SINO-PLATONIC PAPERS

Number 265 January, 2017

A Study on the Origin of Chinese Lost-wax Casting from the Perspectives of Art, Technology, and Social Agency

by
Peng Peng

Victor H. Mair, Editor
Sino-Platonic Papers
Department of East Asian Languages and Civilizations
University of Pennsylvania
Philadelphia, PA 19104-6305 USA
vmair@sas.upenn.edu
www.sino-platonic.org

SINO-PLATONIC PAPERS

FOUNDED 1986

ISSN
2157-9679 (print) 2157-9687 (online)

SINO-PLATONIC PAPERS is an occasional series dedicated to making available to specialists and the interested public the results of research that, because of its unconventional or controversial nature, might otherwise go unpublished. The editor-in-chief actively encourages younger, not yet well established, scholars and independent authors to submit manuscripts for consideration. Contributions in any of the major scholarly languages of the world, including romanized modern standard Mandarin (MSM) and Japanese, are acceptable. In special circumstances, papers written in one of the Sinitic topolects (*fangyan*) may be considered for publication.

Although the chief focus of *Sino-Platonic Papers* is on the intercultural relations of China with other peoples, challenging and creative studies on a wide variety of philological subjects will be entertained. This series is **not** the place for safe, sober, and stodgy presentations. *Sino- Platonic Papers* prefers lively work that, while taking reasonable risks to advance the field, capitalizes on brilliant new insights into the development of civilization.

Submissions are regularly sent out to be refereed, and extensive editorial suggestions for revision may be offered.

Sino-Platonic Papers emphasizes substance over form. We do, however, strongly recommend that prospective authors consult our style guidelines at www.sino-platonic.org/stylesheet.doc. Manuscripts should be submitted as electronic files, preferably in Microsoft Word format. You may wish to use our sample document template, available here: www.sino-platonic.org/spp.dot.

Beginning with issue no. 171, *Sino-Platonic Papers* has been published electronically on the Web at www.sino-platonic.org. Issues 1–170, however, will continue to be sold as paper copies until our stock runs out, after which they too will be made available on the Web.

Please note: When the editor goes on an expedition or research trip, all operations (including filling orders) may temporarily cease for up to three months at a time. In such circumstances, those who wish to purchase various issues of *SPP* are requested to wait patiently until he returns. If issues are urgently needed while the editor is away, they may be requested through Interlibrary Loan. You should also check our Web site at www.sino-platonic.org, as back issues are regularly rereleased for free as PDF editions.

A Study on the Origin of Chinese Lost-wax Casting from the Perspectives of Art, Technology, and Social Agency

Peng Peng

Princeton University

Recently it has been hotly debated whether the lost-wax technique really existed in Bronze Age China. As my study has verified,[1] however, Eastern Zhou lost-wax castings, such as the famous *jin* (altar table) from Henan Xichuan 淅川 Xiasi 下寺 M2 and the *zun-pan* (wine service) set from Hubei Suixian 隨縣 Leigudun 擂鼓墩 M1, make it clear that early Chinese foundries could well have relied on using section molds even after they had already begun to use the lost-wax process with sophistication. This means that it is possible that Chinese casters had mastered lost-wax or similar processes considerably earlier. The question remains, was the lost-wax process independently developed in China, or was it introduced or perhaps its development stimulated from outside? When, where, why, and how was the art of lost-wax casting transmitted? At present there are three main hypotheses: (1) that the lost-wax process was developed locally in China from the earlier method of "burn-out" casting, (2) that the lost-wax process was introduced from the southwest, and (3) that the lost-wax process was introduced from the north. I will test these hypotheses using known archaeological materials and look for new clues.

HYPOTHESIS NO. 1: INDEPENDENT INVENTION IN CHINA?

Eastern Zhou lost-wax castings make it clear that early Chinese foundries still relied on using section molds in many cases even when they had already learned to use the lost-wax process at a

1 My study, presented in the 78th Annual Conference of SAA (Society of American Archaeology) at Honolulu, 4/2013, is in press.

sophisticated level. This makes it possible that Chinese casters might have mastered lost-wax or similar processes considerably earlier. Barnard has found fiber-like imprints on the swing handle of some early bronzes in the *lingnan* 嶺南 region (Guangdong, Guangxi, and Hainan provinces), but no "mold mark" is visible, showing that its model might have been made of a rope that would then have been incinerated and cleared away.[2] According to Barnard, such a "lost-cord" process emerged in the *lingnan* region no later than the beginning of the Spring and Autumn period.[3] Tan also observed a similar phenomenon in even earlier bronzes.[4] For instance, the swing handle of a double-owl *you* in the Shanghai Museum, attributed to the Anyang period (c. 1200–1050 BC) (Fig 1.1, 2) is designed as an intertwined rope, on which neither a mold mark nor an erased trace has been found; however, on both ends of the handle, the mold mark appears with the imprint of a string bundle (see Fig 1.3). [5]

2 Barnard 1996 (Chinese version, *Sichuan Wenwu* 4 [1996]): 75; Hua 1999: 179.

3 Hua 1999: 179.

4 See Tan 2007a (most points of this article were published earlier in Tan 1994).

5 Tan 2007a: 38.

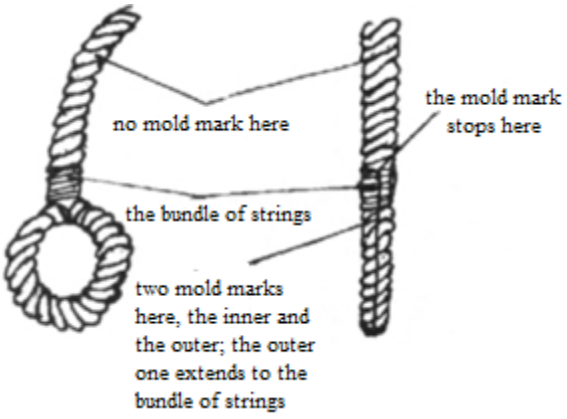


Figure 1. Double-owl *you* in the Shanghai Museum. Anyang period. H.20.5 cm. (1) Vessel, (2) the swing handle, and (3) its diagram. Sources: Chen 2004: 312, Pl. 153; Tan 2007: Fig 5.

According to Tan, the manufacturing procedure for this swing handle was as follows: the rope model with the string-tied loop at the ends was coated with the investment mold, which was made sectional only around the "loop"; afterward the rope-model was burnt to ashes by baking and the ashes cleared off from the "loop" areas; after the small "section-molds" around the loops were reassembled, the molten bronze was then poured in, and the handle was finally cast.[6] According to Tan (1994), a swing handle with the same features has also been found on another Anyang-style vessel, in the Changsha Museum of Hunan.[7] Actually, according to Tan's observations, a rope-like swing handle without a mold mark appeared no later than the Transition Period (c. 1300 BC), represented by a *hu* from Beijing Pinggu 平穀 Liujiahe 劉家河 (Fig 2).[8] Later examples include three *yan* from Anhui Tongling 銅陵 in the Spring and Autumn period (Fig 3).[9] These artifacts, according to Tan, were all made by Barnard's "lost-cord" process, or more generally, the "burn-out" process, in the term bestowed by Tan himself.[10]

6 Tan 2007a: 38–39; Hua 1999: 179–180.

7 Tan 2007a: 38; Hua 1999: 180.

8 Tan 2007a: 38; 2007b: 491.

9 Tan 2007a: 38; Hua 1999: 180.

10 Tan 2007a: 38; Hua 1999: 180.

Figure 2. *Hu* from Beijing Pinggu Liujiahe. Transition Period, c. 1300 BC. Vessel (left) and its swing handle (right).

Figure 3. One of the three *yan* from Anhui Tongling, in the Spring and Autumn period. H. 58.2 cm. Vessel (1) and details of the swing handle (2–4). Sources: 1 & 2: *Zhongguo gudai yishu zhuzao xilie tushuo* (No. 39): color plate, Fig 2, 3 & 4: Zhou et al. 2007: Figs 12.1, 12.2.

Tan's "burn-out" examples include not only the supposed "lost-cord" cast pieces mentioned above, but also other bronzes in the following categories: (1) artifacts that have narrow and deep sunken decorations throughout the body and are cast from a limited number of section molds, such as the depiction of a tiger from Jiangxi Xingan 新干 (c. 1300 BC) (Fig 4.1), and an Eastern Zhou *nao* bell from the Zhejiang Changxing 長興 (Fig 4.2).[11] According to Tan, when a mold section is removed from the model in a certain direction, some protruding ridges that remain on it, corresponding to the groove-shaped ornaments of the model, would unavoidably be broken off (see diagram, Fig 4. 3).[12] (2) Artifacts with indented ornaments having an opening narrower than the interior, such as the *gui* of the Spring and Autumn period from Zhejiang Changxing (Fig 5.1–2; for corresponding diagram, see Fig 5.3).[13] (3) Artifacts with hooked undercutting ornaments, such as the *nao* bell from Jiangxi Xingan (Fig 6).[14] According to Tan, for all these artifacts, the mold decoration cannot be kept intact when removing the mold section from the model. Thus, his "burn-out" process had to be adopted in the manufacture of all these artifacts.[15] As Tan argues, the model for such items had to be (at least partly) made of a material that is easy to carve on as well as to burn (e.g., wood, plant fiber, starch). To clear off the burned ashes, an investment mold for these artifacts also had to be wholly or partly made into sections, leading to the mold marks on the objects.[16]

11 Tan 2007a: 37.

12 Tan 2007a: 37.

13 Tan 2007a: 38.

14 Tan 2007a: 38.

15 Tan 2007a: 37–38.

16 Tan 2007a: 38.

Figure 4. (1) Bronze tiger from Jiangxi Xingan Dayangzhou. c. 1300 BC. (2) Decoration of the *nao* bell from Zhejiang Changxing, Spring and Autumn period. (3) Diagram of the bell (drawn by Tan Derui). Sources: 1–3, respectively, Jiangxisheng et al. 1997: Pl. 49; Tan 2007a: Pl. 3, Fig 2.

