Chapter 27
Metallurgy in Ancient Eastern Asia: Retrospect and Prospects

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Introduction

The use of metals and the development of metallurgy are considered fundamental to the emergence of complex societies in many locations in the ancient world, but particularly in western and eastern Asia. Metallurgical technology provided copper, iron, and their alloys, which in turn furnished ritual and working implements, weapons, and materials for construction. How the knowledge of and interest in metals developed in present-day China has been the subject of much speculation, with the place of origin often the central topic of debate. Until fairly recently, however, little evidence could be gathered to argue convincingly that the Chinese Bronze Age was an indigenous affair, or one that was sparked by impetus from beyond the Great Wall. In light of recent excavations in both China and adjacent regions of Eurasia (Hanks and Doonan, this volume) and Southeast Asia (White and Hamilton, this volume), and of analytic approaches developing to explain the emergence of the technology that include a broader focus on societal change, the situation in China can be reassessed and different models for its development can be proposed. Such changes in approach may require the application of new research questions and even perhaps field methods.

Debates and assessments of incipient metallurgy and its consequences in the ancient western world have centered on several crucial factors: the presence of ores and the corollary existence or creation of adequate trade networks; the presence of knowledgeable local and/or itinerant artisans who knew metals and their properties;

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a community able to support such workers, or with a degree of social and/or ritual complexity to create a demand for metal products; the ability to create high temperature furnaces for smelting and refinement of ores and final castings. The most sophisticated metal-producing industries were located in or near the more complex societies in the Near East, where these products were used for many purposes ranging from utilitarian to luxury items, for use in activities ranging from the everyday to solemn rituals. Such questions are not always behind the study of metallurgy in China.

Consideration of the Chinese development of metallurgy and its setting has centered on two issues: first, documentation and scientific examination of the internal development of metal technologies and second, and more recently, on the emergence of metallurgy in eastern Asia and whether any stimulus from outside was responsible for its inauguration.

Background: Archaeology in China

Since the founding of the People's Republic in 1949, we have witnessed a period when archaeology has served many functions in China : scientific, nationalistic, touristic, and economic, to name a few. Since the introduction of scientific archaeology in the 1920s, archaeological activity has followed two paths in China; historiographically oriented Neolithic and Bronze Age archaeology and Paleolithic archaeology aimed at the study of human evolution. Because there is a common approach, some discussion follows on both.

These divisions can be found in two different bureaucratic houses in Beijing, provincial government and university offices and institutions. Both divisions have histories based on inherited Chinese intellectual traditions as well as those appropriated from the West. Chinese Paleolithic archaeology was strongly influenced by the French tradition of the 1920s and 1930s; Neolithic and historic archaeology was modeled on the field methods and philological traditions introduced both from Europe and from the USA. Even so, all archaeological research in China can be said to emerge from a common Chinese intellectual tradition. Whether attempting to reconstruct Pleistocene human prehistory or to explain the emergence of Dynastic China, the most fundamental issue addressed by archeologists has been to reconstruct the origin and development of the Chinese people and their civilization.

The search for the origins and locations of archeological cultures has been tied to theories of cultural diffusion and migration. Traditional historiography as well as the modern Marxist model are particularistic and evolutionary and propose that Chinese civilization emerged in the Yellow River "core" and then spread to "peripheral" areas by way of political expansion and cultural diffusion over many millennia. Most Chinese archaeologists have accepted the main premise of this model. The underlying assumption is that there is a cultural norm so that major early excavations were concentrated in those areas where the archaeologists expected, or at least hoped, to verify the early histories through the construction of chrono-typologies for material cultural, human and faunal remains. Thus, the most prestigious and guarded research

is that on the Yellow River Basin. Even in Paleolithic studies, the evolution of human Pleistocene prehistory has been sought within China, and comparative studies are a relatively recent endeavor. Chinese archaeologists have very rarely gone abroad to work, although with the new policy of the Ministry of Education in 2005 that underwrites Chinese graduate students to go abroad as visiting scholars for one year, this could be changing.

Many factors have affected Chinese archaeology, including material science and historical metallurgy. The sheer volume of materials unearthed in scientific excavations in the twentieth and early twenty-first century is probably the most significant factor. Regulations on preservation of cultural remains instituted since 1949 have necessitated examination of sites through construction work; this has produced data from beyond the core area have come to light and have fundamentally affected the analysis of early China (Fong 1980, pp. 20–34; An 1989; Faulkenhausen 1995, pp. 198–217; Chang 1981, pp. 156–168; Linduff 1998, 2000, pp. 1–29; Liu and Li 2007).

In addition, since the early l980s the central government has loosened its controls on provincial and local efforts, and archaeological investigation has witnessed an increase in regionalism as a result of decentralization. Since then most provinces have developed their own teams led either by University faculty or by Museum scholars and many publish journals dedicated to presenting area finds. The officially sanctioned journals continue (*Kaogu, Wenwu*, *Kaogu Xuebao*, *Kaogu yu Wenwu*, etc.) with the addition of several journals that focus on regions (*Southern Ethnography and Archaeology*), or Provinces (*Archaeology of Inner Mongolia, Sichuan Cultural Relics*), for instance. Some are cleared for export, but many are not available outside of the People's Republic of China (PRC). The publication of monographs and field reports is now and will continue to be expensive and the exception frequently depends on subvention from outside sources.

The primary focus of these publications is now, and presumably will continue to be, the reporting of new sites and the typology and periodization of objects or the decipherment of the iconography of decor. These typologies are the basis of geographic and temporal definition of "cultures" in China today. How to interpret the new material and its implications for Chinese history has met with much more interest and controversy than discussions of method and theory.

With the archaeological fieldwork conducted in the last 25 years, perhaps the single most challenged notion about the formation of early Chinese culture has been whether it emerged in a unilinear fashion, from a single core which developed in the Central Plain and spread from there to other parts of Asia, or otherwise. Most current research suggests that "otherwise" is the more plausible explanation. Many questions follow from the new data. Along with late twentieth-century efforts in the PRC to maintain a unified nation, archaeological investigations have been useful when they studied areas where ancient minorities might be traced. More recently, when the mononuclear theory necessarily weakened as more and more diverse materials were unearthed, a regional paradigm has been proposed (Zhang 1986; Lin 1986; Wu 1995). Using Su Bingqi's regional model, some (Zhang 1986) suggest that among the many goals of Chinese archaeology the search for the origins of the "Hua", or the ethnic Chinese, as well as for the ancient minorities is especially worthy. But what and

who contributed to Chinese culture are questions that strike deep into nationalistic, as well as ethnic sentiments. For instance, the most recent attempts to 'regularize' the chronology of early dynastic, or Bronze Age, China engaged over 200 Chinese scholars and produced a well-informed, but consistently unilinear, chronology (XSZ 2000). And whatever the nature of one's interpretation of culture and its formation and change, the point or points where such questions could be tested have not, until very recently, been identified archaeologically.

