and western areas. See Su, 2019, pp. 49-67; Wang and Zhang, 2004, pp. 174-323.

[52] See Fitzgerald-Huber, 1995, pp. 52-59 (compare Figures 10a-b, 11a-c).

[53] Admittedly, the star and the cross are relatively simple forms that can conceivably have been invented more than once in human history, and perhaps easily reproduced and varied. E.g., for the motif of the star polygon dated millennia earlier than BMAC or Erlitou in the Middle Yangzi Valley and nearby regions, see Zhou, 2021, pp. 83-87. For the discussion of the "universal motif," see Bagley, 2015, p. 108. Even falling into the category of "universal motif," some simple patterns or forms, if appearing together as a chain of evidence, will be much more indicative than a single correspondence.

Figure 24. Artifacts with decorative crosses (1a) and stars (1b, and 2–3) from the BMAC ("Bactria–Margiana Archaeological Complex," ca. 2400/2250–ca. 1950/1700 BC) affected sphere: Bronze seal-amulets (1) from Bactria, painted pottery sherd (2) from Altyn-tepe, southern Turkmenistan, and terracotta box with carved openwork from Ak-tepe, southern Turkmenistan. Adapted from Fitzgerald-Huber, 1995, p. 55, Figure 11c–d.

Figure 25. Cast tin-bronze mirror from Tomb 25, Guinan Gamatai貴南尕馬台, Qinghai province. Dia. 8.9 cm. Late stage of Qijia齊家 culture (ca. 2300–ca. 1500 BC). On the left is a Shaman dress of the Numinchens adorned with metal mirrors and bells as an ethnographical inspiration. Photographs adapted from Beijing Daxue Kaogu Wenbo Xueyuan and Qinghai sheng Wenwu Kaogu Yanjiusuo, eds., 2016, p. 130, Figure 116; Jaang, "Long-distance Interactions as Reflected in the Earliest Chinese Bronze Mirrors," p. 35, Figure 1; drawing of the Gamatai mirror (top middle) by the author's team.

At present, with some controversial points (e.g., ceramic imitation of rivets) and radical advocates (e.g., John

D. La Plante[54]), the proposal that the sheet-metal era in China preceded the cast Bronze Age is still stuck in a quagmire without hard evidence. Though some possible candidates are known from BMAC, no tangible pre-Erlitou hammered vessel has been unearthed anywhere in present-day China, much less the Central Plains or its adjacent areas. Yet the various indirect clues noted by Bagley, Fitzgerald-Huber, and others, though strongly contested by Barnard (1980, pp. 7-27) and subject to ongoing scrutiny, cannot be easily dismissed. In particular, Hwang Ming-chorng黃銘崇 (2014, pp. 602-603) has lately identified certain *he*-reminiscent vessels with a tubular spout from Shahdad (e.g., see Figure 19: 3), in addition to the hammered *jue* and *gu* "affinities" noted by Fitzgerald-Huber (1995, pp. 59-63) in the same BMAC-affected region in Southeast Iran. Further west and likely even earlier sheet-metal counterparts of the BMAC and Erlitou vessels, such as a slender-spout pitcher excavated from Tepe Gilweran (Figure 19: 4, ca. 2750–ca. 2250 BC), a site in the old metallurgical center of Luristan in western Iran, has recently been brought to the attention of Chinese academia (e.g., Su, 2021, p. 97),[55] bringing this issue into the context of Bronze Age Eurasia.

FINAL REMARKS

The longstanding lost-wax and sheet-metal debates both have a deep entanglement with the question of the origins of the bronze industry in early China. To me, the first debate is approaching an end, but it is unlikely that the second will be resolved without further archaeological discovery. If a pre-Erlitou sheet-metal tradition of vessel production is ever established—though its existence remains uncertain—such evidence would significantly support the out-of-Steppe-stimulus thesis that I intend to propose in an upcoming study concerning the emergence of bronze metallurgy in China; after all, metal vessels used by the Steppe groups—and in the more civilized Southwest Asia behind them—were predominantly beaten in shape. Such a transition from hammering to casting, of course, could have occurred inside China without external stimulus. Yet if concurrently hammered prototypes of Erlitou ritual bronzes or Qijia "skeuomorphs" someday appear in the archaeological record during the time when metallurgy in China leapt forward to the use of tin bronze (a widely utilized alloy in the contemporaneous Steppe and select adjacent regions), they will be a telltale sign. Even without the support of the arguable sheet-metal tradition, the Steppe stimulus is evident in metal designs (e.g., single-edged knives, Figure 26) and techniques (e.g., tin bronze) in the "Crescent-shaped Cultural-Communication Belt"[56] defined by Tong Enzheng 童恩正 (1987) and later in the Central Plains; the physical evidence of Steppe penetrations farther to the south of Yellow River (e.g., the Seima-Turbino-style spears spotted at the Nanyang南陽 Basin, southern Henan, Figure 27, along with other examples distributed in present-day China, compared to those from the Ural and Altai regions, see Figure 28) is startling but undeniable. With the forthcoming resolution of the lengthy lost-wax debate, it is anticipated that the assertion of lost-wax "ignorance" in Bronze Age China will no longer provide a thoughtworthy justification for the belief in an autonomous development of Chinese bronze metallurgy. Note, however, that this is just a thoroughgoing denial of the claimed absence of lost-wax casting in Bronze Age China, not a wholesale refutation of the independent origins of Chinese metal technology.

