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CURRENT RESEARCH AT KÜLTEPE-KANESH

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An Interdisciplinary and Integrative Approach to Trade Networks, Internationalism, and Identity

edited by

Levent Atici, Fikri Kulakoğlu,
Gojko Barjamovic, and Andrew Fairbairn

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METAL TECHNOLOGY, ORGANIZATION, AND THE EVOLUTION OF LONG-DISTANCE TRADE AT KÜLTEPE

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Abstract

This paper addresses the relationship between technology, the organization of production, and the evolution of long-distance exchange using metallurgical data from Middle Bronze Age Kültepe. To date, textual lines of evidence dominate our understanding of metal industries during this time period. This evidence demonstrates how individuals and firms participated in an elaborate regional copper-exchange system to generate a profit, while at the same time exporting silver and gold to Mesopotamia in exchange for exotic tin and textiles. Textual evidence also suggests that resident social groups at Kültepe cooperated in networks across regions to enhance predictable access to these valuable materials. Yet despite this important work, the scientific analysis of archaeological metal has rarely been incorporated into our understanding of metal production at Kültepe. This new work provides evidence for metallurgical technologies that are not well attested in the texts. Together with the textual evidence, systematic analysis of metallurgical debris at the site provides evidence for a high degree of specialization among metal producers and support for a multitiered, highland–lowland complementarity model of production.

The relationship of specialists, the craft economy, and urban states in the Near East has long been a topic of anthropological and archaeological interest (see, e.g., Algaze 2008; Stein 1996; Yoffee 1995; Lamberg-Karlovsky 1975; Adams 1974; Childe 1956). The craft economy, which consists of the production, distribution, and consumption of crafted goods, is often cited as a fundamental aspect of increasing social complexity (Costin 1991; Clark and Parry 1990; Brumfiel and Earle 1987), and it has been closely linked with the development of regional centers (Shimada 2007; Sinopoli 2003; Stanish 2003; Kenoyer 1997). Both the acquisition and accumulation of craft goods and production materials helped drive connections within social networks between individuals and between organizations, and their exchange played an important role in the elaboration of social hierarchies.

Although archaeologists and textual specialists have begun to address the complex relationship between urban centers and the craft economy, particularly within the context of Bronze Age Mesopotamia, we still know very little about how these two aspects of ancient Anatolian society interacted. This is in part due to the relatively late arrival of a textual tradition, which often serves as a primary understanding of the social dynamics within the craft economy and its relationship to urban centers.

The goal of this chapter is to address the relationship between Kültepe, one of the largest urban polities in Anatolia, and a diversified craft economy with particular focus on understanding the nature of this interaction and the integration of craft specialists into the polity. To do this I incorporate a combination of archaeometallurgical and archaeological data as well as contemporary textual sources to reconstruct the organization of production and exchange that provided Kültepe with metal products. I argue that metal technologies can be accurate proxies for economic behavior in the context of complex societies, and that a nuanced understanding of their organization can reflect on certain fundamental elements of society including social structure and interregional relations. By investigating metal production and exchange at the site of Kültepe from an archaeological perspective, I add further nuance to what we know of the craft economy in central Anatolia from the rich textual perspective.

Background: Metal Craft Economy and Society in Highland Anatolia

One of the principal characteristics of a craft economy in complex societies is the tendency for producers to specialize their activities. Craft specialization can be defined as the "differential participation in specific economic activities" in which producers rely on extra-local economic relationships and consumers rely on producers for products (Costin 1991). The sustained efforts made to diversify and focus time and energy on production has particular advantages when most members of society participate, where diversification and an efficient labor organization can lead to increased returns and wealth (Stanish 2003, 23). Inherent economic advantages associated with these economies of scale conferred mutual economic gains among varying social groups in cooperative relations. The economic and social environment that develops under these conditions can allow for the evolution of cooperation among varying levels of society from individuals to groups (Carballo, Roscoe, and Feinman 2012). High degrees of cooperation, which is necessary for the development of social complexity, leave a distinct signature in the archaeological record (see Carballo 2013, Vidale and Miller 2000, 115). For example, DeMarrais et al. (1996, 17) note that the production of prestige goods—usually objects that are highly valued due to being produced from scarce materials and labor-intensive technologies—is often closely related to the emergence of elites. However, the mass production and standardization of utilitarian goods is also a marker of high degrees of cooperation and specialization (Rice 1981, 220).

Metal technology is an important proxy of highly cooperative behavior because as a technology it requires a high amount of labor and access to highly dispersed resources. In many ways, an efficient metal technology requires cooperation. However, the evolution of this technology over time in Anatolia has resulted in several different regional configurations, suggesting that there is no single optimal strategy in metal production (Yener 2000, 4-10). Rather, empirical evidence suggests that people made a wide variety of metals by intentionally utilizing a diverse resource and knowledge base that is culturally contingent.

This observation is somewhat contrary, although not entirely, to how archaeometallurgists understand the organization of metal production in the Near East, which is dominated by research in the southern Levant (see Thornton 2009). In the Levantine models, Thornton describes an important shift from site-centered smelting and melting during the Chalcolithic and EB I (ca. 4200–3000 BCE) to a more diversified, large-scale, and centralized production that took place outside of habitation areas during the EB II–III (ca. 3000–2300 BCE; Genz and Hauptmann 2002; Levy 1995), where ingots of metal were imported rather than locally produced (Golden, Levy, and Hauptmann 2001, 961). In this lowland model of production, similar also to how Mesopotamian metallurgy is understood (Stech 1999), peripheral highland resource areas supplied lowlands with valuable metal products (Algaze 2008; Stein 1990; Kohl 1987).