Figure 5. *Gui* from Zhejiang Changxing. Spring and Autumn period. H. 9.9 cm. (1) Side view, (2) top view, and (3) diagram, all drawn by Tan Derui. Sources: *Zhongguo gudai yishu zhuzao xilie tushuo* (No. 36): color plate, Fig 1; Tan 2007a: Fig 3.

Figure 6. One of the three *nao* from Jiangxi Xingan Dayangzhou. 13th cent. BC. H. 43.5 cm. artifact (1) Detail of decoration (right). Source: Steinke 2014: Figs 28, 29.a.

Although Tan was among the first to understand bronzes in the abovementioned categories (1)–(3) as "burn-out" castings, his argument on the difficulty of withdrawing molds from a model is not new. The discussions centered on transferring the decoration between positive and negative have a long history in the literature.[17] Differing with Tan, most scholars, such as Nickel and Zhou et al., chose to solve this "problem" by suggesting that the undercutting decorations were made from molds.[18] However, undercuts as intricate as those using the illustrated openwork ornament (Fig 7.2) were still achievable by Houma foundries during the middle of the first millennium BC by way of transfer, demonstrated by the baked clay pattern blocks with identical decorations (Fig 7.1).[19] Obviously none of Tan's examples has undercuts as deep or tricky as the Houma piece. Tan's diagrams (Figs 4.3, 5.3) seem to fit the technical logic, but, as was commented concerning similar diagrams drawn by Nickel[20]: "diagrams and logic are very poor guides to the capabilities of a craftsman with years of practice and centuries of knowhow behind him."[21]

17 Bagley 2009: 49.

18 See Nickel 2006: 11–16, 33; Zhou et al. 2007: 47.

19 Bagley 2009: 50–51.

20 Nickel 2006: 24, Fig 13; 25, Fig 19.

21 Bagley 2009: 51.

Figure 7. A clay model used to make duplicate molds for casting openwork ornaments (top), and a bronze ornament with almost the same design (bottom) found in the ancient Houma foundry. Source: Bagley 2009: Figs 17, 18.

Barnard and Tan's "lost-cord" examples are indeed thought-provoking. However, some of them, such as the handles of the Tongling *yan* (Fig 3.1), as Zhou et al. noticed, seem to be cast from mold sections, judging by the vague long marks on them (Figs 3.3, 3.4).[22] In addition, with almost the same design as the double-owl *you* in Shanghai Museum (Fig 1), another piece from the Fogg Art

22 Zhou et al. 2007: 48.

Museum (Fig 8), not noted by Tan, also possesses the swing handle with the "string bundle" on the ends.

Figure 8. The double-owl *you* in the Winthrop collection, Fogg Art Musuem. H. 19 cm. Anyang period. Artifact (1, 2) and detail of its swing handle (3, 4). Source: Bagley 1987: Fig 153.

Yet this swing handle was obviously cast by the section-mold process, based on the clear mold mark that runs through. Was this section-mold cast handle an imitation of the supposed "lost-cord" cast piece of the Shanghai Museum *you*? Or, was the latter also a section-mold casting whose mold mark had been perfectly polished? Is it possible, as Zhou et al. argued,[23] that all the supposed "lost-cord" castings listed by Tan were actually section-mold castings? According to Zhou et al., the "burn-out"/"lost-cord" process is not tenable, because (1) it is not necessary to burn out the cord even if one really was used as the model; in other words, mold sections could easily be made from such a cord-model; (2) the molds, after baking, usually would not be opened again before casting, and therefore the burnt ashes are difficult to clear, especially for those without any mold mark—with ashes within the mold, a casting cannot be well cast.[24] Such points, though not completely persuasive, do offer useful inspirations. Furthermore, was the supposed "lost-cord"/"burn-out" process, if it existed, really the source for the lost-wax process of early China? Mainstream scholars like Tan and Hua believe so.[25] However, as Zhang points out, the "burn-out" process, "used on the bronzes of Late Shang or the Shang–Zhou Transition periods," was separated from the Eastern Zhou lost-wax process both in time and in technology, and therefore cannot be the source for the latter.[26] Though several assumed "lost-cord" castings might date to the Spring and Autumn period,[27] not as early as Zhang supposed, it is indeed not indisputable to consider the lost-wax process to have been derived from the technically distinct "burn-out" process. In other words, a gap has to be bridged if taking the former as the source for the latter; otherwise the lost-wax process would have originated in other ways, such as ones introduced or stimulated from outside.

23 Zhou et al. 2007: 46–48.

24 Zhou et al. 2007: 47.

25 See Tan 1994; 2007a. Hua 1999: 179–180.

26 For details, see Zhang (2007).

27 See Tan 1994, 2007a; Hua 1999: 179.

DIFFUSION FROM THE SOUTHWEST?

Since some realistic and highly three-dimensional bronzes supposed to be lost-wax castings first were discovered at the necropolis of Jinning 晉寧 Shizhaishan 石寨山 in the Dian 滇 area of Yunnan province in the 1950s,[28] many scholars have believed that the Chinese lost-wax process was introduced from the southwest of modern China or from even farther away (e.g., Southeast Asia or South Asia). For instance, as Barnard suggested, investment casting, including variations such as "lost-wax," "lost-cord," and "lost-lead" methods, was introduced to the Chu 楚 region via Yunnan and perhaps also the *lingnan* region, ultimately from Southeast Asia (e.g., Thailand).[29] However, the lost-wax method that emerged in Yunnan might not be as early as Barnard supposed (c. seventh–sixth centuries BC)[30]. According to recent research, the incipient copper-based metallurgy in Yunnan (c. thirteenth–eighth centuries BC), represented by the hammering and open/bivalve-mold casting activities at the Haimenkou 海門口 site, was probably introduced from steppe-related cultures in the north in the late second millennium BC,[31] and also likely was influenced by the Indochina Peninsula, especially the bronze culture in northeast Thailand.[32] Around the seventh century BC, a group of copper and bronze drums, the first large section-mold castings, appeared in west-central Yunnan, represented by the ones discovered at Chuxiong 楚雄 Wanjiaba 萬家壩.[33] The first lost-wax castings emerged in Yunnan probably no earlier than the Middle/Late Warring States period(c. 350 BC), represented by a three-dimensional openwork plaque from Chenggong 呈貢 Tianzimiao 天子廟 M41 (Fig 9)[34]; slightly later

28 See the series of archaeological reports: Yunnan1956; 1959a; 1959b; 1963; 1964.

29 Barnard 1996 (Chinese version, *Sichuan Wenwu* 4 [1996]): 75–76.

30 Barnard 1996 (Chinese version, *Sichuan Wenwu* 4 [1996]): 76.

31 For details, see Chiou-Peng 2009; 2011.

32 Li 2011: 157.

33 Chiou-Peng 2011: 20–21.

34 Li 2011: 64. For burial context, see Kunming 1985.

lost-wax examples include several similar plaques such as the hunting scene from Jiangchuan 江川 Lijiashan 李家山 M13, probably around the third century BC (Fig 10).[35]

Figure 9. An openwork plaque from Yunnan Chenggong Tianzimiao, M41. H. 6.5 cm. Mid-late Warring States period, c. 350 BC. Source: *Zhongguo qingtongqi quanji* (14): 124.

35 Li 2011: 64; Meyers 2011: 34–35. For burial context, see Yunnan 1972.

Figure 10. A hunting scene placque from Yunnan Jiangchuan Lijiashan M13. Late Warring States period, third century BC. L. 12.5 cm. Source: *Zhongguo qingtongqi quanji* (14): 126.

The Shizhaishan assemblage, although possessing many lost-wax bronzes, is basically in the range of the Western Han dynasty (202–8 BC).[36] The reason Barnard[37] and some other scholars[38]

36 Li 2011: 5.

overestimated the time of the Yunnan lost-wax casting is probably related to a *single* and *problematic* radio-carbon dating of Jiangchuan Lijiashan M21, which yielded lost-wax artifacts, shown as 625 ± 105 BC (or 550 ± 105 BC, if taking the radiocarbon half-life as 5570 rather than 5730 years).[39] This data was questioned by scholars such as Wang[40] and Pilazzoli,[41] and now is basically abandoned by academia.[42] As no local technical tradition is known, the lost-wax process seems to have been imported, probably from the steppes of Eurasia, likely with other metallurgical techniques such as tinning, gilding, chasing, and inlay.[43] Some newly emerged designs and artifacts, such as animal combat and horseback-riding motifs, trident-shaped iron swords with bronze hilts, and animal-shaped openwork plaques, also support the likelihood of "steppe" influence.[44] Chu 楚 cultural impact, although limited, also began to appear, perhaps partly related to the arrival of the Chu army headed by Zhuang Qiao 莊蹻 in the early third century BC, if what the received texts record[45] is true. Now Barnard's suggestion that the investment-casting technique was transmitted from Yunnan and southern China to the north[46] seems to be incorrect, perhaps even opposite to the true case.