Because the salvage recovery has been, and presumably will continue to be, the norm for Neolithic and historic archaeology, those regions that are most prosperous or where new road-building, housing, or nationally designated projects (such as the Three Gorges Dam project) are undertaken will be where most new information will be yielded. Surely South and South-central China will see increased archaeological activity as a result of the booming economy there. Even so, we will probably not see a de-emphasis on research on or in the Central Plain, but unless unexpected prosperity reaches the region, few new large-scale projects will be initiated there soon without outside funding.

An exception to activity centered on salvage recovery will be that provided by Sino-foreign projects (Murochick 1997). In the 1990s a few Sino-foreign teams began to conduct problem-oriented research that spans the Bronze Age (Liu 1996; Underhill et al. 1998; Linduff et al. 2002–2004). These regional surveys and test excavations have focused on the reconstruction of human behavior. This is a significant shift in emphasis, but one in which previously developed typologies and chronologies often play a significant role. Both new methods and theory, particularly those developed in North America since the 1960s, including computer technology, are of great interest to mid-career and younger Chinese archaeologists and have allowed real cooperation to develop. Experimentation and use of newly created collaborative methods inside of China are underway (CICARP 2003).

Emphasis on the context of human behavior has allowed some increased interest in systematic collecting and testing of information on environment, climate, ecology, animal and plant evolution, and so forth, although increasingly the data are integrated into studies of overall patterns of behavior in some regions (see, for example, Li et al. 2006). Technical studies on materials, such as those on metals and ceramics, on the other hand, do take place with some regularity and are quite telling in relation to the activities of communities in many regions.

The Study of Early Metallurgy in China

Most studies of incipient metallurgy focused only on fully developed phases dating from the second millennium BC. There is no question that by the early dynastic period in China, or no later than the Shang Dynasty (c. 1550–1050 BC), the ancient Chinese had already considered technological options and made technological choices about metals (Barnard 1961, Gettens 1967; Barnard and Tomatsu 1975). For use in ritual, they preferred tin-bronze for use in ritual to either silver or gold, even though resources for both were close at hand (Bunker 1993, 1994a, b; So and Bunker

1995; Linduff et al. 2000: Map 8, p. 277). They had developed a very sophisticated piece-mould system of casting, understood the properties of metals, and used their knowledge in the alloying process. A prescriptive tin-bronze industry was highly developed at that time and was supported by patrons of the political and social elite.

The tin-bronze items produced were used in rituals that paid reverence to ancestors, including the recently deceased, and were often placed in elaborate burials. As signs of political and/or social position and wealth associated with it, such metal items are unmistakable evidence of social inequality in the already highly stratified society of the late Shang period. Metal farming implements as well as tools are absent from the archaeological record of the Shang period, for instance, further confirming the exclusivity of the technology and highlighting its restricted use. This dedicated role for metal production and its resulting artifacts mark late Shang society in the Central Plain as well as elsewhere (Sichuan for instance), where large production centers have now also been found. This is unusual among ancient world cultures, for in Mesopotamia, for example, metal items served multiple purposes including utilitarian ones.

But this late Shang tin-bronze industry was not a primitive stage in the development of metallurgical technology; it was simply the first one documented in East Asia. Research on ritual tin-bronzes and the implications of their use among the Shang have been refined over the years since the discoveries were first made in the late 1920s, but questions about where and how metals were used and about how and where the technology developed prior to that period have suffered from lack of information from excavated contexts. This situation has changed in the past two decades. More than 70 sites that can be dated either by C and/or by archaeological context earlier than 1500 BC have been published (Linduff et al. 2000: Table II, pp. 355–384). These published sites yielded metal artifacts and/or metal production materials such as crucibles, or slag, and so forth (Linduff et al. 2000: Tables I and II, pp. 322–384). Analysis of the data, including the metallurgical content of many items, casting technology, as well as the types and uses of metal artifacts in the period from about 3000–1500 BC, leads to some surprising observations about the advent of metallurgy in eastern Asia and about its role and development in complex society.

Recent syntheses that investigate early China usually now view the archaeological landscape during the fourth millennium BC as a mosaic of regional groups that interacted with each other (Chang 1986). When dealing with the period of early metal use however, most Chinese archaeologists have accepted a traditional model which regards the Central Plain of northern China as the dynamic center of social, political, and technological change and propose that complex societies emerged in Asia through a process of interaction with the Yellow River Basin (BUIST 1981; An 1993; Linduff et al. 2000: Map 1, 2, 3, 4, 5) (Fig. 27.1). The elevated position of metal artifacts as well as the highly specialized and sophisticated multi-piece mold technology developed to produce them in early Chinese society have fueled the assumption/conclusion that the commencement of metallurgy in East Asia was to be found inside the early Chinese cultural, and/or even the political, sphere (BUIST 1981; An 1993; Barnard 1987, 1993). Now this conclusion is being challenged because there is adequate information to show that metal artifacts, in at least one other area, to the west of the Central Plain, were locally produced in enough volume

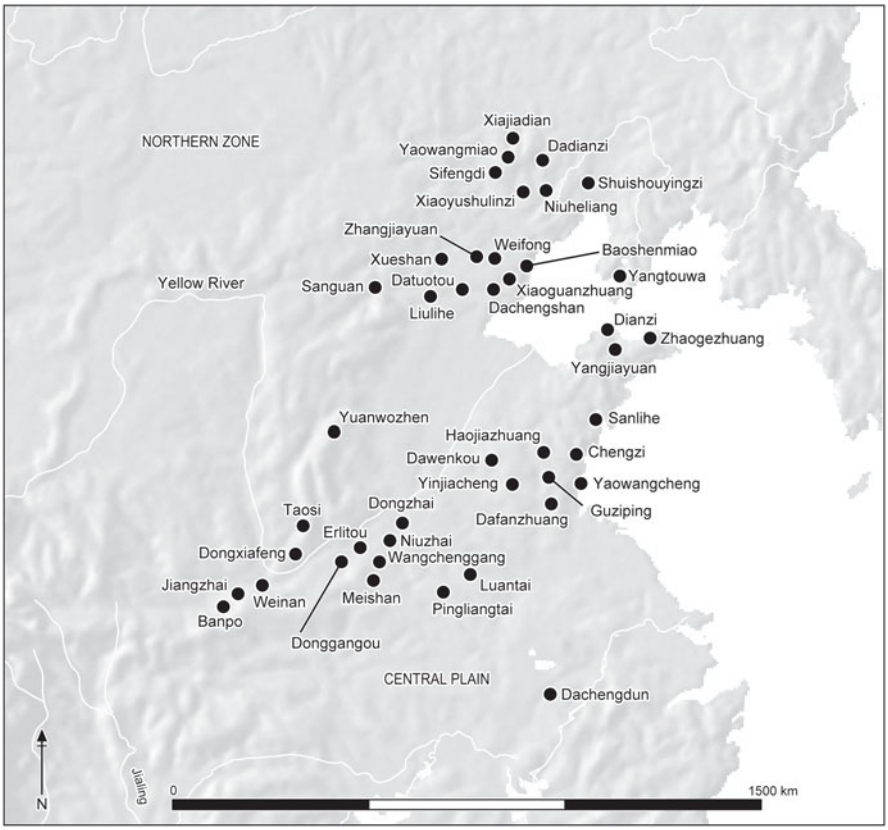

Fig. 27.1 Northern China, Yellow River Basin, showing key early metal sites

to confirm its regular use (An 1993; Mei and Shell 1998; Mei 2000; 2003a; Linduff et al. 2000: Maps 1–4, I.2, pp. 1–29; Liu and Li 2007). In addition, the types of objects found in this region as well as the component percentages of metals in the mix do not correspond to tin-bronze types and alloying formulae found in the Central Plain (Linduff et al. 2000: Table I, II.10; Sun and Han 1997).