Following Yener (2000), Thornton switches focus to the metallurgy of more highland regions in Anatolia and Iran, where a more-explicit highland model of production better fits the data. In this model, highland production areas rich in metal resources were not simply unified suppliers of raw materials and semifinished products, but rather highly adapted culturally specific regions with varying metal technologies. Multiple centers of metal production in these regions made up what Yener described as the "balkanized technological horizon" (p. 26) in the Anatolian Chalcolithic (ca. 4500–3500 BCE). However similar to the development in the southern Levant, there is a corresponding shift in the organization of production during the later part of the third millennium BCE in Anatolia, where production activities diversified, and many of the primary production centers moved into the highlands. Göltepe, a specialized mining community in the central Taurus and dated to the EBA (3000–2000 BCE), is one such example (Yener and Vandiver 1993). Additionally, data indicate that metal production in Bronze Age Anatolia is not limited to specialized sites nor is production necessarily centralized, but production activities also occur in a wide range of urban contexts.

Raw Materials and Technologies

This developed highland–lowland relationship, or rather simply the relationship between regional centers and dispersed resource areas, is a pronounced feature of the metal-based craft economy evident at Kültepe. An understanding of the sequences of metal production allows for a better understanding of these relationships. Identifying these production sequences in the archaeological record, therefore, allows us to build powerful inferences concerning how people chose to operate within economic systems. In the following, I categorize metal production into three categories: raw material acquisition, primary production, and secondary production. While these categories do have cross-cultural relevance (e.g., Killick and Fenn 2012; Tylecote 1976, xi–xii), they should be considered as heuristic categories and not actual salient cultural categories that communities in Anatolia would have used themselves.

Highland Geography in Anatolia and the Distribution of Raw Materials

Anatolia is primarily composed of a series of high mountain ranges and steppes as a result of relict continental agglomeration, tectonic activity, and volcanism. As part of a larger metallogenic belt within the Alpine-Himalayan orogenic system (Okay 2008), Anatolia has extensive deposits of copper, iron, lead, silver (mostly in the form of argentiferous lead), and zinc in addition to rarer deposits of antimony, arsenic, nickel, gold (Bayburtoğlu and Yıldırım 2008; de Jesus, 1980; Tetkik and Enstitüsü 1972, 1971, 1970). The three largest massive sulphide-ore bodies include the metallogenic zones of Ergani in the eastern Taurus block and Küre and Murgul/Göktaş along the central and eastern Pontide block (Wagner and Öztunalı 2000). The geological history of the Anatolian landmass resulted in mineralizations of different ages—a determining factor in the success of extensive lead isotope research conducted in the greater Anatolian region.

The geographic distribution of ore bodies roughly follows the contours of the Pontide and Tauride orogenic zones in northern and southern Turkey. Polymetallic copper and lead-zinc-silver ores are particularly abundant in the eastern sectors of these regions (Wagner, Begemann et al. 1989; Seeliger et al. 1985). Arsenic and antimony-rich ore of the fahlore type are evident in both Pontide and Tauride sources (Özbal, Pehlivan, Adriaens et al. 2008; Özbal, Adriaens et al., 1999, 2002; Özbal, Pehlivan, and Earl 2001). A major copper-nickel sulphide deposit near modern Bitlis in eastern Turkey has also been reported (Çağatay 1987). The Bolkardağ mining district of the central Taurus includes major deposits of iron, argentiferous lead, copper-lead-zinc ores and, to a much lesser extent, minor occurrences of oxides and sulfides of tin including stannite and cassiterite and some gold (Yener, Sayre et al. 1991; Yener and Özbal 1987, 1986; Pehlivan and Alpan 1986). Tin is also reported to occur in the Kayseri-Hisarcık region (Yalçın and Özbal 2009), although neither the size of the occurrence nor if it was utilized in antiquity is yet clear. In the northwest, the Troad sources reveal a diverse array of complex ore deposits, including copper, lead, silver, and gold (Pernicka, Eibner et al. 2003; Wagner et al. 1985; Pernicka, Seeliger et al. 1984). The central Anatolian highland, which is in part distinguished by granitic plutons and associated with the Central Anatolian Crystalline Complex (CCAC), is less abundant in copper resources. Exceptions include the polymetallic copper-lead-silver ores located near Akdağmadeni, small oxidic and native copper deposits near Sungurlu, and secondary copper ore deposits near Karaali south of Ankara (fig. 1).