Actually the Yunnan industry is the earliest large-scale lost-wax production in Southeast Asia, although small objects such as figurines and bracelets *might* have been made by this process during the early Bronze Age of Southeast Asia.[47] For instance, bangles (bracelets, ankles, and rings) believed

---

37 Barnard 1996 (Chinese version, *Sichuan Wenwu* 4 [1996]): 76.

38 E.g., Hua 1999: 179; Tan 1989: 42–43.

39 See the Radiocarbon-dating Report 4 (*Kaogu* 考古 1977[3]: 200–204): 203.

40 Wang 1980: 67.

41 Pilazuoli 1990: 78.

42 Li 2011: 13.

43 Li 2011: 152–155.

44 See Qiu 2006: 239–240; Han and Li 2009: 178–179; Li 2011: 152–155.

45 See *Shiji:*史記 vol. 116; *Houhanshu,*後漢書 , vol. 86.

46 Barnard 1996 (Chinese version, *Sichuan Wenwu* 4 [1996]): 75–76.

47 Meyers 2011: 34, 39.

to be made by the lost-wax process, seem to be characteristic of northeast Thailand[48]: at the Ban Na Di site (lasted c. 1200 BC–200 AD?), insect wax was said to be found between the central clay core and the corroded metal of one bracelet from Mortuary Phase 1b, Level 7 (c. 900–500 BC?) as well as with two other bracelets there.[49] Yet it is quite surprising that wax could survive the casting process. Bangles assumed to have been made by the lost-wax process have also been found at other northeast Thai sites such as Non Nok Tha and Ban Chiang.[50] On a parallel in terms of technology with northeast Thailand, Vietnam *might* also have grasped the investment casting process no later than the Go Mun phase (formerly understood to be c. 1000–500 BC[51]), judging by certain presumably lost-wax cast items,[52] although no convincing evidence has been given. Higham and Kijingam also suggest the use of the lost-lead process with the stone molds based on a lead-tin casting sprue.[53] However, the chronology of Bronze Age Southeast Asia, especially in northeast Thailand, is a long-debated issue. As White insisted, bronze metallurgy appeared in northeast Thailand around 2000 BC, represented by the early metallurgy at Ban Chiang (c. 2000–1700 BC).[54] However, Higham believed that bronze emerged at Ban Chiang, and elsewhere in Southeast Asia, no earlier than 1500 BC.[55] Recently, based on Higham and Higham's new chronological framework by analyzing seventy-five radiocarbon datings from the well-stratified site Ban Non Wat[56] (close to the site Ban Chiang), more scholars[57] are willing to believe that metalworking started in Southeast Asia shortly before 1000 BC. If we accept the new

48 White 1988: 178.

49 Higham and Kijingam 1984: 81, 124; White 1988: 178.

50 For details, see Agrawal 2000.

51 For details, see Murowchick 1988.

52 For details, see Higham 1988.

53 See Higham and Kijingam 1984: 14.

54 E.g., White 1988, 1990, and 2008.

55 E.g., Higham 1988; 1996: 240.

56 For details, see Higham and Higham 2009.

57 E.g., Bunker and Latchford 2011: 1–3.

chronology, the time for the lost-wax casting there would also be postdated correspondingly. Now it seems that lost-wax casting in the Southeast Asian lost-wax process was practiced not much earlier (if not later) than China.[58] Actually there is not even any conclusive evidence to demonstrate whether the lost-wax process was ever practiced in Bronze Age Southeast Asia, because castings as simple as the bangles could easily have been cast by the piece-mold method, then polished well. The announcement that wax was discovered within the casting, as mentioned above, also requires further consideration.

Compared with Yunnan and Southeast Asia, Sichuan is more closely connected to the Central Plain of China (the Middle Yellow River valley) and the Middle Yangzi region in bronze technology, as evidenced by the section-mold casting practiced at Sanxingdui 三星堆.[59] Recently Davey suggests the use of the lost-wax process based on his inspection of a mask from Sanxingdui Pit 2 (Fig 11.1) (c. twelfth century BC).[60] According to him, the rear of the mask shows parts of the "investment mold" such as those attached to the nose cavity, and a scratch close to an opening seems to be a "false cut" originally made in the wax model (Fig 11.2). Based on this single piece evidence, Davey suggests, "The wax model of the mask would have been made from sheets of wax. The openings would have been cut with a knife…"[61] By suggesting that the 4,600 cowrie shells possibly came from the Indian Ocean, Davey linked Sanxingdui with South Asia, one early center at which the lost-wax process was practiced, and argued that the technique could have been transmitted by the same path as the later

58 The Southeast Asian lost-wax process, if not practiced considerably earlier than Bronze Age China, would not seem to be the source for the latter, where the lost-wax process was practiced far more sophisticatedly. Yet it is not impossible that the lost-wax process, once mastered, even if not deeply explored, by skilled Chinese casters, could still have quickly attained a high level of practice. Considering the long-lasting connection between Southeast Asia and the *lingnan* region (for details, see Higham 2006), which in turn was linked to the Chu region at Hunan during the early Eastern Zhou period, based on bronzes (Fong 1980: 256), it is still possible that the lost-wax process in early China might have been introduced from Southeast Asia. However, since there is still no conclusive evidence for the use of lost-wax casting in Southeastern Asia, there is no convincing reason to follow this suggestion further.

59 Xu 2001: 60.

60 Davey 2009: 151.

61 Davey 2009: 151.

"south-western silk road."[62] As the "investment mold" remains cited by Davey could also have been left by the mold sections, and the scratch could be a false cut made on the clay model, Davey's argument is far from persuasive. The proposal for the connection between Southwest China and South Asia based on the cowrie shells is thought-provoking, but the shells from Sanxingdui have not been verified as originating from the Indian Ocean, and similar discoveries are widely distributed in China, such as at Anyang in the Chinese Central Plain and Dadianzi 大甸子 in Inner Mongolia. Does this mean that Anyang and Dadianzi also got their casting technique from India? Obviously not. Perhaps the only point these cowries make is that trade was probably going on everywhere, over vast distances.

62 Davey 2009: 152.

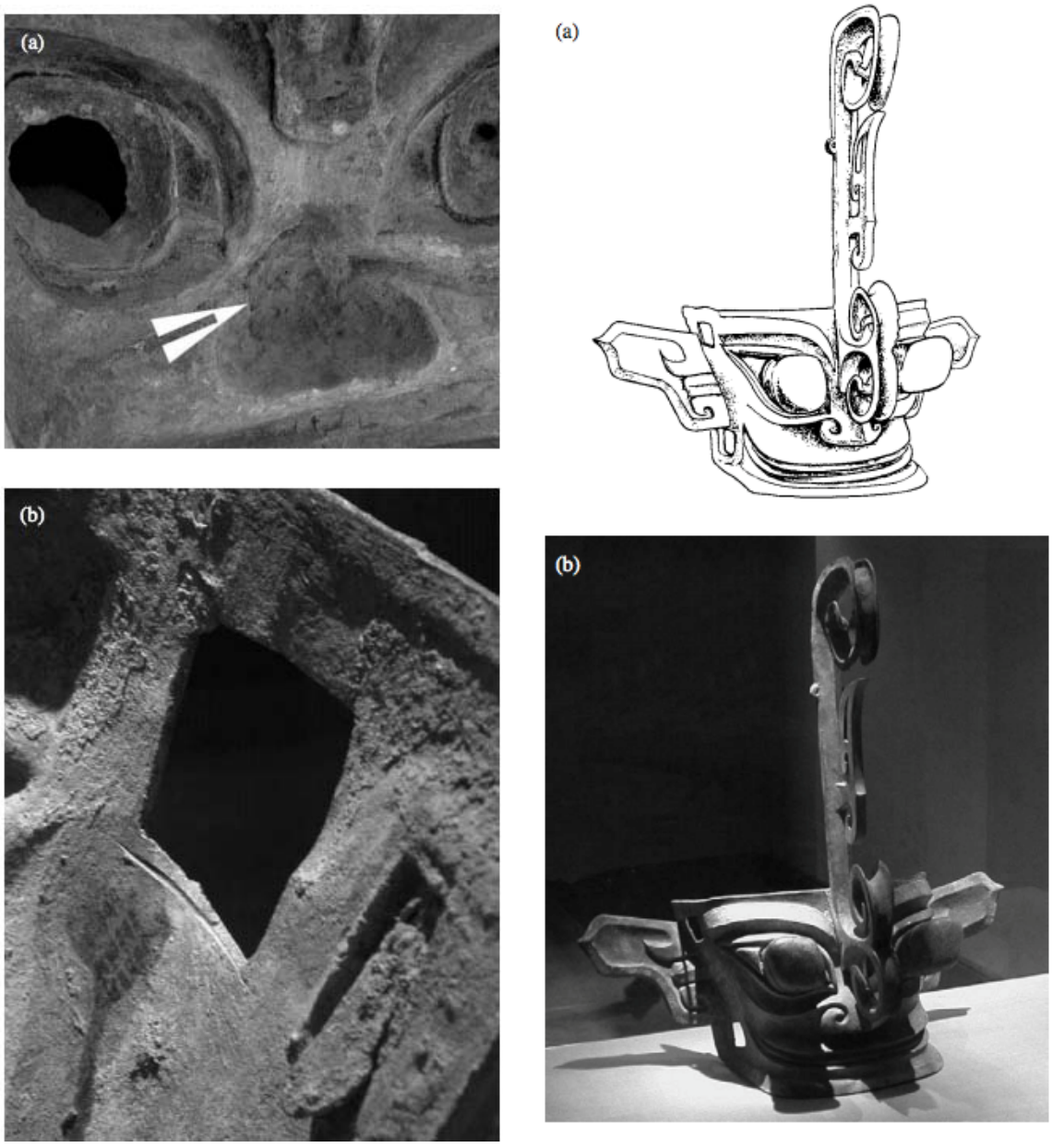


Figure 11. (1): Bronze mask with trunk-like projection from Sichuan Guanghan Sanxingdui K2. H.84.3 cm, Height of mask 31.7 cm. Drawing (a) and photograph (b). (2): Detail of the rear of the mask showing mold remains in the nose cavity (a) and possible "false cuts" originally made in the wax model. Source: Davey 2008: Figs 4, 5.