From these recently excavated and reported sites where metal artifacts have been reported dating prior to 1500 BC, we can see that one of the most striking, as well as usual, additions to late Neolithic village life in northeastern Asia was the beginning of the use of metals. Cultures where metals (including copper as well as alloyed metals) were first used and manufactured are located across a large area from the west, across the northern frontier, to the eastern seaboard in and to the north of what has been traditionally been called 'China proper.' The growth of the industry did not solely, or even primarily, occur in the Central Plain associated with early dynastic China, but in several regions (Linduff et al. 2000: Map 1). Moreover, preliminary observations on the process by which and the places where the technology developed

as well as the role of metals and metal objects in these societies suggest that whereas each locus was quite distinct culturally even during the early dynastic period, they were also probably interconnected.

Scientific examination of metal artifacts dating prior to 1500 BC has been playing a major role in the study of early metallurgy in China. Leadership in this arena has been consistently provided by the Institute of Historical Metallurgy and Materials (IHMM) and University of Science and Technology Beijing (USTB), first under the direction of Ko Tsun, Han Rubin, Sun Shuyun, and Mei Jianjun. Although research interest in the development of ancient metal technologies appeared in China as early as the 1920s, the history of metallurgy as a discipline became established only in the mid-1970s, when Ko Tsun and a small group of scholars (Archaeometallurgy Group) from several different institutions in Beijing initiated a series of research programs on ancient Chinese metallurgy, including the first systematic scientific investigation of early copper and bronze artifacts recovered in the present-day China. The mid-1980s witnessed the introduction of training programs for graduate students in the history of metallurgy, an important step that brought in young generations of scholars who have now become active in the field in China. While the science-oriented research approach has become widely adopted and has been making substantial contributions to a new understanding of early metallurgy in China, the need for an interdisciplinary approach that would combine social, anthropological, and scientific perspectives has become increasingly obvious. A emerging new trend emphasizes the examination of early Chinese metallurgy within its social and cultural context and the exploration of relationship between early metallurgy and social complexity.

The Evidence

The earliest sites that have yielded metal objects date to the late fourth and third millennia BC (Linduff 1997, pp. 306–418; Mei 2000) (Fig. 27.1). Quite early metal-using communities are found in Qijia/Siba sites in Gansu, with comparable sites in Xinjiang in the west, and others in Shandong, Liaoning, and Inner Mongolia in the east and north, and in the Central Plain in the lowest levels at Erlitou (Fig. 27.1). Because several levels of excavations are 14C dated and those dates have been matched up to ceramic types and styles, chronologies are more secure. An approximate chronological correspondence between the sites in the eastern Eurasian steppe and China is now clear, and suggests that the emergence of metallurgy was supraregional (Linduff et al. 2000, pp. 1–28).

Analysis of the data, including metallic composition, casting technology, as well as types and uses in the period from about 3000–1500 BC yielded evidence of the use of metals in late Neolithic in northeastern Asia as far east as the Russian Far East. Sites where metals (including copper as well as alloyed metals) were first used and manufactured are located across this large area, showing that the growth of the industry was not confined to the Central Plain. Moreover, preliminary observations on the process and patterns of use of the technology are both shared and diverse such as at Siba and Erlitou (Sun and Han 1997).

Areas in China where metallurgical knowledge was in use emerged near ore sources of metals, especially copper in several combinations (Barnard 1993, pp. 3–48; Barnard 1987, pp. 3–37; Linduff 1997; Linduff 1998, pp. 619–643). For instance, arsenical copper objects produced in Gansu at Siba sites must have been manufactured by exploiting local arsenical copper resources still available in present-day Gansu. All areas developed a taste for items made from 'pure' copper and copper alloys, and gold items have been found in the Northeast and Northwest China. Trumpet-shaped earrings, for instance, have been found all over eastern Eurasia and northern China and were made from copper, tin-bronze, as well as gold and sliver, according to the local preference and show a clear regional choice, unlike that in the central Yellow River Basin where the earliest Chinese states were located (Liu and Chen 2003, pp. 80–81). The lack of consistency in formulae suggests that knowledge was gained from several sources and not through local invention (Sun and Han 1997; Mei 2003a, b).

Areas where metal objects were recovered stretches across an area from the west, across the northern frontier (of early dynastic China), to the eastern seaboard, and these are dated from the third and early second millennia BC.

These are:

1. Area I: **The Qijia** culture (c. 2500–1900 BC) of Qinghai, Gansu and western Shaanxi has yielded copper and copper-based alloyed utilitarian items and gold, copper, and copper-based alloyed personal ornaments. The earliest dates for metal in this region are found at a Majiayao site at Linjia (see Fig. 27.2), Dongxiang, Gansu. "Copper" (analyses of metal knife and awl showed 99 % copper with impurities of lead, tin, and so on of less than 0.4 %) implements including knives, chisels, awls, and rings, and in one site a mirror (at Gamatai in Guinan, Qinghai see Fig. 27.2) were unearthed in several sites (KGYWW 1980).
2. Area II: **Zhukaigou** (Levels 3, 4, and 5; c. 2000–1500 BC), in South-central Inner Mongolia, has yielded copper, tin-bronze and bone weapons, and tools typical of both the Central Plain and the Steppe cultures (both Andronovo and Karasuk) (KGXB 1988).
3. Area III: the **Lower Xiajiadian** culture (c. 2000–1600 BC) in eastern Inner Mongolia, Liaoning, northern Hebei produced highly specialized pottery and walled villages as well as copper and copper-based alloyed utilitarian tools and personal ornaments which parallel those of the Andronovo culture (KG 1978; Zhang 1986).
4. Area IV: **Erlitou**, Henan, in the Central Plain (Phases 3 and 4; c. 1750–1530 BC) is exemplified by tin-bronze tools, weapons and piece-mould vessels, jade ritual materials, as well as walled villages.
5. Area V: the **Yueshi** culture (c. 2400–1600 BC) in Shandong yielded bronze and brass utilitarian items including nose rings, but larger than those from Huoshaogou in Gansu (Linduff et al. 2000: I.6; Xu 1989).