Raw Material Acquisition

Metal technologies can use a surprising amount of different raw materials, including different choices of waxes and resins, ceramic materials, stone, fuel, and of course different ores and fluxes. By the late Chalcolithic and Early Bronze Age in Anatolia (ca. 4000–3000 BCE), ores were collected first by hammering out exposed and weathered veins of metal-rich ores, including mostly carbonates and oxides. In many places where ore deposits are particularly large, such as in northeastern Anatolia or Ergani in the Upper Tigris region, weathered ores formed caps on deeper nonweathered sulphide deposits. The collection of sulphide deposits, and other deep deposits, required mining, which in turn required a larger labor investment and more organization. The earliest mining activities conservatively date to the late fourth and early third millennia BCE, evident at Derekutuğun in Çorum (Yalçın and İpek 2011), Kozlu in Tokat (Giles and Kuijpers 1974), and Kestel in the Taurus (Yener, Özbal et al. 1989). However, numerous types of polymetallic, oxidic, and sulphidic ores have been identified at a number of fifth- and fourth-millennium settlements such as Değirmentepe (Esin 1985; Özbal 1985) and Arslantepe (Hauptmann et al. 2002; Palmieri, Sertok, and Chernykh 1993) along the Upper Euphrates, and Çamlıbel Tarlası in modern Çorum province (Schoop 2010), suggesting that a spectrum of diverse and intensive acquisition and provisioning strategies likely date earlier.

Very little archaeological evidence of mining activities is documented for the Middle and Late Bronze Ages (ca. 2000–1200 BCE). Despite the apparent increase in production of metals during this time period, we know very little about how raw materials were extracted and/or how that labor was organized. This is likely due to both a lack of research in highland regions and later mining activities that would remove previous workings.

Primary Production

The primary production of metal from ores is a complex process that depends on both the careful selection of raw materials and the control of redox conditions of the atmosphere in the reaction vessel with high temperatures. By the second millennium BCE in central Anatolia, we can be fairly certain that most metals were produced by the reduction of ores into relatively pure metal using both crucibles and furnaces, often together with induction enhancing tools like tuyères and pot bellows. The techniques for reducing different metals will differ based on the chemical and thermodynamic properties of the raw materials and desired outcome. Ore composition plays a large role in this. For example, copper sulphide ores must first be roasted in temperatures between 600˚ and 800˚C to partially transform chemically the sulphides into oxides. These oxide ores can then be smelted in a reducing environment where oxygen bonds with silicates in the ores and flux leaving slag as a waste product and relatively pure copper metal. Lead metal is easily extracted using similar techniques.

Early silver metal was produced through a two-step process, where lead carbonates or lead sulphides were smelted under reducing conditions to produce argentiferous lead. Then through a process called cupellation, silver would be separated from this solid solution through the selective oxidation of lead. Silver produced by this method always leaves a minor amount of lead, and practically all of the analyzed third- and second-millennium silver in the Near East contain around 0.1 wt% lead or suggesting cupellation was widely used to produce silver (Moorey 1994). The earliest examples of silver extraction through cupellation date to the late fourth millennium BCE from