[54] Said to present his sheet-metal argument as early as 1972, La Plante radically claims that the Neolithic "eggshell-thin burnished black ware and the heavier unburnished white ware should logically be seen as attempts to copy the various aspects of metal vessels .... the ceramic vessels do not foretell the metal age, as is often assumed; instead they reflect its already arrived presence near but, apparently, not within the Longshan culture"—a conclusion he admitted was "startling because it is more commonly assumed that the metal vessels are based on the pottery" (La Plante, 1988, pp. 252-253).

[55] For relevant details, see the website of the British Museum: https://www.britishmuseum.org/collection/object/W_1936-0613-200 (accessed 07/07/2023); Herzfeld, 1941, plate XXV.7. For further Luristan metalwork and contextual information, see Calmeyer, 1969; Moorey, 1974.

[56] Stretching from Yunnan and Southeast Asia to Northeast China and beyond (e.g., the Korean Peninsula), this arc-shaped zone served as a vital conduit for cultural interactions between China and the Eurasian Steppe. Here, I choose to follow Anke Hein in the English translation of this notion (see Hein, ed., 2014, p. 1).

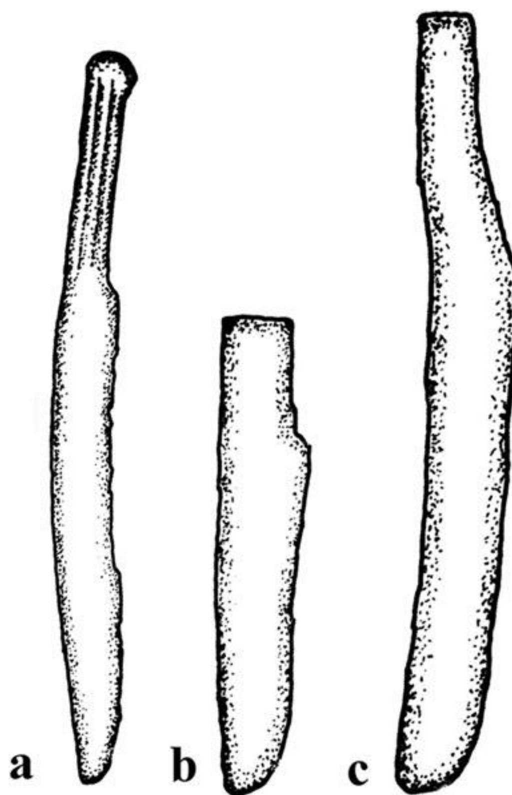

Figure 26. Comparison of single-edged knives: a from Russian Altai of the Elunino culture (ca. 2400/2300–ca. 1700 BC), length around 22cm; b from Shimao石峁, northern Shaanxi, ca. 2200–ca. 1800 BC, length around 10cm; c) from Erlitou二里頭, Central Plains of China, ca. 1700–ca. 1600 BC, length around 25.5cm. After Rawson, 2017, p. 4, Figure 4.

Figure 27. Part of a bundle of four metal spears in the Seima-Turbino style from Xiawanggang下王崗 hoard H181, Xichuan淅川, Henan province. After Li, 2018, p. 165, Figure 4.28.