The archaeological record suggests that at the critical, protodynastic period in the late third and early second millennia B.C., all these cultures were at a similar level

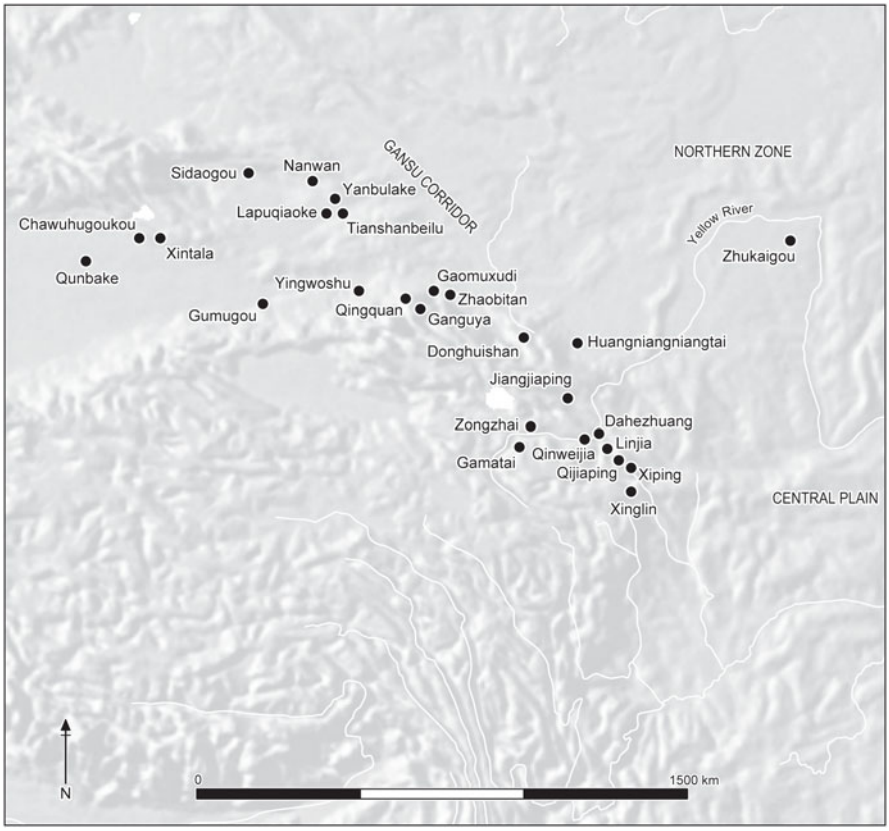

Fig. 27.2 Central China, Gansu Corridor, and upper Yangtze, showing key early metal sites

of societal development. Those outside of the Central Plain were producing both worked and simple cast objects on a small scale (Linduff 1998). These sites locate the use of metal working (Areas I, II, III, and V) and casting (all Areas) as well as regionally specialized ritual materials all at about the same time. With this evidence, the possibility that metal technology was introduced to the Yellow River Basin must be considered, while maintaining the possibility that the elaborate piece-mould casting methods used to cast ritual vessels in the Shang Dynasty may likely have developed independently in the Central Plain.

The appearance, but also the demise of these metal-using communities outside of that in Dynastic China is also a great dilemma. The type of social complexity at Areas II and III worked against their emergence into ranked, hierarchically ordered societies like those developed in the rich agricultural lands of the Central Plains. Their economies likely did not collapse, but rather were recast by increased dependence on pastoralism in Area II (Indrisano 2006) and hunting, trapping, and pig farming in Zone III (Shelach 1994, 1999), thus, dramatically separating their lifeways from that of Chinese agriculturists.

Implications of the Data

Taken together, these sites locate a broad area across northern East Asia where the beginnings of metal use can be located and dated at about the same time. All areas where metallurgy emerged were near ore sources of metals, especially copper in several combinations (Linduff et al. 2000: Maps 5–8). For instance, the distinctive arsenical copper objects must have been manufactured by exploiting local resources that are still available in present-day Gansu. (Linduff et al. 2000: Map I) Although each area developed a taste for items made from copper and copper alloys, gold items have been found only in the northeast and northwest. These gold items (earrings and nose ring) are only occasionally found, and may be imports, valued perhaps for their rarity, or they may have been manufactured locally and used because of their form to signify group affiliation. The earring (including nose rings) types were known in far greater numbers made from copper and tin-bronze, and especially in Qijia and Siba sites in Area I.

The makeup of each culture area, even in this preliminary survey, belongs to a distinctive archaeological culture identified by its pottery and speculated upon by some according to ethnicity (Linduff et al. 2000, I.9, II.10). In all regions, the economy is mixed; excavated villages have yielded evidence of both cultivated crops and domesticated animals, as well as the continued practice of hunting with improved arrowheads made of tin-bronze. Many early copper products show an uncanny resemblance to each other across the Northern Corridor—from Gansu, to Lower Xiajiadian in the northeast, to Yueshi in the Shandong Peninsula. Metal ornaments and simple tools seem not to designate rank in any of the sites outside of the Central Plain as, for example, in burials at Huoshaogou, where metal items are included in most burials. That is to say, the material of their manufacture is not noticeably restricted as it is in sites associated with dynastic China throughout the mid-second and first millennia BC.

The presence of comparable tin-bronze tools and many other shared traits mentioned above suggests, nevertheless, that there was a network of some type, however loosely connected. As part of a network, those outside may have contributed to the development of state-level society in the Central Plain (oracle taking, for instance, or more substantively through interdependent economic systems) (Shelach 1994; Linduff 1998), rather than merely acting as passive receivers of metallurgical technology and other features of complex society from the Central Plain, as has been suggested in the past. They are linked through comparable artifact types and by shared metallurgical technologies not easily transmitted without movement of craftworkers or even larger groups of travelers.

The expansion of the metal tool-kit and the production of it in alloyed metals in the early second millennium BC in Gansu and the surrounding area did not witness an intensification of its use as a political marker, as was the case with tin-bronze items produced and buried in the Central Plain, but perhaps as a cultural identifier. The consistently local character (pottery types and styles) of sites, as well as the appearance of metal items with affinities to cultural debris of Bronze Age southern Siberia, suggests that there was movement into the Gansu Corridor of newcomers

who were possibly horse herding (Anthony 2007), but certainly metal-producing peoples of Andronovo background (Peng 1998; Mei and Shell 1998, 1999). Movement of groups along a north–south path must also be considered as such movements are still very much part of life on the eastern Eurasian steppe today (Sandra Olsen personal communication). Among those eastern Inner Eurasian peoples, animal sacrifice also signified status and/or leadership in burial and metal items included tools, weapons, and personal ornaments associated with individuating societies, not with one whose symbol system was used to identify all members of the same political unit, as exemplified by the use of the tin-bronzes at Erlitou.

Still, the best-known cultural trajectory is the one at Erlitou and its surrounds. The sophisticated tin-bronze industry was apparently the exclusive commodity of the elite and developed along with the emergence of social complexity and ritualized social hierarchy (Chang 1980). This development is already apparent in the second millennium BC, where status-based and role-related social decorum operated in the religious, social, and political spheres (Keightley 1990, p. 42) and demanded the production and use of the ritual items such as vessels and weapons cast out of tin-bronze as at Erlitou. They experimented with metals in the region in the late third and early second millennium BC, but by about 1750 BC, they were on a different track from the cultures to their northeast and northwest. The emergence of state-level society no later than the Shang was synonymous with tin-bronze production. Where the advanced methods of piece-mould casting were invented is yet to be determined, but their restricted use of alloyed tin-bronze was apparent from at least as early as the sites at Erlitou, Henan.