DIFFUSION FROM THE NORTH?

Rather than from the southwest, the lost-wax technique is more likely to have come from the north, via the region variously termed the Northern Corridor, the Northern Frontier, or the Northern Zone.[63] This region, "stretching from Xinjiang and Gansu in the west to Jilin in the east and including parts of Inner Mongolia and Liaoning, along with much of Hebei, Shanxi, and northern Shaanxi,"[64] includes two geographically and culturally distinct zones: the Northwest (or *xibei* 西北) and the Northeast (or *dongbei* 東北), divided by the Taihang 太行 Mountains, roughly following the boundary between modern Shanxi and Hebei provinces.[65] As one scholar concluded, "whatever the date of its arrival, the lost-wax process is likely to have come to China by way of the northern steppes, and highly sophisticated technological transfer along this route is attested as early as the first century of the Anyang period[66] by the horse-drawn chariot, a West Asian invention that figures in Anyang burials."[67] As horse-drawn chariotry was a technological complex involving construction, use, and maintenance,[68] it seems likely that Anyang around 1200 BC adopted chariotry, horse breeding, and

63 Bunker et al. 1997: 18.

64 Bagley 1999: 221.

65 So and Bunker 1995: 34. As Bunker (2002: 9) summarizes it, "West of the Taihang, the land is characterized by grasslands conductive to large-scale herding. East of the Taihang, the mountainous, forested land is more suited to hunting, trapping, and fur trading, while farther east, in the Dongbei region, the fertile soil of the Liao River valley could sustain limited agriculture, hunting, fishing, and settled stock breeding." Yet it is over-simplistic to consider the northwesterners as herders and the northeasterners as hunters, fishers, and fur traders. The numerous non-Chinese tribes practiced different subsistence economies according to local environment (land, climate, and vegetation), which might go through considerable diachronic change. From time to time the these ethnic groups themselves also varied, because of migration, conquest, and immigration. All these would accordingly be reflected in their material cultures, including artifacts (pottery, metals, semiprecious stones, and stone tools) and faunal and flora remains, as well as social organization and complexity.

66 The Anyang period (c. 1200–1050 BC), so termed by Robert Bagley, starts from around 1200 BC, when Yinxu 殷墟 became an important city, corresponding to late Phase 1 and early Phase 2 of Yinxu in pottery seriation. See Bagley 1999: 181.

67 Bagley 1987: 63–64, note 245.

68 Piggott 1992: 45–48; Bagley 1999: 207.

management, as well as other necessary knowledge and skill, through some sort of exchange.[69] This exchange is also supported by the mutual borrowings between Anyang and the Northern Zone, such as northern artifacts (e.g., bow-shaped objects, mirrors, knives) found at Anyang, and bronze vessels in the Northern Zone.[70] It is noteworthy that some Anyang-period knives with intricately formed animal-head terminals unearthed in the Northern Hebei and Shaanxi were likely lost-wax castings (Fig 12).[71]

69 Bunker et al. 1997: 31.

70 Lin 1986: 238–241; Bagley 1999: 222.

71 Bagley 1987: 44.

Figure 12. Dagger from Hebei Qinglong Chaodaogou (top) and its intricately formed animal-head pommel (bottom). Late 2nd millennnum BC. Source: *Zhongguo qingtongqi quanji* 15: 3.

Although such artifacts spread both west and east to the Taihang Mountains, they seem to have been left by the same or culturally unified non-Chinese communities[72] and to have a common

72 According to So (So and Bunker 1995: 37–38), most artifacts east of the Taihang Mountains during the second

connection with the far north (e.g., southern Siberia and Mongolia), probably the Karasuk culture of the Minusinsk Basin during the late second millennium BC,[73] which belonged to the much larger metallurgical sphere of "Eurasian Steppe Belt Cultures."[74] A hair ornament from the Sackler Collection (Fig 13), without any visible mold marks and essentially verified as lost-wax cast, together with two superb cast-gold ornaments of the same Karasuk style from central Mongolia (Fig 14) (c. thirteenth–eleventh centuries BC),[75] clearly show the mastery of the lost-wax process in the region of the Karasuk culture. Given the frequent technical communications between the Eurasian steppes and China, as well as the likely use of the lost-wax process in the Northern Zone as early as the Anyang period, one scholar concluded that "Chinese metalworkers may well have known of the technique long before they chose to make any appreciable use of it."[76] In other words, Anyang casters might not have been ignorant of the lost-wax process, but just chose to neglect it. The lost-wax cast northern knives could have been imitated by Anyang casters, simplifying the design and using the method of bivalve casting.[77]

---

millennium BC, including the probably lost-wax cast animal-pommeled knives, come mainly from caches, not from burials, and are far fewer in number compared with artifacts west of the Taihang Mountains. As So infers, "the scattered finds of non-Chinese artifacts east of the Taihang Mountains probably mark temporary settlements or seasonal migrations of peoples from the west who came for trade, pasture, or hunting."

73 Loehr 1949: 135; Bagley 1999: 224.

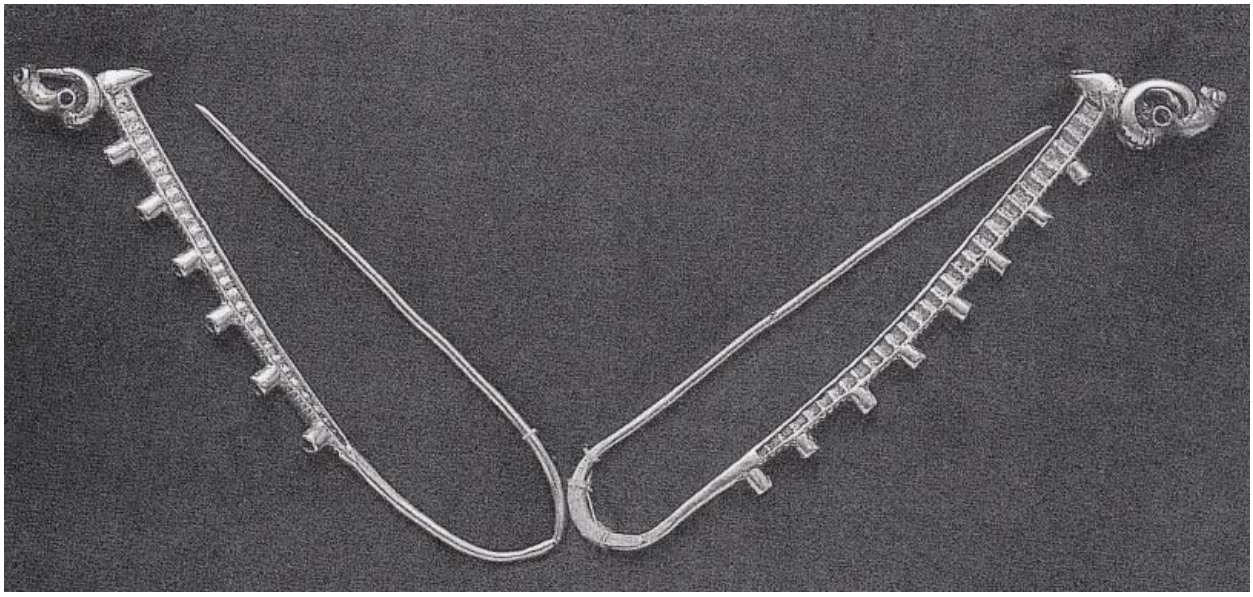
74 For details, see Chenykh 1992: 264–295; 2009: 3–5.

75 Bunker et al. 1997: 142–143.

76 Bagley 1987: 44.

77 Bagley 1987: 63, note 244.

Figure 13. Bronze hair ornament from the Arthur M. Sackler Collections, probably from Western Mongolia, thirteenth–eleventh centuries BC. L. 9 cm. (1) Artifact and (2) detail of the ram's head). Source: Bunker et al. 1997: 142, No.32.