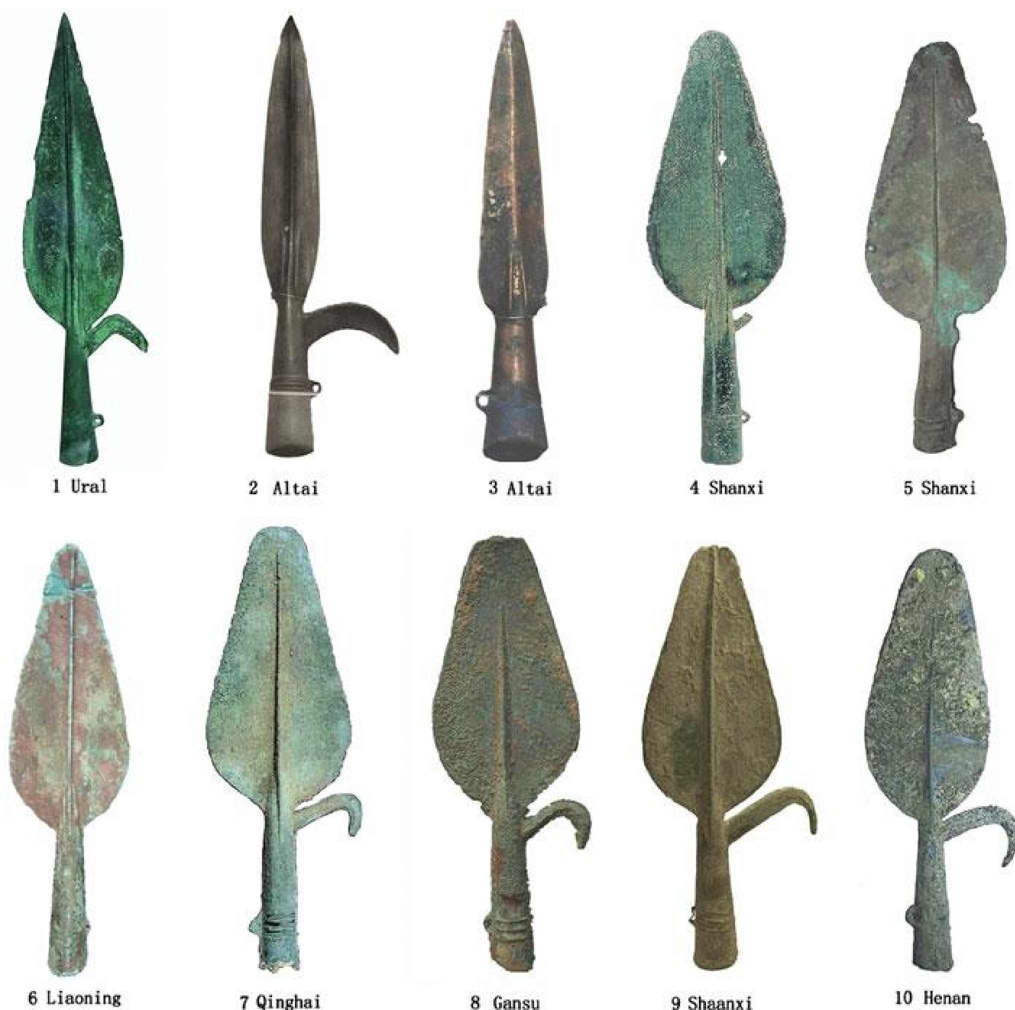

Figure 28. Spearheads in the Seima-Turbino style from China (4–10, some are unprovenienced pieces) in comparison to those in the Ural and Altai regions (1–3). After Lin & Liu, 2017, p. 2, Figure 1.