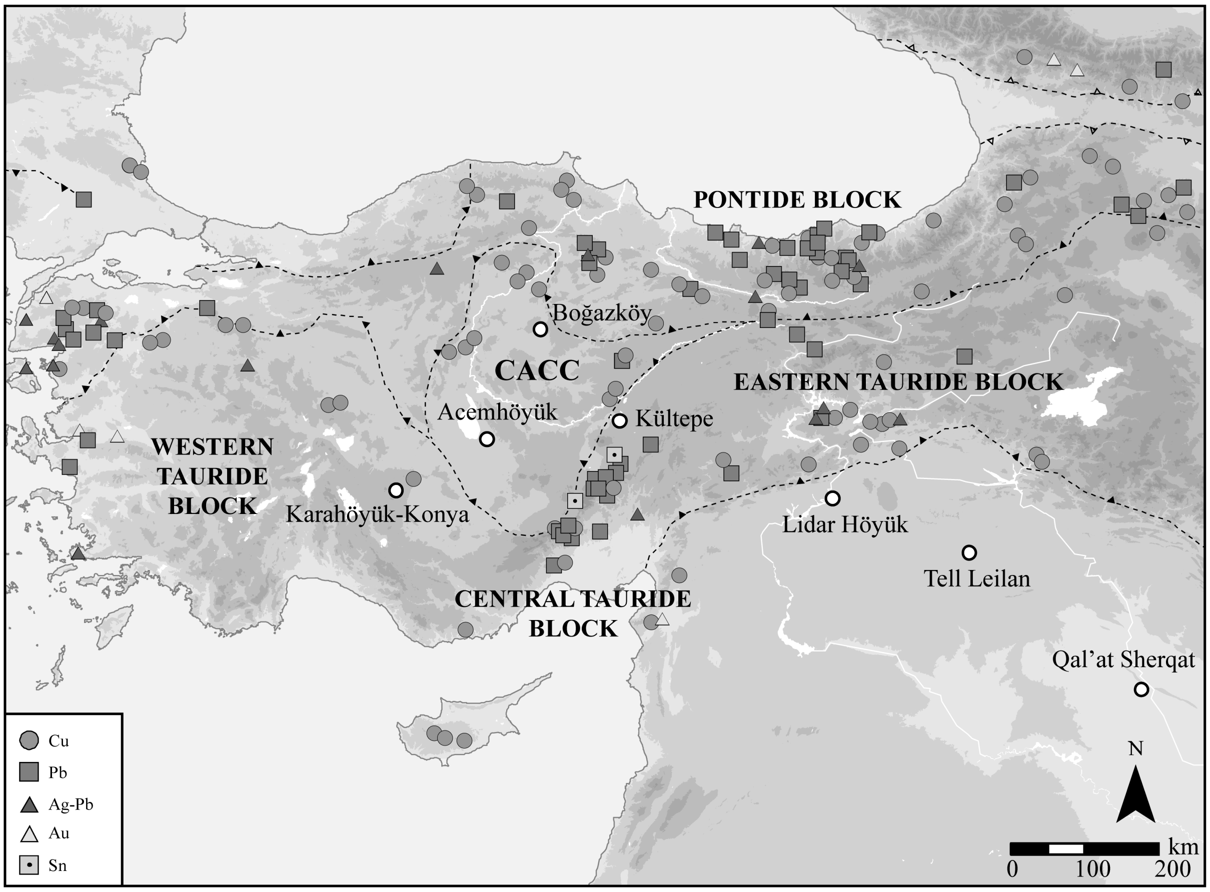

Fig. 1. Map of major distinguishing tectonic features of Anatolia with known analyzed ore sources.

Fatmalı-Kalecik (Hess et al. 1998) and Habuba Kabira (Pernicka, Rehren, and Schmitt-Strecker 1998). During the Bronze Age in Anatolia, gold or electrum would have most likely been collected by panning in stream beds or mining veins. It is unlikely that silver was removed from native gold in the Bronze Age, which is achieved through the cementation process (Ramage and Craddock 2000; Bachmann 1999).

Iron production also deserves some mention for the Anatolian Bronze Age. Redating of the Alaca Höyük irons, including the iron dagger with gold handle, places them firmly with the later part of the third millennium BCE (Yalçın 2011). In addition, numerous iron objects from Kaman-Kalehöyük Stratum III dating to the early second millennium BCE attest to some degree of control of iron and possibly steel production (Akanuma 2006). Several texts demonstrate the importance of this metal as costly, rare, and controlled (Dercksen 2005; Maxwell-Hyslop 1972). Additionally, amorphous iron lumps discovered in a large house from the lower city at Kültepe (Müller-Karpe 1994, 55; T. Özgüç 1959, 56) give material evidence to its use in the city. Iron of this nature is almost certainly produced from the reduction of iron-rich ores into metal by smelting. It is yet unclear whether iron production was intentional or rather a byproduct result of high temperature copper smelting (Akanuma 2006). However some persist in explaining the origin of these metals not through smelting but through the hot and cold working of meteoritic iron or even terrestrial iron (telluric iron; for further discussion, see Waldbaum 1999; Pernicka 1990, 60–63). The presence of nickel in iron metal may help distinguish it from terrestrial iron in origin, however nickel can also accompany many iron ores and remain in the metal after a smelt. Both forms of naturally occurring iron metal have distinct crystalline microstructure that is identifiable under a microscope even if the object was heavily worked.

Extracted metals either went directly into the production of finished objects or were formed into ingots for transportation. Two of the most common shapes in the Middle Bronze Age, and evident both at Kültepe and Acemhöyük (e.g., N. Özgüç 1995), are bun-shaped and bar-shaped ingots. Presumably bun-shaped ingots were produced in the smelting installation, where the segregated molten metal sinks and takes the shape of the furnace floor. However, little empirical archaeological evidence exists in support of this. Alternatively, bun-shaped ingots can also be produced from copper pooling, recycling, or raffination. Bun-shaped and bar-shaped ingots can also be recast into molds, and there are numerous examples of these located in the metal workshops in the lower city of Kültepe. Depending on the efficiency and technique of the smelt, these ingots could vary considerably in composition, which may reflect quality and purity. For example, bun-shaped copper ingots from the Uluburun shipwreck are relatively pure in copper (Hauptmann, Maddin, and Prange 2002), while contemporary ingots from the Caucasus are noted to be high in constituents like arsenic (Gambaschidze et al., 2001) and lead (Hauptmann 2000), and ingots from Oman having significant concentrations of arsenic and nickel (Prange 2001). Producers may also choose to remelt ingots with additional fluxes to refine the metal and remove unwanted slaggy inclusions in the metal.

What we may perceive as impurities in raw metal may very well have been intentional. Particularly controversial is the isolation of arsenic for use in alloys with copper. To date, there is no evidence that pure arsenic metal was traded like copper or tin, ingots of which were used to produce tin bronzes or other intentional alloys. Current evidence suggests that the addition of arsenic was achieved through other means early in the primary production chain. It is not clear whether copper-arsenic alloys were produced via a mixed or co-smelting process involving copper and arsenic-rich ores (Lechtman 1996, 1991) or through the addition of an arsenic-rich secondary product like speiss (a material often found in copper slags rich in iron and arsenic) to molten copper in a crucible (Rehren, Boscher, and Pernicka 2012; Thornton, Rehren, and Pigott 2009). Arsenic is highly volatile at high temperatures, so it is difficult to control arsenic and copper mutually in a single environment. Producers likely developed specific ways to time the addition of arsenic carefully without losing significant amounts of the metal. This has particular relevance for the Kültepe metals because arsenic persists as a common constituent in copper and copper alloys in Anatolia until the end of the Late Bronze Age, ca. 1200 BCE (Lehner 2012; Kuruçayırlı and Özbal 2005).