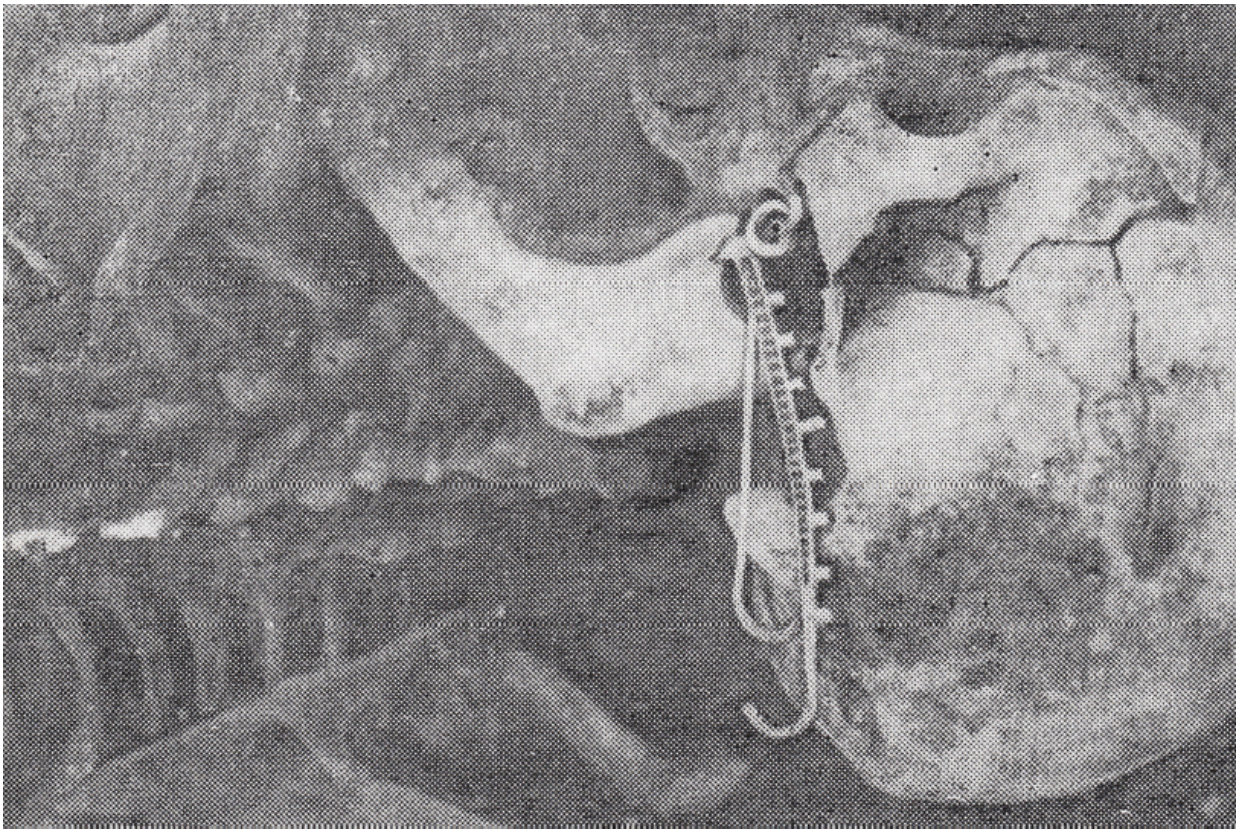


Figure 14. Two cast-gold ornaments from the slab grave of a Europoid, Tevsh uul, Ovorhangai aimag in the Hangai Mountains, central Mongolia. Karasuk style, thirteenth–eleventh century BC. Source: Bunker et al. 1997: 142, Figs 32.1, 32.2.

Though probably no lost-wax castings from the period are still extant, Western Zhou (c. 1050–771 BC) was a key period for the lost-wax process in China, since the openwork interlace structure, as the basic form for most verified Eastern Zhou lost-wax castings, appears to emerge in China during Western Zhou. In addition, compared with the Anyang period (c. 1200–1050 BC), China seems at this time to have been more frequently interacting with Inner Asia during the early first millennium BC, as reflected in the influx and borrowing of various steppe artifacts, designs, and techniques. For instance, as Rawson asserts, a harness ring from the Luristan plateau (Fig 21) offered a source not only for the interlace design commonly seen in the Western Zhou bronzes (e.g., Fig 23), but also for the intricate chariot fitting from Shaanxi Chang'an 長安 Zhangjiapo 張家坡 (Fig 22), suggesting the possibility of contact in the early first millennium BC between Zhou-ruled China and the Iranian Plateau, which was an early center of lost-wax casting.[78] Probably because Zhou aristocrats themselves were northwestern outsiders more closely linked with Inner Asia than their Anyang predecessors,[79] an influx of various steppe influences arrived in China during the dynastic Zhou period, probably with immigrants from the borderlands. Remarkable examples are carnelian beads, realistic steppe animal designs (e.g., felines and horses), vessels supported by tigers or human figures, various exotic vessel shapes, stone-lined tombs, face coverings, and considerable use of gold and iron.[80]

Although closely linked with Inner Asia, neither the Zhou aristocrats in the Wei River Valley (who were driven to Luoyang 洛陽 after 770 BC) nor their active and usually hostile semi-nomadic neighbors in *xibei* seem to have adopted lost-wax casting during the early first millennium BC. But the case seemed to be different in *dongbei*. In contrast to the scarce and isolated caches from the late second millennium BC, many early first millennium BC *dongbei* finds are in burials, signifying the existence of more stable settlements there.[81] The founding of the state of Zhou's subordinate state Yan 燕 in northern Hebei no doubt sent a tremor through the local political and cultural landscapes.[82] The

78 Rawson 2010: 2.

79 See Rawson 1989b: 79, 93.

80 For details, see Rawson 2010.

81 So and Bunker 1995: 44.

82 For details, see Sun 2006.

sudden proliferation of both Zhou and northern artifacts in *dongbei* seem to have been caused by the eastward expansion of Zhou and colonization in China's Northern Frontier.[83] According to Bunker, the *dongbei* people had close contact with Mongolia and southern Siberia via the "Fur Road," which roughly corresponds to the route of the trans-Siberian railway, bypassing the *xibei* regions.[84] This might well explain why horseback riding emerged in *dongbei* earlier than in *xibei*, and why certain motifs from the far north appeared in *dongbei* vocabularies but never in those of *xibei*.[85] Compared with the stylized *xibei* zoomorphic motifs, the *dongbei* animal designs, showing them either copulating or moving along the knife hilt, are far more naturalistic, indicating a strong pictorial tradition connected to Mongolia and southern Siberia. As Bunker notes, lost-wax casting occurred at *dongbei* earlier than in the Chinese heartland,[86] as evidenced by a number of lost-wax cast jingles or ornaments (Figs. 15, 16) manufactured in *dongbei* during the seventh–sixth centuries BC.[87] Found among archaeological remnants of *dongbei* mining and casting in the early first millennium BC,[88] these lost-wax artifacts were probably local *dongbei* products, iconographically and technically stimulated by the far north. As Bunker observes, the *dongbei* casters probably knew both direct and indirect lost-wax processes in this period.[89]

83 So and Bunker 1995: 41, 44.

84 So and Bunker 1995: 65; Bunker et al. 1997: 154.

85 Bunker et al. 1997: 154.

86 Bunker 2009: 279.

87 Bunker 2002: 60–64.

88 Bunker et al. 1997: 72.

89 Bunker 2002: 60–64.

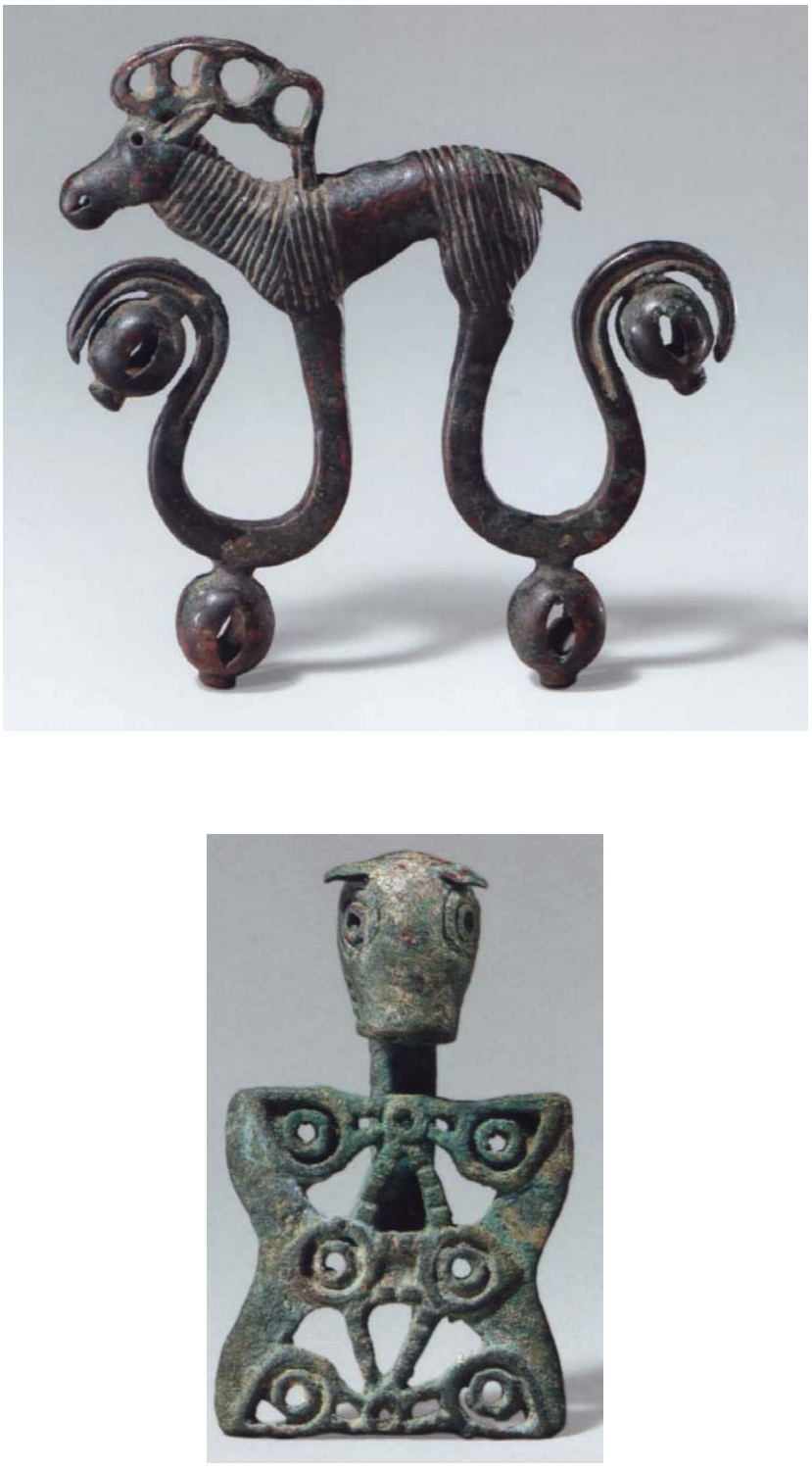


Figure 15. (1) Bronze harness jingle with stag. H. 13.3 cm; (2) Bronze harness jingle with an animal head. H.7.3 cm. Both are considered to be lost-wax cast by a process from Northeast China, seventh–sixth century BC. Source: Bunker 2002: Plates 29, 30.