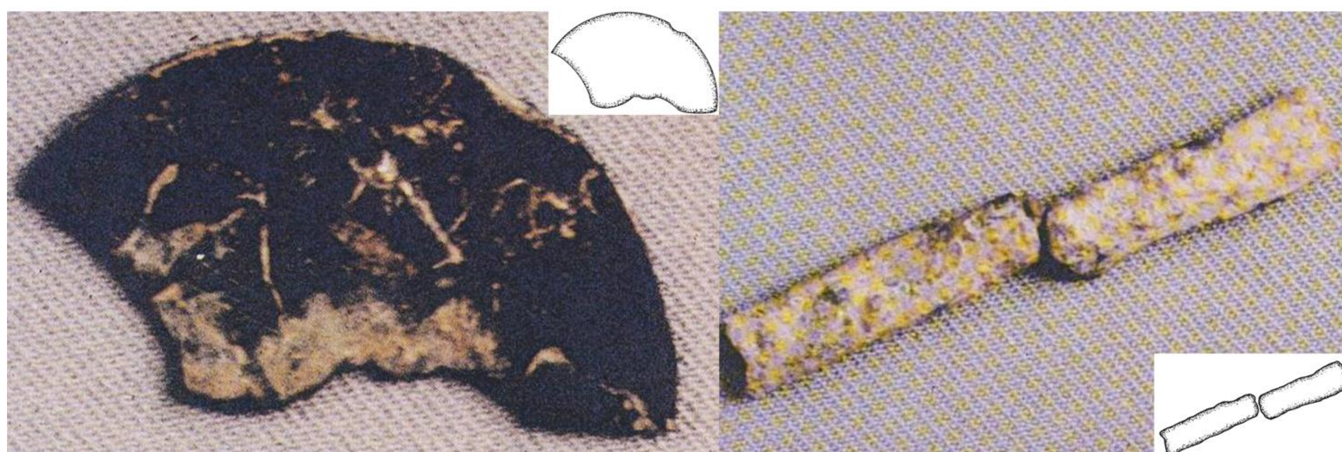

Figure 29. Brass artifacts excavated from Lintong Jiangzhai臨潼姜寨, Shaanxi province; site dated to ca. 4700–ca. 4000 BC. Left: sheet (acc. T74F29:15). Dia. 4.8cm; T. 0.1cm; zinc content, 25.56%. Right: tube (in two pieces; acc. T259②:39), L. 5.0cm; zinc content, 31%. Images after Su et al., 1995, color plates 11 and 12. Illustrations drawn by the author's team.

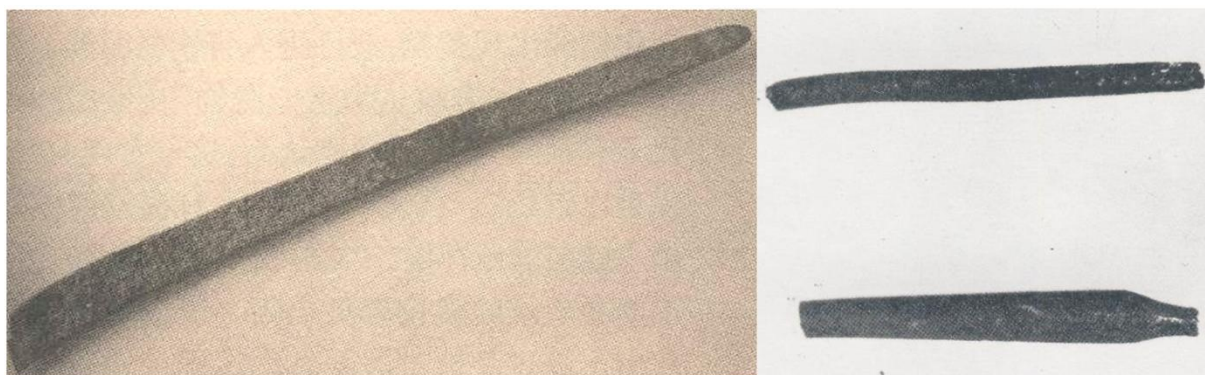

Figure 30. Post-Jiangzhai姜寨 brass artifacts in prehistoric China, not to scale: hairpin-like object (left, acc. T9②) from Weinan Beiliu渭南北劉 (Shaanxi province, the fourth millennium BC), size unclear, zinc level between 27% and 32%; two damaged awl-like objects (right, acc. T110②:11 and T21②:1) from Jiaoxian Sanlihe (Shandong province, ca. 2300–ca. 1800 BC), L. 3.1 and 3.4 cm; zinc levels respectively 20.2% and 22.8% for the two measured ends of T110②:11, and 26.4% and 23.4% for the two measured ends of T21②:1. After Su, 2012, p. 43, Figure 16.

The origins of copper-based metallurgy in China are complex, shaped by diverse traditions and marked by multi-layered developments, with metalworking serving as a crucial aspect of the technological toolkit. Indeed, the foundations and inceptions of bronze metalworking in China remain inadequately understood; this is especially true concerning the interactions between external and internal traditions. To gain a deeper understanding of how these interactions affected the emergence of bronze metalworking that can be distinctly identified as "Chinese," it is essential to re-evaluate the techno-cultural phenomenon of "Eurasia in China" (e.g., Figures 26–28) while also examining the coordination of internal resources that propelled the formation of Bronze Age China. To me, the intricate and distinctive bronze metalworking of the Chinese Central Plains could not have emerged from mere passive learning or unprepared encounters with foreign metalworkers. To exemplify, the molding of some pottery pieces (e.g., the hollow legs of lobed tripods) in Neolithic China has been proposed by Hwang (2014, p. 586) as a basis for the invention of section-mold casting (Figure 4: right),[57] a point that is thought-provoking but that overlooks the use of sectional molds outside China (e.g., see Maryon & Plenderleith, 1954, p. 626; Lechtman, 1988, pp. 352-353). Hwang's teacher, the late Harvard professor K. C. Chang, also maintained that section-mold casting "was distinctively Chinese and in all likelihood developed indigenously" (Chang, 1983, p. 106), concurring with the opinion of Noel Barnard, among others.[58] Though section-mold use long predated the Chinese use of it (see my review of the lost-wax debate above), in view of the more prevalent Steppe application of open or bivalve molds nearby, we indeed need to consider the likelihood that the first sectional molds in China were not directly introduced, but rather were developed based on simpler stone molds and facilitated by pottery (Hwang, 2014, pp. 629-632). Regardless, the use of molds in pot-making in Neolithic China may have played some role in assisting the smooth adaptation or reinvention of section-mold casting on the eve (e.g., at the Taosi陶寺 site in Shanxi province, ca. 2300–ca. 1900 BC, a metal bell with a height of 2.65 cm and a thickness of 0.28 cm was cast using the section-mold process) or at the dawn (e.g., at the Erlitou site, Figures 8–10) of Bronze Age China.[59] Furthermore, significant innovations and improvements in the Erlitou and post-