Outside of the Central Plain, the story is different, and the archaeological record is beginning to clarify those differences. Each area experimented with metal use at the household level well before 1750 BC. Each area made artifacts from copper or alloyed metal items of comparable shape and style for utilitarian or decorative use; and each followed its own local historical path. The Shandong peninsula contributed to and finally was absorbed into the Chinese dynastic society in the second millennium BC. The cultures in the northeast region continued a sedentary lifestyle and increased independent tin-bronze production substantially after about 1000 BC. In the northwestern region, the local cultures called the Qijia and Siba were seemingly more connected with cultures to their own west, never established centrally managed state-level societies, and remained outside of the Chinese cultural and political dynastic arena until the Qin conquered these lands in about the fifth century BC. This area seems not to have been inspired by the Central Plain about tin-bronze metallurgy or much of anything else detectable in the archaeological record. Their knowledge of horses and of certain metal tools were eventually probably imported into the Central Plain.

The communities in these four areas are all late Neolithic agricultural communities, but their economic strategies, social organization, probably their political systems, and surely their ideologies differed. Some, especially those west of the Wei River, gained much greater benefit from their western neighbors, who inhabited the plains of eastern Inner Eurasia, than from the Chinese dynasts to their east and remained outside of Chinese political control and cultural sway for centuries following.

China and Eurasia

Because little was documented to suggest an earlier phase of metallurgy and because of the prevalence of a diffusionist model of explanation among western scholars, knowledge of metals in regions east of the Caucasus has most often been explained by proposing a route of transmission from the Near East across Russia to the Far East. Two possible routes have been suggested: the Northern and/or a Central Asiatic. Both routes were thought to have begun in the Anatolian–Iranian area and traversed the Caucasus across the Eurasian Steppe or from Iran up to the Amu Darya and over the Tianshan Mountains to Kashgar (Tylecote 1976, pp. 14). Such diffusionist theories rested on the chronology of the Near Eastern sites. The lack of reports on early use and manufacture and the limited availability of reports written only in Russian and Chinese have hindered reliable testing of the diffusionist model.

Among Chinese and Russian scholars, study of the industry and proposals about who initiated the movement of ideas have been affected by mutual lack of information because of language barriers, but especially because of political borders and nationalistic sentiments. The now-dated debate between Profs. B. Karlgren and M. Loehr presented judgments on the direction of transmission for the technology, for example, based on analysis of style of artifacts and the manner of its transformation across time and space (Karlgren 1945; Loehr 1949a, b). Their arguments, Karlgren as the champion of China and Loehr of Siberian cultures as the primary source for certain artifact types and ultimately for the technology itself, were mounted at a time when excavated, tested, and dated materials earlier than about 1250 BC were lacking from both sides. And although archaeologists and metallurgists have questioned the diffusionist model, this view and others are now being reassessed in light of new archaeological information (Mei 2003a; Liu and Li 2007).

The translation of Evgeny Chernykh's text on the early metallurgy in the USSR has allowed access to readers of English to excavated materials from the territories between the Near East and central Siberia (1992). In addition, better and more complete reports on copper- and metal-using as well as mining sites in Russia, especially those east of the Ural Mountains such as Arkaim and Sintashta-Petrovka (Gening et al 1992; Chernykh and Kuz'minykh 1989) and Kargaly (Chernykh 2003) and from northern East Asia dated to the third millennia BC are also available, still largely in the local languages (Linduff 1997; Chase and Douglas 1997). Not only do such reports suggest that there was contact between cultures of the eastern Eurasian steppe and China, but also that the beginnings of metallurgy in this part of the world was regional and took direction according to the host culture and local demands. Wide-ranging studies on the process of this development are still rare (Barnard 1983, 1987; Linduff 1997, 1998; Linduff et al. 2000, pp. 1–28). These studies do not allow independent evaluation of the sources, however, by those trained either outside of Chinese area studies or in metallurgy.

The Chinese preoccupation with the notion of the primary role of the Central Plain to the emergence of Chinese civilization (An 1989; Chang 1977; Chen 1988; Olsen 1987; Falkenhausen 1993) is apparent still, even though it is also clear that there

are many early, precocious metal-producing sites outside the area considered as the homeland of the dynastic Chinese. This struggle has an extensive and very well-argued history in Chinese scholarship, making long-held mononuclear notions about the rise of Chinese civilization not only hard to change, but also striking when the view is challenged. For example, An Zhimin's 1993 article suggesting that there may have been multiple centers where the experimentation with metals took place was a landmark in Chinese scholarship. This well-established leader of the archaeological community in China joined other, earlier speculations on the matter, but it was his voice that was widely heard. The introduction of sophisticated methods of scientific examination of the composition, structure, and sources of metals has added yet another, very powerful analytic tool to the study of early Chinese technology.

Another problem has vexed Chinese archaeologists as they excavated and published early materials—the question of dating. Of central concern to archaeologists in China as elsewhere, the use of carbon dating and the calibration of these dates have revolutionized methods of dating, formerly based entirely on stratigraphy and the development of ceramic, or other, diagnostic typologies. The combination of these two methods is now in use in many locations in China and yields evidence of periodization that can be more confidently accepted and compared to other areas of the world. In some cases, these newly calculated Chinese dates have necessitated a reevaluation of those metal-producing sites across its borders in Russia (Mei 2000, 2003b). A collection of essays, bibliography, lists of calibrated C14 dates, and maps have made available some important papers and data, but much was not covered in that text (Linduff et al. 2000). Work on mining, for instance, brings data to the discussion that was all but missing before the mid-1980s (Hua 1986, 1987, 1991; Li, et al. 2007).

This region of eastern Eurasia is linked through comparable artifact types, by closeness to ores, and by shared metallurgical technologies not easily transmitted without movement of craft workers or even groups of travelers. The consistently local character of pottery types and styles in sub-areas, as well as the appearance of metal items with affinities to cultural debris from Bronze Age southern Siberia, suggests that there was movement into the area of western China, likely metal-producing peoples from eastern Kazakhstan and/or Transbaikalia (Shui 1993; Chen and Hiebert 1995; Mei and Shell 1999). As mentioned above, animal sacrifice signified status and/or leadership in burial and metal items included tools, weapons, and personal ornaments associated with individuating societies in the region of Gansu, metal items ultimately were used to identify only elite members of a centralized political unit at Erlitou in the center of early dynastic China. As Kuz'mina suggests (2003) the appearance of wheeled transport, metallurgy and use, and/or breeding of horses signal not only movement of ideas, technology, and perhaps peoples, but also significant societal change, and often lead to a more complex social order. This process may or may not characterize the village settings in western and northern China (Linduff et al. 2000, pp. 1–29), but changes in social complexity are clearly identifiable in and around Erlitou in the Central Plain.