Figure 16. (1) Bronze harness ornament with tiger and bird's head. L. 10.6 cm., (2) bronze harness ornament with crouching tiger. L. 10.2 cm., (3) bronze harness jingles with mounted hunters. All are considered to be lost-wax cast using a wax model formed in a two-piece mold, from Northeast China, seventh–sixth century BC. Source: Bunker 2002: Plates 27, 28, 26.

Northern Hebei, which geographically belongs to the *dongbei* but whose artifacts lack certain *dongbei* features,[90] must be discussed separately here. With access to the "Fur Road" via the modern Zhangjiakou 張家口 city, northern Hebei could also be linked to the far north while bypassing the *xibei* regions, which could well explain why certain motifs traceable to the tradition of the far north did not appear in the *xibei* until considerably later.[91] A series of intricate zoomorphic finials from regions in the center of northern Hebei (Fig 17) can be verified as lost-wax castings from around the seventh–sixth centuries BC.[92] As such zoomorphic finials are more common in southern Siberia,[93] where canopies and funerary carts were ritually buried with the elites,[94] it is quite likely that the method of lost-wax casting was transmitted from the far north. Long-distance trade, historically passing through Zhangjiakou and Ulaan Baatar, might be a likely reason for the interaction between the two regions.

90 Bunker 2009: 279.

91 Bunker 2009: 281.

92 Bunker et al. 1997: 177; Bunker 2002: 58–60.

93 Bunker et al. 1997: 177.

94 Bunker et al. 1997: 177; Bunker 2002: 58.

Figure 17. (1) A set of four finials with single wild ram, in a private collection, New York. H.16.2 cm; (2) finial with single wild ram, in a private collection, New York. H. 15.5 cm; (3) finial with two wild rams from Hebei Chicheng; (4) finial with single horse in the Arthur M. Sackler Collection. H. 10.9 cm; (5) finial with single horse/ass from Hebei Zhangjiakou; (6) finial with single water bird from Hebei Kangbao. All considered to be lost-wax cast in the direct process, seventh–sixth century BC, from regions in the center of northern Hebei. Note the open eye-holes used in all animals depicted. Sources: (1)-(2): Bunker 2002: Plates 24, 25. (3)-(6): Bunker et al. 1997: 177, Figs 92.3, 92, 92.1, 92.2.

The existence of lost-wax casting in northern Hebei can be further verified by several gold pectorals, such as the crouching feline plaque from Beijing Yanqing 延慶 Jundushan 軍都山 (Fig 18.1).[95] Most Hebei pectorals were still piece-mold cast of bronze, so the art represented by these gold pectorals demonstrates the technological sophistication of the lost-wax process and a deep understanding of the properties of the metal—gold cast by lost wax tends to result in a better quality product compared with section-mold casting.[96] Indeed, bronze pectorals cast by the lost-wax process in northern Hebei also exist, such as the crouching feline plaque in the Levy and White collection (Fig 18.2) and two others of the same style in the Sackler collection.[97] According to Bunker's research, they were both made from a wax model formed in a two-piece mold.[98] As individuals buried in the northern Hebei tombs during the seventh–sixth centuries BC had much in common with their *xibei* neighbors,[99] they are often understood to be the Shanrong 山戎 of received texts, who moved eastwards from northern Shanxi in 714 BC and thereafter attacked the Zhou states Qi 齊 (in 706 BC) and Yan 燕 (in 664 BC).[100] However, according to Bunker, the northern Hebei inhabitants appear to have been traders of exotic furs and leather-working who had Chinese as their near neighbors, although the presence of daggers in their graves indicates a somewhat warlike character.[101]

95 So and Bunker 1995: 50.

96 Bunker 2009: 280.

97 See Bunker 1997: 188–189, Nos. 111, 112.

98 So and Bunker 1995: 112–113; Bunker et al. 1997: 189.

99 So and Bunker 1995: 50.

100 Bunker et al. 1997: 175.

101 Bunker 2009: 282.

Figure 18. Pectorals of crouching feline: (1) Gold plaque from Beijing Yanqing Jundushan; (2) bronze plaque in the Levy and White collection, from northwest China/northern Hebei. L. 9.4 cm. Source: So and Bunker 1995: Fig 18, Plate 27.

As mentioned above, it is quite likely that Anyang casters might already have been acquainted with this technique through communication with northerners during the late second millennium

BC.[102] On the other hand, any technique has to be maintained through continuous practice. Because of the technical inertia of the dominating section-mold casting process, the lost-wax process, even though it might have been learned by Chinese metalworkers in the late second millennium BC, could still have been forgotten from time to time. With the same lost-model principle but comparatively "primitive" and crude features, the abovementioned "burn-out"/"lost-cord" castings, if they truly were employed, might be a clue that the lost-wax process was unknown or forgotten in the corresponding space and time.[103] Thus, the lost-wax manufacture in the *dongbei* and especially in the northern Hebei regions during the early-to-middle first millennium BC (no later than seventh–sixth century BC) could be either a direct source or at least a refresher for the lost-wax technique used in the Chinese heartland not long after. In addition to the proper timing, the *dongbei*/northern Hebei regions were also geographically appropriate, that is, adjacent to the main Zhou states Yan in the north and Qi in the northeast, as well as some minor Zhou states nearby. In particular, the northern Hebei was almost within the sphere of Zhou—even if the bordering people there were not the Shanrong in received texts, they were no doubt interacting extensively with the Zhou states, given their proximate location. Cultural intrusion from the *dongbei*/northern Hebei, for instance, was reflected in some gold articles found at Shandong Yishui 沂水 Liujiadianzi 刘家店子 M1, "dating perhaps from the middle or third quarter of the seventh century BC."[104] The use of gold was already common in the Northern Zone as early as the late second millennium BC, and it was introduced into the Zhou states no later than the eighth century BC (e.g., states Rui 芮, at Shaanxi Hancheng 韓城 and Guo 虢 at Henan Sanmenxia 三門峽).[105] The recently discovered *huang* 璜 from the Western Zhou cemetery of Shanxi Yicheng 翼城 Dahekou 大河口 (Fig 19) most clearly verifies that the Chinese used gold.

---

102 For details, see Bagley 1987: 44.

103 On the other land, it is also possible that Chinese metalworkers, even if they already knew the lost-wax process, might still have invented and used the "burn-out"/"lost-cord" process: for one thing, the "burn-out"/"lost-cord" process partly adopts the commonly used section-mold process, since ashes have to be cleaned off from the small mold sections; for another, the fiber-like texture left by the cord might have been an effect the casters desired.

104 So 1995: 19.

105 For details, see Bai 2006; Rawson 2010.

Figure 19. *Huang* from Shanxi Yicheng Dahekou M6022. Cast gold. Western Zhou period. Photograph courtesy of the Shanxi Provincial Institute of Archaeology.

However, according to So, a gilt ladle from Liujiadianzi M1 was the earliest Eastern Zhou example of sheet gold used on vessel exteriors.[106] The triangular and cowrie-shaped pieces of sheet gold used on it (Fig 20.1)[107] probably had a connection with the gold foils covering bronze cowrie shells from the Yuhuangmiao 玉皇廟 cemetery, Beijing Yanqing 延慶 Jundushan 軍都山.[108] Actually, the use of gold sheet to decorate lacquered vessels was also a feature in the *dongbei* and northern Hebei regions.[109] A northern-style gold-hilted dagger also from Liujiadianzi M1 (Fig 20.2) further suggests

106 So 1995: 19–20.

107 See So 1995: 19.

108 Bunker et al. 1997: 64.

109 For details, see Bai 2006.

contact between the Zhou world and the northerners by the seventh century BC.[110] In light of such verified contact, it is quite possible that the lost-wax process might also have "crept" into the Zhou states from the *dongbei* and/or northern Hebei during this period.