[57] Hwang's (2014, p. 586) point, which holds a certain rationality in itself, is likely inspired by David Keightley's proposal of the "mentality" in the "making of China": "Unlike the more practically shaped Northwest pots, most of which would have been built up holistically by coiling and shaping at one time, many of the characteristic East Coast pots [...] would have required the separate molding and piecing together of several elements-feet, stand, legs, spout, neck, handle, and so on, in a prescriptive method of manufacture. This distinction between holistic and prescriptive is of fundamental importance to my attempt to link artifacts to mentality" (Keightley, 1987, p. 128). For a similar but more problematic proposal (the "Chinese" way of "modular" art production) and the critique of it, see Ledderose, 2001; Bagley, 2008b, pp. 113-120.

[58] Cf. the similar argument in Barnard, 1961; Barnard and Tamotsu, 1975. In fact, the dichotomy of section-mold casting in China and lost-wax casting in the West is a popular cliché shared by many Mainland Chinese as well: for example, as pronounced by Su Bingqi蘇秉琦, "Chinese bronzes of Shang dynasty were cast using composite clay molds (...), which was in a tradition completely different from the lost-wax method used in ancient Western civilizations (including India)" (Su, 2019, p. 91).

[59] At least since the Middle Neolithic period, various sites had witnessed the use of the model/mold in making ceramics, such as Qin'an Dadiwan秦安大地灣 (Gansu), Baoji Beishouling寶雞北首嶺 (Shaanxi), and Lintong Jiangzhai臨潼姜寨 (Shaanxi). That long-lasting Neolithic practice within present-day China likely provided a foundation of technical expertise in

Erlitou earthen section-mold construction that gave rise to unambiguous "Chinese" ritual bronzes (e.g., Figures 4, 5, 8–11, and 15) would have been impossible to achieve without pottery tradition of long standing behind them (see Peng, 2020, pp. 13-24, for relevant details). Vessels are the most common type of artifacts in the regions centered on the Middle Yellow River valley, whether in Neolithic ceramic or Bronze Age metal assemblages. The ritual significance of some ceramics has long been acknowledged to have played a notable role in the rise of comparable bronzes in early China (e.g., compare Figures 15–17). In addition to pottery and its associated practices—such as a profound understanding and sophisticated use of clay, as well as advancements in pyrotechnology essential for firing pottery—the technological and ritual dynamics that facilitated the rise of bronze metallurgy in early China may have also been significantly influenced by the production and consumption of jade, along with other native resources in prehistoric China. To introduce an additional layer of complexity, it is important to consider whether any indigenous metalworking traditions in China predated the emergence of revolutionary bronze metallurgy. This issue has long been important, yet it has often been overlooked or avoided due to the contentious evidence surrounding the intriguing Jiangzhai姜寨 brass from Xi'an Lintong西安臨潼 in Shaanxi province (Figure 29), dated to the fifth millennium BC, along with other copper-zinc artifacts from the Middle to Late Neolithic period (Figure 30). The intricate origins of metal-making in China will be explored in greater depth in an upcoming publication, likely a book.

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transferring desired shapes, replicating available designs, and assembling separate pieces in clay. Of course, the transition from pottery production to metal casting required artisans to adapt their mold-making techniques to handle new properties of clay that, if used as a mold, could withstand the impact and scorching of heavy molten metal without disshaping or clay-metal adhesion. At first, metalworkers had to experiment with various attempts by, for example, reducing the mud content from the washed loess and blending it with fine sands and plant ashes. See Su et al., 1995, p. 17; Su, 2014, pp. 352-353.

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