Further, we may note that this change evidenced for the earlier to middle second millennium BC was not a one-time affair. That was not the only period of interchange

between the peoples of western China and points west. Continued stimulation, moving in both directions, can be witnessed in the later second and early first millennia BC. Nor are the border regions of present-day western China the limit of that exchange system. Both local pottery and early metal artifacts suggest that knowledge of metallurgical traditions and artifact types extended into northeastern China and into what is now the Russian Far East.

Nevertheless, when considering the advent of metallurgy in the late fourth and third millennia BC, all the criteria of the Eurasian Metallurgical Province (EMP) defined by Chernykh are found in the "Chinese" contexts. If separated from modern nationalistic and centric views of ancient culture and considered as part of a larger metallurgical context, even the multi-piece-mould casting method developed in the early second millennium BC at Erlitou, thought of as a hallmark invention of early dynastic China, may be seen as a local technological variation within the easternmost Eurasian territory made for specialized ritual use (Linduff 2004).

The Future

It is clear that more work needs to be done before analysis of metallurgy and societal change can be productively carried out. A few suggestions follow:

Further regional and local analysis needs to be done, including multidimensional study of communities including excavation of habitation sites, hopefully production sites, as well as mines, etcetera. From these contexts, clearer chronologies could be created. Study of the region would benefit from expansion to a more concentrated analysis that includes southwestern and south central China, which is not studied well and could be important to further analyses. Connections with Southeast Asia are just beginning to be investigated systematically (Higham and Higham 2009; Pigott and Ciarla 2007; White and Hamilton, this volume).

More intensive technological analysis would add immeasurably to the discussion. Both metallographic and compositional analysis could lead to discussion about where and how alloys were produced. Especially problematic is the fact that technical data on excavated materials produced in the Central Plain are largely absent. These data are essential to any study in East Asia. Although scientific examination of dozens of metal objects excavated at the Erlitou site, for instance, has been completed, the results have not yet been published. The major alloy types of the Erlitou metals include Cu–Sn and Cu–Sn–Pb, though there are a small number of artifacts made of Cu–As, probably an indication of connections to other regions. Generally speaking, the Erlitou tin-bronze industry is slightly later than what we have seen in Northwest China. Therefore, evidence for the existence of some borrowing from Northwest and North China in the Central Plain during the Erlitou period is becoming strong, but this is not yet decisive or adequately documented. Regional interaction needs to be documented as well, especially from several distinctive regions including the Central Plain, Gansu-Qinghai, Xinjiang, and the Northern Zone.

In addition, perhaps one of the most intriguing questions yet to be addressed systematically is about the invention of piece-mould casting methodology. We need to examine this issue from both technological and socio-cultural angles.

More study of mining and ores would allow a more firm understanding of sources and the relationship between trade and interaction with the emergence of societal complexity. Although we suspect that in all the metal production regions local mineral resources existed, we cannot deny the importance of interregional trade networks. Some hard evidence for mining has been located in recent years. In 2007, for instance, an early mining site (Lower Xiajiadian period?) was discovered in Inner Mongolia, and analytical work is now being carried out on the data from that site. Similarly, also in 2007, two early smelting sites (second millennium BC) were discovered at unexpected locations in the Hexi corridor in Gansu. The discovery has raised questions concerning the organization of early mining and smelting activities, as one site is located in the desert, almost 100 km away from the Qilian Mountain where the most likely source for the metal ores is located. This suggests that it may become increasingly important to look at the societal context of early metallurgy, since it is likely that early communities in the Hexi Corridor were village level societies and could presumably only support metallurgical activity on a relatively small scale.

If as more and more sites are excavated, greater information on soil, on animal life, on diet, on regional patterns including economic, political, and social organization were gathered, analysis of the data could lead to more firm explanations for cultural interaction, trade, as well as for the function of metal products and their production in society.

In contexts where manufactured metal artifacts have been found in China, excavated villages have yielded evidence of both cultivated crops and domesticated animals, as well as the continued practice of hunting with improved arrowheads made of metal, especially in the northeast. Chernykh's fanciful speculation that the Seima-Turbino was formed through a fusion of metallurgists and warrior horse riders of the forest zones of the Altai and eastern Siberian taiga mobile hunters (1992), he claims, is supported in the recent excavations of the village at Gorny (Chernykh et al. 1998), Kargaly (Chernykh 1997; 2002–2007), and many others including Arkaim and related sites (Zdanovich 1997). Located close to vast resources of ores in the Urals, these excavations reveal that isolated groups of miners and metallurgists worked in specialized communities for many generations supplying patrons across western, and possibly eastern, Eurasia. In China's Central Plain, with an emerging ruling class, state-level society and the ritual significance given to alloyed metals, the network included not only the regional importation of metal ores, but also of salt (Liu and Chen 2003, pp. 80–81), and supported a very specialized metal industry that developed quite differently and perhaps independently from those communities/polities in areas to the north, northeast, and west of ancient China (Linduff et al. 2000). Those outside of the Central Plain emerged perhaps in concert with, however, interactions with eastern Eurasia.

Therefore, in considering the directions for future research, four points may be emphasized: first, technological analysis is basic and should be carried on, with a greater emphasis on the samples collected from production sites, including slag,

ores, and furnace materials. Comparative studies based on analytical data should be done in order to characterize the regional technological features, which could be used as evidence understanding the pattern of contacts or interactions between various regions. Second, regional analysis may include an examination of sociocultural context for metallurgical production, such as ceramic production, ritual preference, burial custom, religious tradition, artistic choice, and so on. More attention should be paid to exploring how early metallurgical activities were organized and what they contributed to the increase of social complexity. A combination of technological and archaeological approaches will be necessary. Third, local innovations and long-distance contacts are two vital issues that are worthy of in-depth exploration by employing an interdisciplinary approach. Several important early metallurgical innovations have been noted, such as piece-mould casting, arsenical copper, leaded bronze, decorated mirrors, but how they emerged and developed still remain unclear and required further research. Fourth, more comprehensive scientific dating must guide all considerations above, and could be provided in new as well as previously excavated and surveyed locations. Then, if these issues were examined within a wider Eurasian context, the contributions from both local innovations and outside impetus could be properly highlighted. It is important to understand the scale, patterns, and mechanisms of early interaction, including trade and exchange, movement of people, as well as community conflict.

Furthermore, as western research approaches as well as theoretical thinking continue to be introduced into China, academic discussion and debate among scholars will be stimulated. Much more is still to be learned and close collaboration and academic exchange between Chinese and other scholars should and is being encouraged.

Bibliography

An, Z. (1989). Chinese archaeology: Past and present. *Archaeological Review from Cambridge*, *8*(1), 12–18.

An, Z. (1993). On Early Copper and Bronze Objects in Ancient China. *Kaogu*, *12*, 1110–1119.

Anthony, D. W. (2007). *The horse, the wheel and language*. Princeton: Princeton University Press.

Barnard, N. (1961). *Bronze Casting and Bronze Alloys in Ancient China*. Australia & Lagya: Canberra.

Barnard, N. (1983). Further evidence to support the hypothesis of indigenous origins of metallurgy in ancient China. In D. N. Keightley (Ed.), *The origin of Chinese civilization* (pp. 237–277). Berkeley: University of California Press.