Secondary Production

The transformation and working of raw metal from ingots or scrap into desired shapes is secondary production. Empirical evidence demonstrates that this stage of production was technologically related to primary production; however the limiting constraints in secondary production evolved around the requirements of finished objects rather than the reduction of ores into raw metal. This stage includes the remelting of metals, ranging from raw primary-produced metal to worked scrap, alloying, casting, and working. Typically, Bronze Age workshops in Anatolia associated with melting have less expedient, reusable installations and associated tools as a result, including a large type-range of furnaces, crucibles, and molds (see Müller-Karpe 1994). As a result, secondary production technologies in Bronze Age Anatolia are frequently associated with permanent architecture, ranging from independent households to attached workshop quarters in palaces.

Innovations and experimentation in the secondary production stage led to a high variation in shapes and forms of finished metal objects as well as metal alloy types. By the Middle Bronze Age, we observe many different alloy types, and it is clear that past metallurgists were certainly aware of the effects that varying concentrations of metals in alloys had on the desired outcome. For example, the addition of tin and arsenic to copper in low percentages create broadly similar alloys in terms of hardness and tensile strength, yet they can produce different colors (tin bronzes tend to be more golden yellow and arsenical copper alloys tend to be more reddish to silvery) and aural pitches when struck (Hosler 1995). Recent research suggests that because tin melts at a lower temperature than arsenic, it is theoretically more efficient and cheaper to cast when charcoal fuel sources become scarce (Kaufman 2013). This likely had a large effect on fuel choice, whether sourced from timber or dung.

Table 1. Old Assyrian descriptive metal lexicon for copper (Dercksen, 1996).

	Qualification of Copper	Notes
High Quality	*werium*	copper
	masium	“washed” or refined
	dammuqum	fine, traded in form of finished ingots (šabburum)
	watrum	excellent
	zaku’um	clean
Low Quality	*lammunum*	poor, raw
	massuhum	dirty, occurs with silver and tin
	sallāmum	black
	ša masā’im	copper that requires refining

Metal Production at Kültepe: A Textual and Archaeological Synthesis

Archaeological excavations at Kültepe provided numerous details on the organization of metal production at the site. In addition to the rich archaeological record, the textual documents found at the site reveal aspects of the nature and organization of metal production. The published translations and interpretations of the Kültepe texts reveal in some detail the Anatolian–Mesopotamian networks in addition to the inter-Anatolian trade networks associated with metal industries (Barjamovic 2011; Veenhof 2008; Dercksen 1996; Larsen 1976, 1967).

The production and exchange of copper, tin, gold, and silver, which has been scrutinized in some detail by Dercksen (2005, 1996), indicates the presence of at least two main systems of exchange. One concerns the long-distance exchange of tin and wool for silver between Assur and Anatolia, and another consists of an intra-Anatolian copper-exchange system in which Assyrians also participated. Donkeys and carts loaded with hundreds of kilos of copper of varying qualities would be transported by Assyrian caravans, and presumably other social groups, over hundreds of kilometers to trading centers like Purushhaddum in exchange for silver to be reinvested in the copper trade or sent back to Assur to purchase more tin and textiles.

The Old Assyrian metal and metallurgical lexicon from the tablets excavated at Kültepe indicate a precise but varied categorization of raw-metal qualities, morphologies, and sources. Dercksen (1996, 33–39) details the suggested meanings and contexts of several Assyrian words that describe a spectrum from high-quality to low-quality copper. Table 1 lists some of the Assyrian words and their respective translations according to Dercksen. Technologically, the meanings embedded in the categories of qualities used by the Assyrian merchants suggests that there not only existed a great variety of metal qualities based on relative purity, but also that there was variety in metallurgical sophistication and technology.

The quality of copper also fluctuates based on where it was produced (Dercksen 1996, 43–45, 154–57), which is consistent with a multitiered model of production. Much like the varying qualities of copper, there are also a significant number of other qualifiers to copper that refer to its specific source or origin. Toponyms associated with copper, such as *ša Purušhaddim* (from Purushhaddum) or *Tišmurnāyum* (from Tishmurna), indicate that copper can be signified with a particular place. Sites of known high-quality metals are also attested to have a *kārum* and a palatial establishment where a local ruler resided, including the textually known cities of Wahshushana, Durhumit, Purushhaddum, and, of course, Kanesh. There is also an observable relationship between sites known textually for poor-quality copper and a close proximity to copper sources.

While the textual evidence does not indicate the entire production operation from primary processing sites to urban centers—from ore to pure metal—there is at least an indication of a particular hierarchy of production centers. Poor-quality smelt products, probably in the shape of bun ingots, were taken from primary processing sites to secondary processing sites where they were further refined. The refining process increased the purity of the metal, adding intrinsic value. Apparent refining centers, such as Durhumit, were significant links in the production chain of metals (Dercksen 1996, 154–55; Michel 1991). Satellite sites, perhaps Kunanamit and Tishmurna, supplied poor-quality and relatively impure copper-smelt products to Durhumit so that the smelt products are further refined and exchanged for various other products, including tin, wool, textiles, and rarely, silver (Dercksen 1996, 155).