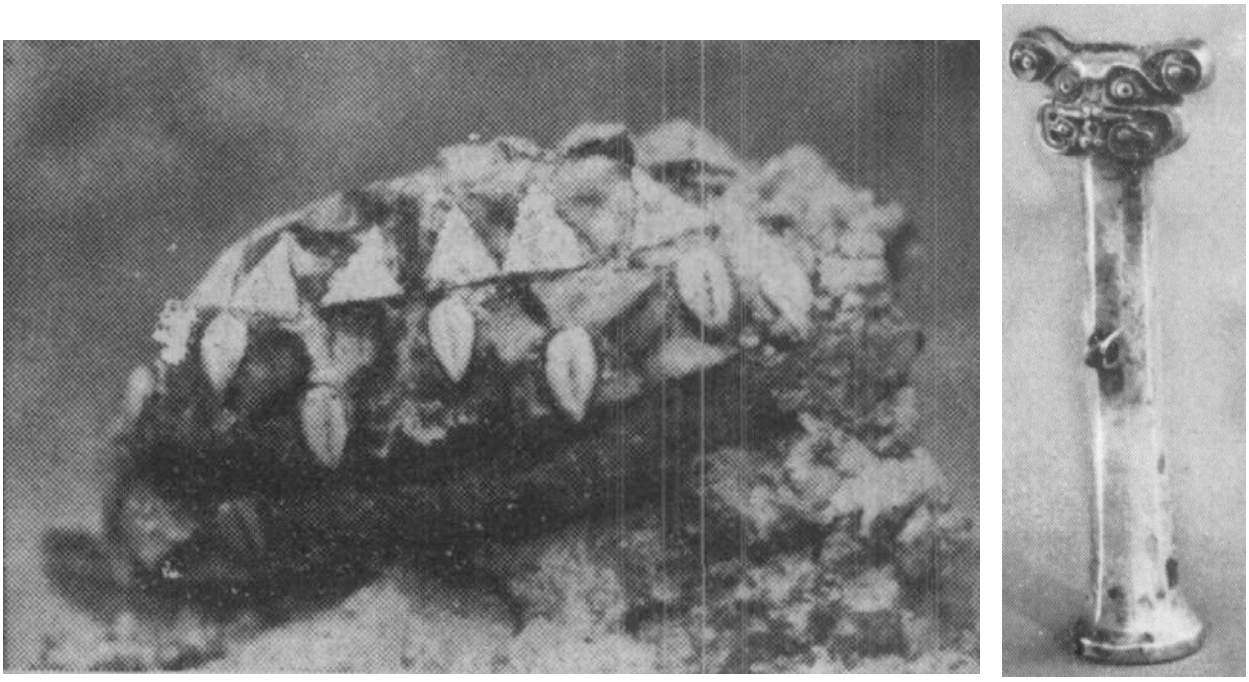


Figure 20. (1) Ladle with triangular and cowrie-shaped pieces of sheet gold. Dia. 8 cm. (2) Northern-style gold-hilted dagger. L. 9 cm. c. Middle or third quarter of seventh century BC. Both from Shandong Yishui Liujiadianzi M1. Source: Luo 1984: Fig 10, Plate 2.4.

110 See So 1995: 19–20. As So (in Fong 1980: 254) points out, "the Qi state, under the leadership of its greatest ruler, Duke Huan (685–643 BC), was the first of five hegemons to come to power in the Spring and Autumn period." As a superpower with many allied states, even the Zhou court (reflected on a dowry bronze *yu* 盂 basin found at Luoyang; see Fong 1980: 253), Qi in present-day Shandong probably interacted with other Zhou states extensively during the seventh–sixth centuries BC. Especially, to prevent the spread of Chu, Qi founded alliances with many Zhou states including some petty ones in the *hanhuai* 漢淮 region close to Chu. Actually, Zhou's closeness with many *hanhuai* states was long lasting. For instance, the marriage alliance between Qi and Chen 陳 in the southeastern Henan is suggested by a set of eleven eighth-century BC bronzes found in Shandong, among which was "a pair of wine vessels with inscriptions indicating that they were made to accompany the daughter of a marquis of Chen in marriage" (Fong 1980: 253). It is possible that the lost-wax process, if it was not spread to multiple directions, was likely to have been introduced from the *dongbei*/northern Hebei via Shandong, Henan, and the *hanhuai* region, and finally flourished in the Chu region.

Large numbers of ornamental gold sheets with repoussé designs of interlaced serpentine patterns from the first half of the sixth century BC discovered at Henan Xinzheng 新鄭 Lijialou 李家樓[111] showed further exploitation of sheet gold and related steppe techniques later in the Chinese Central Plain. Although stimulus from the northwest could not be ruled out, such gold sheets, presumably to decorate bronze surfaces,[112] were more likely to receive influences from the north or northeast. It is also noticeable that turquoise inlays, presumably borrowed early from non-Chinese groups in the north, disappeared from bronze ornamentation during Western Zhou, finally being revived at Xinzheng during the early sixth century BC, indicating a renascent or enhanced contact with the nomadic world.[113] The "nomadic world" here probably could be linked to the *dongbei* and especially Northern Hebei, since such a practice did not take place in the Zhou states in the northwest until considerably later. With artifacts stylistically succeeding Xinzheng, the supposed Chu tombs at Henan Xichuan 淅川 Xiasi 下寺 (c. second quarter of sixth century BC) not only revealed ornaments of sheet gold and inlays of semiprecious stone, but also verified the use of the lost-wax process.[114] Moreover, "cast-copper" and gold inlays practiced at Xiasi seemed to be novel techniques.[115] The origin of the unconventional "cast-inlay" process is still unclear.[116] This technique was probably a Chinese invention inspired by the use of spacers in casting,[117] but the idea might have been motivated by the northern "decoration of woodwork, textiles and bronze," as suggested by Rawson.[118] The gold inlay with the more conventional hammering technique,[119] on the other hand, was no doubt influenced by the north, since both the material (gold) and technique (hammering) seem to be features of the

111 See So 1995: 24.

112 So 1995: 24.

113 So and Bunker 1995: 101–102; So 1995: 24, 73–74: note 88.

114 So 1995: 34–35.

115 So 1995: 34–35.

116 So 1995: 34.

117 For details, see Zhang 1988.

118 Rawson 1987a: 52–53.

119 So 1995: 35.

Eurasian Steppes. Considering the stylistic succession of bronzes from Xinzheng to Xiasi, both "cast-copper" and gold inlays at Xiasi might have been partly inspired by the turquoise inlay first revived at the north-influenced Xinzheng. Considering the comparatively late presence of these techniques in Jin 晉 and other nonwestern Zhou states, it is quite possible that the foreign source/motivator for the novel techniques at Xiasi, such as "cast-copper" and gold inlays as well as the lost-wax process, was probably the first millennium BC *dongbei* and especially northern Hebei.

Figure 21. Bronze harness ring. C.1000–700 BC. H. 13.2 cm. Heeramaneck Collection.
Source: Rawson 2010: Fig 2c.

Figure 22. Bronze chariot fitting from Shaanxi Chang'an Zhangjiapo. M2.H.9 cm. Source: Rawson 2010: Fig 2a.

Figure 23. The Shan Wu Fu *hu* from a cache of Shaanxi Meixian Yangjiacun. Late Western Zhou. H.59.6 cm. Source: Rawson 2010: Fig 2b.

BIBLIOGRAPHY

Bagley, Robert W. 1987. *Shang Ritual Bronzes in the Arthur M. Sackler Collections*. Washington, D.C.: Arthur M. Sackler Foundation; Arthur M. Sackler Museum, Harvard University; distributed by Harvard University Press, Cambridge, Mass.

———. 1990. "Shang Ritual Bronzes: Casting Technique and Vessel Design," *Archives of Asian Art* 43 (1990): 7–20.

———. 1999. "Shang Archaeology." In *The Cambridge History of Ancient China*, ed. Michael Loewe and Edward L. Shaughnessy. Cambridge: Cambridge University Press, pp. 124–231.

———. 2008. *Max Loehr and the Study of Chinese Bronzes: Style and Classification in the History of Art*. Ithaca: East Asia Program, Cornell University.

Barnard, Noel. 1996. "The Entry of Cire-Perdue Investment Casting, and Certain Other Metallurgical Techniques (Mainly Metalworking) into South China and Their Progress Northwards." In *Ancient Chinese and Southeast Asian Bronze Age Cultures*, ed. F. David Bulbeck and Noel Barnard, vol. 1, pp. 1–94. Taipei: SMC.

Becker, Lawrence, Lisa Pilosi, and Deborah Schorsch. 1994. "An Egyptian Silver Statuette of the Saite Period-A. Technical Study," *Metropolitan Museum Journal* 29: 37–56.

Bunker, Emma C. 2009. "First millennium BCE *Beifang* artifacts as historical documents." In *Social Complexity in Prehistoric Eurasia: Monuments, Metals, and Mobility*, ed. Bryan K. Hanks and Katheryn M. Linduff, 272–295. Cambridge and New York: Cambridge University Press.

Bunker, Emma C., Trudy S. Kawami, and Katheryn M. Linduff. 1997. *Ancient Bronzes of the Eastern Eurasian Steppes from the Arthur M. Sackler Collections*. New York: Arthur M. Sackler Foundation; distributed by Abrams, New York.

Chen, Peifen. 1997. "Early Chinese Bronze Mirrors," *Orientations* March 1997: 88–93.

Chernykh, Evgeniĭ Nikolaevich. 1992. *Ancient Metallurgy in the USSR: The Early Metal Age.* New York: Cambridge University Press.

———. 2009. "Ancient Metallurgy in the Eurasian Steppes and China: Problems of Interactions." In *Metallurgy and Civilisation: Eurasia and Beyond*, ed. Jianjun Mei and Thilo Rehren, 3–8. London: Archetype.

Dong Yawei 董亞巍, Pan Lu 潘路, Wan Quanwen 萬全文, Zhou Weirong 周衛榮, Ma Juncai 馬俊才, and Wang Changsui 王昌遂. 2008. "Zaitan Zenghou Yi Zun-Pan de Zhuzao gongyi 再探曾侯乙尊盤的鑄造工藝 (Rethinking the casting craft of the *zun-pan* of the Marquis Yi of Zeng)," *Zhongyuan Wenwu* 中原文物 (Cultural Relics of Central China) 1 (2008): 97–107.

Fairbank, Wilma. 1962. "Piece-mold Craftsmanship and Shang Bronze Design," *Archives of the Chinese Art Society of America* 16 (1952): 18–32.

Fong, Wen, ed. 1980. *The Great Bronze Age of China: An Exhibition from the People's Republic of China*. New York: Metropolitan Museum of Art and Alfred A. Knopf Inc.

Gettens, Rutherford. 1965. "Joining Methods in the Fabrication of Ancient Chinese Bronze Ceremonial Vessels." In *Application of Science in Examination of Works of Art*, 205–217. Boston: Museum of Fine Arts.

Guo Baojun 郭宝钧. 1981. *Shangzhou Tongqiqun Zonghe Yanjiu* 商周銅器群綜合研究 (A comprehensive research on Shang and Zhou bronzes). Beijing: Wenwu Chubanshe.

Hemingway, Seán. 2000. "Bronze Sculpture." In *Making Classical Art: Process & Practice*, ed. Roger Ling, 37–46. Stroud: Tempus; Charleston, SC: Published in the United States of America by Arcadia.