Barnard, N. (1987). Bronze casting technology in the peripheral 'Barbarian' Regions. *Bulletin of the Metals Museum*, *12*, 3–37.

Barnard, N. (1993). Thoughts on the Emergence of Metallurgy in Pre-Shang and Early Shang China, and a Technical Appraisal of Relevant Bronze Artifacts of the Time. *Bulletin of the Metals Museum*, *19*, 3–48.

Barnard, N., & Tomatsu, S. (1975). *Metallurgical Remains of Ancient China*. Tokyo: Nichiosha.

BUIST (Beijing University of Iron and Steel Technology, Archaeometallurgy Group). (1981). A Preliminary Study of Early Chinese Copper and Bronze Artifacts. *Kaogu xuebao*, *3*, 287–302.

Bunker, E. C. (1993). Gold in the Ancient Chinese World: A Cultural Puzzle. *Artibus Asiae*, *LIII*(1/2), 27–50.

Bunker, E. C. (1994a). The Metallurgy of Personal Adornment, *Adornment for Eternity: Status and Rank in Chinese Ornament* (pp. 31–39). Denver: Denver Art Museum and The Woods Publishing Co.

Bunker, E. C. (1994b). The enigmatic role of silver in China. *Orientations*, *25*(November), 73–78.

Bunker, E. C., Kawami T., Linduff K. M., & Wu E (1997). *Ancient Bronzes of the Eastern Eurasian Steppes from the Arthur M. Sackler Collections*. New York: the Arthur M. Sackler Foundation.

Chang, K. C. (1977). Chinese Archaeology since 1949. *Journal of Asian Studies*, *XXXVI*(4), 623–644.

Chang, K. C. (1980). *Art, Myth and Ritual: The Path to Political Authority in Ancient China*. Cambridge: Harvard University Press.

Chang, K. C. (1981). Archaeology and Chinese Historiography. *World Archaeology*, *13*(2), 156–168.

Chang, K. C. (1986). *The Archaeology of Ancient China* (4th Ed). New Haven: Yale University Press.

Chang, K. C. (1989). Ancient China and its Anthropological Significance, in *Archaeological Though in America*, edited by C.C. Lamberg-Karlovsky, pp. 155–166. Cambridge: Cambridge University Press.

Chase, W. T., & Douglas, J. G. (1997). Appendix 2: Technical Studies and Metal Compositional Analysis of Bronzes from the Eastern Eurasian Steppes. In E. C. Bunker, et al. (Ed.), *Ancient Bronzes of the Eastern Eurasian Steppes from the Arthur M. Sackler Collections* (pp. 306–418). New York: The Arthur M. Sackler Foundation.

Chen, C. (1988). Chinese Archaeology and the West. *Archaeological Review from Cambridge*, *8*(1), 26–35.

Chen, K. T., & Hiebert, F. (1995). The Late Prehistory of Xinjiang in relation to its neighbors. *Journal of World Prehistory*, *9*(2), 243–300.

Chernykh, E. N. (1992). *Ancient Metallurgy in the USSR: The Early Metal Age*. Cambridge: Cambridge University Press.

Chernykh, E. N. (1997). *Kargaly, Zabytyi mir* (Kargaly: The Forgotten World). Moscow: Izdatel'stvo 'NOX'.

Chernykh, E. N. (2002–2007). *Kargaly Vols. 1–5*. Moscow: Nauka.

Chernykh, E. N., & Kuz'minykh S. V. (1989). *Ancient Metallurgy in the Northern Eurasia: Seyma-Turbino Phenomenon*. Moscow: Nauka.

Chernykh, E. N., Antipina, E. E., & Lebewedeva E. Y. (1998). *Produktionsformen der Urgesellschaft in der Steppen Osteuropas (Ackerbau, Viezucht, Erzgewinnung und Verhuttung)*, *Das Karpatenbeckens und die osteuropaische Steppe: Nomadenbewegungen und Kulturaustausch in der vorchristlichen Metallzeit (4000–500 v. Chr.)*. Sudosteuropa-Geselschaft, München. B. Hensel und Rahhen/Westf: Leidorf, pp. 233–252.

CICARP The Chifeng International Collaborative Archaeological Research Project 赤峰中美联合考古研究项目 (编著) (2003). *Regional Archaeology in Eastern Inner Mongolia: A Methodological Exploration*. 内蒙古东部 (赤峰) 区域考古调查阶段性报告, Beijing 北京: Science Press 科学出版社. (In Chinese and English)

Falkenhausen, L. von. (1993). On the historiographical orientation of Chinese Archaeology. *Antiquity*, *67*, 839–492.

Falkenhausen, L. von. (1995). The regionalist paradigm in Chinese archaeology. In P. Kohl & C. Fawcett (Eds.), *Nationalism, Politics, and the Practice of Archaeology* (pp. 198–217). Cambridge: Cambridge University Press.

Fong, W. (1980). *The Great Bronze Age of China*. New York: The Metropolitan Museum of Art.

Gening, V. F., Zdanovich G. B., & Gening, V. V. (1992). *Archaeological Sites of Aryan Tribes of the Ural-Kazakh Steppes*, Chelyabinsk.

Gettens, J. R. (1967). The *Freer Chinese Bronzes*. Washington, DC: Smithsonian Institution (Oriental studies, no. 7).