The production and exchange of metals according to the proximity of urban centers to active ore sources is thus an important aspect to consider. As indicated above, there does appear to be a hierarchy of production and refinement according to the texts; however, what effect does this have on exchange equivalencies? In fig. 2, one can observe from ranked exchange equivalencies between high quality copper and silver that a rough 100 percent profit is gained when a direct exchange from the source areas to the urban centers of either Kanesh or Purushhaddum occured. These profits would dramatically increase through the process of indirect exchanges from city to city, which is a known economic strategy (Larsen 1967). Significantly, this pattern indicates not only that a clear cost-distance relationship exists, but also that it suggests a significant degree of economic centralization with at least two regional centers at both Kanesh and Purushhaddum, at least during the *kārum* II period ca. 1950–1836 BCE (Veenhof 2003, 57).

In addition to describing indirectly the interregional economic environment associated with metal materials, the Kültepe tablets also provide evidence for craft organization at the level of the individual and workshop. In the Kültepe excavation reports, Özgüç (1955, 1986) notes that excavated workshops in the lower city were most likely local artisans rather than their Assyrian counterparts. Closer analysis of the textual record by (Dercksen 1996, 71) indicates, conversely, that metal smiths had both Anatolian and Assyrian names. While it does not appear that the metal smiths kept records as merchants did, merchants regularly interacted with metal smiths and kept records of these interactions. According to the texts, the metal smiths would take orders in addition to selling prefabricated finished objects, such as metal vessels and tools. While the metal smiths, *nappāhum* in Old Assyrian, of *kārum* Kanesh appear to be organized on the household scale, their productive efforts may have been controlled to a yet unknown degree by the palace. This is indicated by the presence of a "lord of metal smiths" functionary; *rabī nappāhī* in Assyrian. The exact role of this functionary is not entirely known, but it is known that this title belonged to a palace official who often dealt with the exchange of metals with merchants in addition to collaborating with local metal smiths (Dercksen 1996, 71–76).

The merchant records do provide a degree of information about the organization of metal production. A hierarchy of production can be gleaned from the texts, suggesting that multiple centers were variably involved in the whole process of transforming an ore mineral into a finished metal. Poor quality and relatively unrefined smelt products were transported and exchanged at central refining centers, such as Durhumit, where an active *kārum* and local palace dictated the terms of the trade to other urban centers further away. Merchants could gain increasing returns because of this hierarchy of production. In addition, the practices of the metal smith and their functionary palace officials also signify that an existent specialization of metal production at urban centers such as *kārum* Kanesh was codified in the Kültepe tablets.

The interface between the textual and archaeological evidence of metal production provides the opportunity to assess the validity of either body of evidence. The exchange system inferred from the Assyrian tablets places the workshops at *kārum* Kanesh near to the end of the metal production cycle. Archaeological evidence from the lower city at Kültepe does in fact indicate that secondary production was the most important metallurgical technology at the site.

At least three workshops were excavated from the *kārum* II period, all suggesting the manufacture of finished goods rather than the smelting of metal from ores. A workshop in the southern lower city (workshop seven) was based in a small three-roomed building that appears to have also been a residence. Finds from two of the rooms

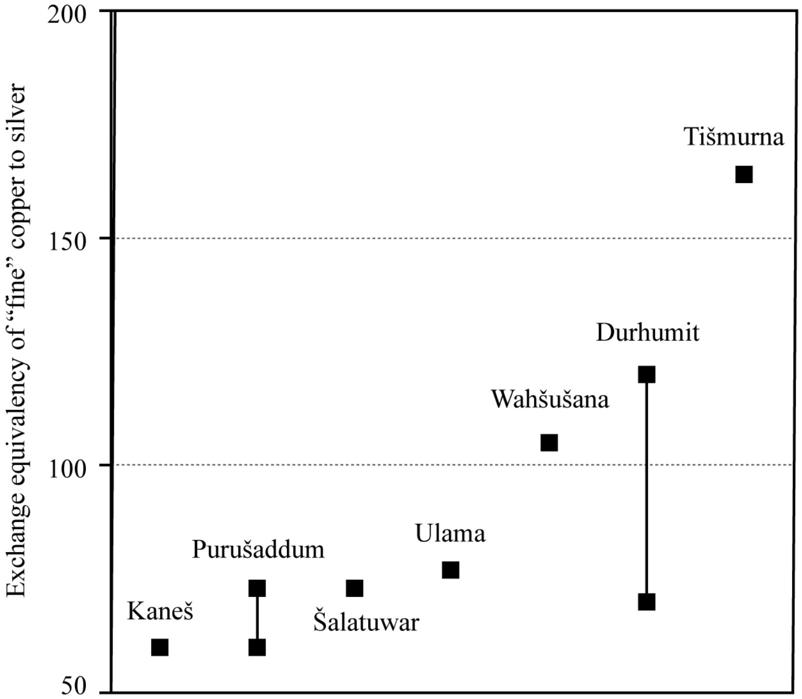

Fig. 2. Exchange equivalencies of fine copper to silver according the Kültepe texts (Dercksen 1996).

include tuyères, stone tools, standardized hematite weights, a lead ingot, several open molds of varying types, small slag deposits and an *in situ* furnace. What is particularly interesting to this workshop are several different types of molds, indicating that the smith was capable of producing several different forms for a diverse community. Two other workshops in the central part of the *kārum* (workshops 8 and 9) were not as well preserved, however they did provide a similar assemblage compared to workshop seven. A furnace with associated blowpipes and bellows was found in two different rooms of a larger structure from workshop eight (Müller-Karpe 1994: 53; Özgüç 1950).