Hua Jueming 華覺明. 1985. "Shilafa zai Zhongguo de Qiyuan he Fazhan 失蠟法在中國的起源和發展 (The origin and development of the lost-wax process in China)." In *Kejishi Wenji: Jinshushi Zhuanji* 科技史文集：金屬史專輯, 63–81. Shanghai: Shanghai Keji Chubanshe.

———. 1999. *Zhongguo Gudai Jinshu Jishu: Tong he Tie Zaojiu de Wenming* 中國古代金屬技術:銅和鐵造就的文明 (The metal technology of ancient China: A civilization made by copper and iron). Zhengzhou: Daxiang Chubanshe.

Hua Jueming 華覺明 and Jia Yunfu 賈雲福. 1983. "Zenghou Yu Zun, Pan he shilafa de qiyuan 曾侯  尊盤和失蠟法的起源 (The *zun-pan* of the Marquis Yu of Zeng and the origin of the lost-wax process)," *Ziran Kexueshi Yanjiu* 自然科學史研究 (Studies in the History of Natural Sciences) 4 (1983): 352–359.

Hubei Sheng Jingzhou Diqu Bowuguan 湖北省荊州地區博物館. 1984. *Jiangling Yutaishan Chu Mu* 江陵雨台山楚墓 (The Chu tombs at Jiangling Yutaishan). Beijing: Wenwu Chubanshe.

Hubei Sheng Bowuguan 湖北省博物館. 1989. *Zeng hou Yi Mu* 曾侯乙墓(The tomb of the Marquis Yi of Zeng). Beijing: Wenwu Chubanshe.

Hubei Sheng Jingsha Tielu Kaogudui 湖北省荊沙鐵路考古隊. 1991. *Baoshan Chu Mu* 包山楚墓 (The Chu cemetery at Baoshan). Beijing: Wenwu Chubanshe.

Karlbeck, Orvar. 1935. "Anyang Moulds," *Bulletin of the Museum of Far Eastern Antiquities, Stockholm* 7 (1935): 39–60.

Li Jinghua 李京华. 2004. "Gushi Hougudui Qingtong Zhuxiang Hongtong Huawen Gongyi Tantao 固始侯古堆青銅鑄鑲紅銅花紋工藝探討 (An exploration of the copper casting craft of making inlaid decorations on bronzes from Gushi Hougudui)." In *Gushi Hougudui Yihao Mu* 固始侯古堆一号墓 (Tomb One at Gushi Hougudui), ed. Henansheng Wenwu Kaogu Yanjiusuo 河南省文物考古研究所, 134–146. Zhengzhou: Daxiang Chubanshe.

Li Xiaocen 李晓岑 and Han Rubin 韩汝玢. 2011. *Gu Dianguo Jinshu Jishu Yanjiu* 古滇國金屬技術研究 (Research on the metal technology of the ancient kingdom of Dian). Beijing: Kexue Chubanshe.

Lin Yun. 1986. "A Reexamination of the Relationship between Bronzes of the Shang Culture and of the Northern Zone." In *Studies in Shang Archaeology*, ed. K. C. Chang, 237–273. New Haven: Yale University Press.

Loehr, Max. 1949. "Weapons and Tools from Anyang, and Siberian Analogies," *American Journal of Archaeology* 53 (1949): 126–144.

————. 1953. "The Bronze Styles of the Anyang Period," *Archives of the Chinese Art Society of America* 7 (1953): 42–53.

Loveday, Helen. 2002. "Diversity in Eastern Zhou Bronze Casting: A Look at a Group of Openwork Vessels," *Journal of East Asian Archaeology* 4.1–4 (2002): 101–142.

Mattusch, Carol C. 1988. *Greek Bronze Statuary: From the Beginnings through the Fifth Century B.C.* Ithaca: Cornell University Press 1988.

————. 1996. *Classical Bronzes: The Art and Craft of Greek and Roman Statuary*. Ithaca: Cornell University Press.

Meyers, Peter. 2011. "Casting Technology in Cambodia and Related Southeast Asian Civilizations." In *Khmer Bronzes: New Interpretations of the Past*, ed. Emma C. Bunker and Douglas Latchford, 27–41. Chicago: Art Media Resources.

Piggott, Stuart. 1992. *Wagon, Chariot, and Carriage: Symbol and Status in the History of Transport*. London: Thames and Hudson.

Smith, Cyril Stanley. 1981. *A Search for Structure: Selected Essays on Science, Art, and History*. Cambridge, Mass.: MIT Press.

So, Jenny F. 1995. *Eastern Zhou Ritual Bronzes from the Arthur M. Sackler Collections*. New York: published by the Arthur M. Sackler Foundation in association with the Arthur M. Sackler Gallery, Smithsonian Institution; distributed by Abrams, New York.

So, Jenny F., and Emma C. Bunker. 1995. *Traders and Raiders on China's Northern Frontier*. Seattle: Arthur M. Sackler Gallery, Smithsonian Institution, in association with the University of Washington Press.

Tan Derui 谭德睿. 1989. *Canlan de Zhongguo Gudai Shila Zhuzao* 燦爛的中國古代失蠟鑄造 (The splendid lost-wax castings from ancient China). Shanghai: Shanghai Kexue Jishu Wenxian Chubanshe.

———. 1994. "Zhongguo Gudai Shila Zhuzao Qiyuan Wenti de Sikao 中國古代失蠟鑄造起源問題的思考 (Considerations on the origin of the lost-wax casting in ancient China)," *Wenwu Baohu yu Kaogu Kexue* 文物保护与考古科学 (Sciences of Conservation and Archaeology) 2 (1994): 43–48.

———. 2007a. "Zhongguo Zaoqi Shila Zhuzao Wenti de Guancha yu Sikao 中國早期失蠟鑄造問題的考察與思考(Observations and considerations of early Chinese lost-wax castings)," *Nanfang Wenwu* 南方文物 (Cultural Relics of Southern China)," 2 (2007): 36–40.

———. 2007b. "Shang Zhongqi de Tiliang Hu 商中期的提梁壺 (A pot with a loop handle from the Middle Shang period)," *Tezhong Zhuzao ji Youse Hejin* 特種鑄造及有色合金 (Special Casting and Nonferrous Alloys) 6 (2007): 491–492.

Wang Jinchao 王金潮. 2002. "Tan Zeng Hou Yi Zun Pan de Zhuzao Gongyi 談曾侯乙尊盤的鑄造工藝 (A discussion of the casting craft of *zun-pan* of the Marquis Yi of Zeng)," *Dongnan Wenhua* 東南文化 (Southeast Culture) 1 (2002): 70–74.

———. 2009. "Zhongguo Qingtong Shidai Loukong Qingtongqi Nifan Zhuzuo Gongyi Yanjiu 中國青銅時代鏤空青銅器泥範鑄作工藝研究 (Research on the clay-mold casting craft of making

openwork bronzes in the Chinese Bronze Age)," *Qingtong Wenhua Yanjiu* 青銅文化研究 (Study of Bronze Cultures) 6: 278–287, 190. Tongling: Huangshan Shushe.

Wang Wei 王玮. 2011. "Zhongqiu Hua Yue Ye, Jiajing Gong Shang Shi 中秋花月夜,佳鏡共賞時 (The night of flowers and moonlight in the Mid-autumn Festival, when fine mirrors are appreciated)," *Wenwu Jianding yu Jianshang* 文物鑑定與鑑賞 (Identification and Appreciation of Cultural Relics) 9 (2011): 26–29.

Wang Wei 王玮, Wang Jinchao 王金潮 and Sheng You 盛友. 2010. "Sanwei Donghua li de Gudai Chuantong Gongyi 三維動畫裡的古代傳統工藝 (The traditional three-dimensional crafts of antiquity)," *Jianghan Kaogu* 江漢考古 (Jianghan Archaeology) 3(2010): 113–122.

White, Joyce C. 1988. "Early East Asian Metallurgy: The Southern Tradition." In *The Beginning of the Use of Metals and Alloys: Papers from the Second International Conference on the Beginning of the Use of Metals and Alloys, Zhengzhou, China, 21–26 October* 1986, ed. R. Maddin, 175–181. Cambridge, Mass.: MIT Press.

Zhongguo Wenwu Jinghua Bianji Weiyuanhui《中國文物精華》編輯委員會. 1992. *Zhongguo Wenwu Jinghua* 中國文物精華 (Essence of Chinese cultural relics). Beijing: Wenwu Chubanshe.

Zhou Weirong 周衛榮, Dong Yawei 董亞巍, Wan Quanwen 萬全文 and Wang Changsui 王昌遂. 2006. "Zhongguo Qingtong Shidai Bu Cunzai Shilafa Zhuzao Gongyi 中國青銅時代不存在失蠟鑄造工藝 (The lost-wax craft did not exist in Bronze Age China)," *Jianghan Kaogu* 江漢考古 (Jianghan Archaeology) 2 (2006): 80–85.

———. 2007. "Zai Lun 'Shila Gongyi Bushi Zhongguo Qingtong Shidai de Xuanze 再論' 失蠟工藝不是中國青銅時代的選擇 (Revisiting "the lost-wax craft that was the choice of Bronze Age China")," *Nanfang Wenwu* 南方文物 (Cultural Relics of Southern China 2 (2007): 41–48, 132.

Since June 2006, all new issues of *Sino-Platonic Papers* have been published electronically on the Web and are accessible to readers at no charge. Back issues are also being released periodically in e-editions, also free.

For a complete catalog of *Sino-Platonic Papers*, with links to free issues, visit the *SPP* Web site.

www.sino-platonic.org