Higham, C., & Higham, T. (2009). A new chronological framework for prehistoric Southeast Asia, based on a Bayesian model from Ban Nok Wat. *Antiquity*, 83, 125–144.
Hua, J. (1986). *On the History of Metallurgy and Casting in China*. Beijing: Wenwu Chubanshe.
Hua, J. (1987). Technological characteristics of metal technology in ancient China. *Ziran Kexueshi Yanjiu 1*.
Hua, J. (1991). A discussion of the origin of chinese metallurgy. *Ziran Kexue Shi Yanjiu*, *4*, 364–369.
Indrisano, G. (2006). *Subsistence, Environmental Fluctuation and Social Change: A case Study in South Central Inner Mongolia*. PhD Dissertation, University of Pittsburgh.
Karlgren, B. (1945). Some Weapons and Tools of the Yin Dynasty. *Bulletin of the Museum of Far Eastern Antiquities*, *XCII*, 101–144.
Keightley, D. N. (1990). Early Civilization in China: Reflections on How It Became China. In S. R. Paul (Ed.), *Heritage of China: Contemporary Perspectives on Chinese Civilization*. Oxford: University of Oxford Press, Ltd.
KG Kaogu. (1978). *1*, 23–34.
KGXB (1988). *Kaogu Xuebao*, *3*, 322–331.
KGYWW (1980). *Kaogu yu Wenwu*, *3*, 22–24.
Li, Y., Willis, K. J., Zhou, L., Cui, H. (2006). The Impact of Ancient Civilization on the Northeastern Chinese Landscape: Palaeoecological Evidence from the Western Liaohe River, Inner Mongolia. *The Holocene*, *16*(8), 1109–1121.
Li, Y., Zhu, Y., & Chen, J. (2007). *Bronze Metallurgy of the Upper Xiajiadian Culture*. BUMA-V Meeting, Beijing, unpublished paper.
Lin, Y. (1986). A Reexamination of the Relationship between Bronzes of the Shang Culture and of the Northern Zone'. In K. C. Chang (Ed.), *Studies in Shang Archaeology* (pp. 237–273). New Haven and London.
Linduff, K. M. (1997). An Archaeological Overview: Section 1. Reconstructing Frontier Cultures from Archaeological Evidence. In E. C. Bunker, et al. (Ed.), *Ancient Bronzes of the Eastern Eurasian Steppes from the Arthur M. Sackler Collections* (pp. 18–33). New York: The Arthur M. Sackler Foundation.
Linduff, K. M. (1998). The Emergence and Demise of Bronze-using Cultures Outside the Central Plain in Ancient China. In, by Victor Mair (Ed.), *The Bronze Age and Early Iron Age Peoples of Eastern Central Asia* (pp. 619–643). Washington, DC: The Journal of Indo-European Studies/The University of Pennsylvania Museum of Archaeology and Anthropology, Monograph Series.
Linduff, K. M., Han, R., & Sun, S. (2000). *The Beginnings of Metallurgy in China*. Lampeter: Edwin Mellen Press.
Linduff, K. M., Drennan, R. D., & Shelach, G. (2002–2004). Early complex societies in Northeast China: The Chifeng International Collaborative Archaeological Research Project. *Journal of Field Archaeology*, *29*, 45–73.
Linduff, K. M. (2004). The beginnings of metallurgy from the Urals to the Yellow River. In K. M. Linduff (Ed.), *Metallurgy in ancient eastern Eurasia from the Urals to the Yellow River* Lewiston: MellenPress.
Liu, L. (1996). Settlement patterns, chiefdom variability, and the development of early states in North China. *Journal of Anthropological Archaeology*, *15*, 237–288.
Liu, L., & Chen X. (2003). *State Formation of Early China*. London: Duckworth.
Liu, X., & Li, W. (2007). Zhongguo zaoqi qingtong wenhua de quyuan ji qi siangguan wenti xintan (A New Study on the Origin of Early Chinese Bronze Culture and Relevant Issues). *Zangxue xuekan (Journal of Tibetology)*, *3*, 1063.
Loehr, M. (1949a). Weapons and tools from Anyang and Siberian analogies. *American Journal of Archaeology*, *LIII*, 126–144.
Loehr, M. (1949b). Ordos daggers and knives: New material classification and chronology. *Artibus Asiae, XII*, 23–83.
Mei, J. (2000). *Copper and Bronze metallurgy in late prehistoric Xinjiang: Its cultural context and relationship with neighboring regions*. BAR International Series 865. Oxford: Archaeopress.
Mei, J. (2003a). Cultural Interaction between China and Central Asia during the Bronze Age. *Proceedings of the British Academy*, *121*, 1–39.

Mei, J. (2003b). Qijia and Seima-Turbino: The Question of Early Contacts between Northwest China and the Eurasian Steppe. *Bulletin of the Museum of Far Eastern Antiquities*, *75*, 31–54.
Mei, J., & Shell, C. (1998). Copper and Bronze Metallurgy in Late Prehistoric Xinjiang. V. Mair (Ed.), *The Bronze Age of Early Iron Age Peoples of Eastern Central Asia* (pp. 581–597, Vol. 2). Washington, DC: Institute for the Study of Man.
Mei, J., & Shell, C. (1999). The existence of Andronovo cultural influence in Xinjiang during the second millennium BC. *Antiquity*, *73*(281), 570–578.
Murowchick, R. E. (1997). The State of Sino-foreign Collaborative Archaeology in China. *Orientations*, *28*(6), 26–33.
Olsen, J. W. (1987). The practice of archaeology in China today. *Antiquity*, *61*, 282–290.
Peng, K. (1998). The Andronovo Bronze Artifacts Discovered in Toquztara county in Yili, Xinjiang. In V. Mair (Ed.), *The Bronze Age and Early Iron Age Peoples on Eastern Central Asia* (pp. 573–580). Washington, DC: The Institute for the Study of Man, and Philadelphia: The University of Pennsylvania Museum Publications.
Pigott, V. C., & Ciarla, R. (2007). On the origins of metallurgy in prehistoric Southeast Asia: the view from Thailand. *Metals and Mines: Studies in Archaeometallurgy* (pp. 76–88). London: British Museum, Archetype Publications.
Shelach, G. (1994). Social complexity in North China during the early bronze age: A comparative study of the Erlitou and Lower Xiajiadian Cultures. *Asian Perspectives*, *33*, 261–292.
Shelach, G. (1998). Settlement pattern study in Northeast China: Results and insights on potential contributions of western theory to Chinese archaeology. *Antiquity*, *72*, 114–127.
Shelach, G. (1999). *Leadership Strategies, Economic Activity, and Interrogational Interaction: Social Complexity in Northeast China*. New York: Kluwer Academic, Plenum Publishers.
Shui, T. (1993). Xinjiang qingtong shidai zhu wenhua de bijiao yanjiu (A Comparative Study of the Bronze Age Cultures in Xinjiang) *Guoxue yanjiu (Studies in Sinology)*, *1*, 447–490.
So, J., & Bunker, E. C. (1995). *Traiders and Raiders on China's Northern Frontier*, Arthur M. Sackler Gallery, Smithsonian Institution, Seattle: University of Washington Press.
Sun, S., & Han, R. (1997). Study of Casting and Manufacturing Techniques of Early Copper and Bronze Artifacts found in Gansu. *Wenwu*, *7*, 54–84.
Tylecote, R. F. 1992 (1976). *A History of Metallurgy*. London: Institute of Materials.
Underhill, A. P., Feinman, G. M., Nicholas, L., Bennett, G., Cai, F., Yu, H., Luan, F., & Fang, H. (1998). Systematic, regional survey in SE Shandong Province, China. *Journal of Field Archaeology*, *25*, 453–474.
Wu, E. (1995). Bronze Artifacts from Yin to Zhou Periods in Northern China. *KGXB*, *2*, 135–55.
Xu, Y. (1989). The Siba Culture at Houshaogou, Donghuishan, Minle County. *The Almanac of Chinese Archaeology* (pp. 246–247). Beijing: Wenwu Press.
XSZ. (2000). Xia-Shang-Zhou Chronology Project Zhuanjiazu. *Xia-Shang-Zhou duandai gongcheng 1996–2000 nian jieduan chengguo baogao, Jianben*. Beijing: Shijie Publishing Co.
Zdanovich, G. B. (1997). Arkaim – kul'turnyi kompleks epokhi srednei bronzy luzhnogo Zaural'ia. (Arkaim: A Cultural Complex of the Middle Bronze Age in the South Ural Region). *Rossiikaia arkheologiia*, (Russian Archaeology) *2*, 47–68.
Zhang, Z. (1986). *Zhongguo Beifang Kaogu Wenjiu* (Collection of Articles on the Archaeology of North China). Beijing: Wenwu Press.