In addition to the three workshops of the *kārum* II period, excavations in the residence of the local dignitary Peruwa demonstrate that this wealthy individual was also involved in the production and exchange of metals. In a central room (room 7) of the fourteen-roomed building, several slaggy deposits in addition to possible crucibles were discovered (T. Özgüç 1959, 36). In addition, the excavator noted that two large iron ingots remained in this central room, however no scientific analyses of these objects have been published. The significance of the presence of iron cannot be overstated. Assyrian words *amūtu* and *aši'u* have been translated as iron or iron ore (Maxwell-Hyslop 1972) and was as much as eight times the value of silver (Yener 2007, 373). Textual evidence demonstrates that iron was a politically charged material during the Middle Bronze Age, and regional palaces attempted to control it. Larsen demonstrated how one individual, Pusu-Ken, was taken and punished for having smuggled iron (Larsen 1976). The degree of control over the exchange and presumably the production of iron stems from the fact that this early technology and material was extremely sophisticated. There is also the possibility that nickel-rich meteoritic iron was the *amūtu*-metal in the Assyrian texts, but this hypothesis, recently tested by Akanuma (2006), demonstrates that early-second-millennium iron from Kaman Kalehöyük was likely produced through smelting. The presence of two iron ingots in the residence of Peruwa is evidence that this individual had access to a highly regulated material, which suggests that he great deal of power, and outside of the palatial complex of the citadel mound.

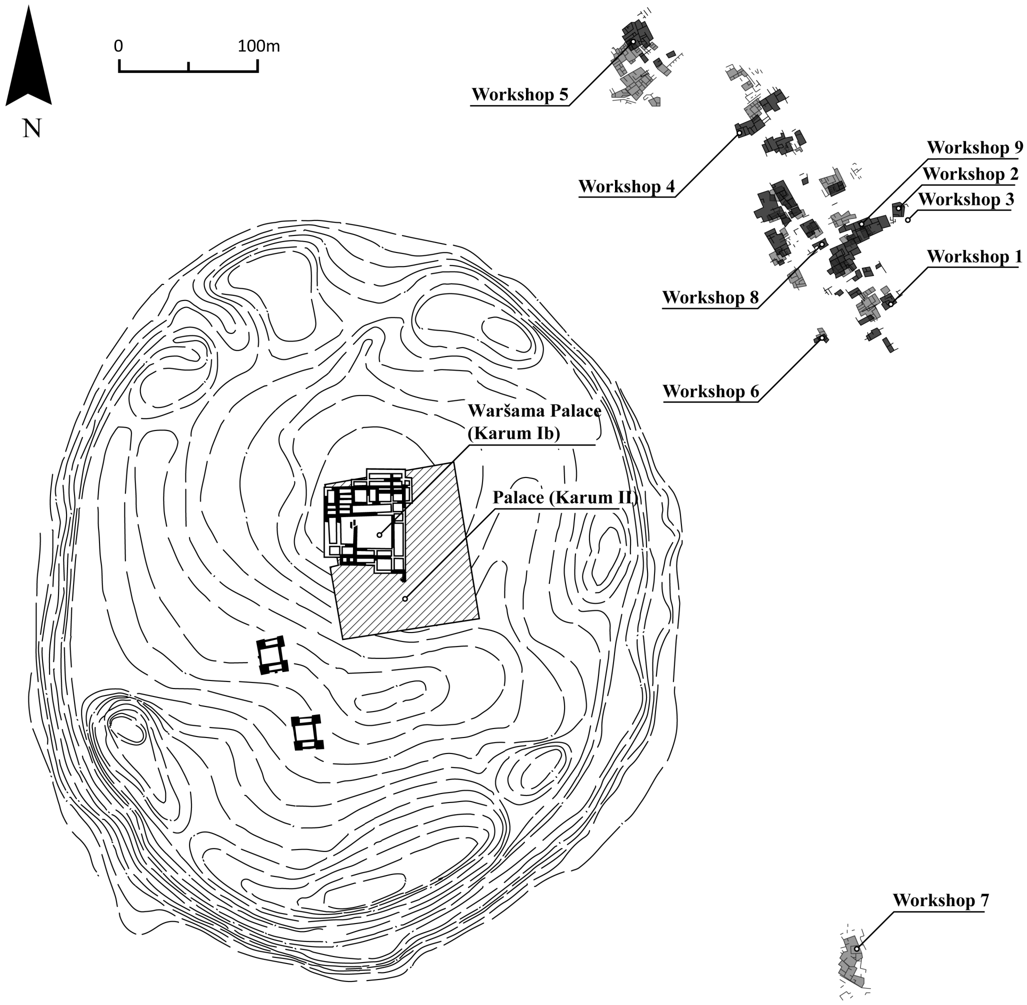

Fig. 3. Map of the Kültepe mound and lower city with special reference to known workshops in *kārum* II (light gray) and *kārum* Ib (dark gray) (adapted from Müller-Karpe 1994: figs. 28, 36).

The preservation of at least six excavated workshops from *kārum* Ib is considerably poorer than those excavated from the previous level *kārum* II (fig. 3). From what information that can be gleaned from the excavation reports, it appears that despite the destruction and hiatus, there is a significant continuity in technology and organization. The presence of crucibles, blowpipes, bellows, and furnaces demonstrates again the melting and possible refining of metals taking place at the workshops. In addition, the *kārum* Ib workshops also appear to be attached to residential households. This is significant because this shows that the production and exchange of metals in the lower city had the same organization as in the previous level.

One workshop in the northern *kārum*, however, had a substantial diversity of finds (workshop four). This workshop had a minimum of five rooms, some of which were probably storage rooms (T. Özgüç 1986). In a corner next to a furnace (see figs. 4 and 5) were the remains of several molds, crucibles, bellows, blowpipes, and tuyères. The density and diversity of these finds indicates the virtuosity of the particular metalsmith and the sophistication of the workshop.

The wide distribution of metal workshops and production areas, as well as other metallurgical devices, such as the wide distribution of lead figurine molds (e.g., Emre 1971), attests to the central role metallurgy had in

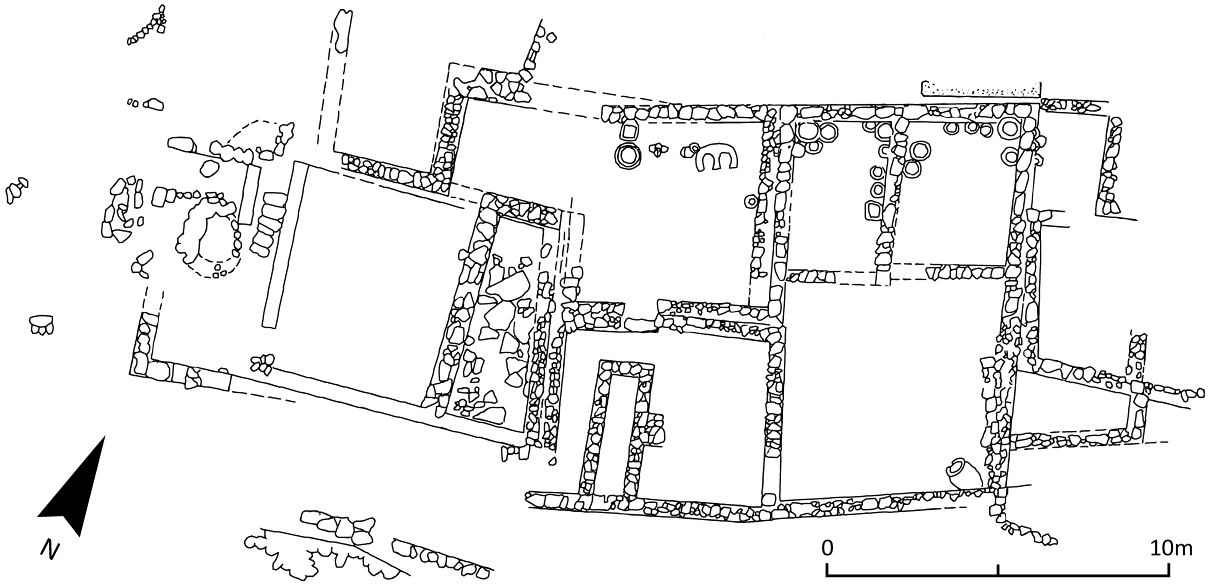

Fig. 4. Workshop 4 (*kārum* Ib) at the lower city of Kültepe (adapted from Müller-Karpe 1994: fig. 38).

Fig. 5. Photograph of Workshop 4 detailing the furnace and assortment of stone mauls, crucibles, and open molds (Özgüc 1986: pl. 82.1).

everyday economic life at the city. However, contrary to large-scale industrial societies, there is as yet no evidence that metal workshops were highly nucleated into identifiable urban areas or neighborhoods. Results of excavations indicate that metal workshops could be accommodated by a wide range of architecture, including relatively small two-roomed houses or in agglomerated constructions. Residential buildings and merchant houses alternated with workshops. In addition, it appears that the workshops adjoined residential spaces indicating that the smiths may have lived and worked in the same place. There is not a steady building type for workshops. In addition, inventories of the buildings in which craft activities were demonstrated show that these houses are not exclusively workshops as much as areas for the preparation of food (Müller-Karpe 1994, 60). All workshops have clear indications that melting and casting was a primary activity instead of smelting. This is demonstrated by the presence of multiple kinds of molds, tuyeres, crucibles fashioned with pouring nozzles, ceramic bellows, and permanent furnaces. Ingots of copper, lead, and possibly also iron have been identified with these workshops, which confirm their connection to primary producers, who likely resided closer to the source areas.

Archaeometallurgical Analysis of Copper, Lead, and Silver

In an unprecedented research program for its time, Ufuk Esin (1969) analyzed over seven hundred copper-alloy samples from over thirty-five different sites in Anatolia from the Chalcolithic to the Middle Bronze Age.[1] This included eighty-five samples from Kültepe, most of which were taken from discernible finished objects from secure contexts in the lower city. Arsenic ranges in all samples from 0.02 wt% to 4.05 wt%, however the mean composition hovers around 1.15 wt%, suggesting that many of the arsenical coppers may not be intentionally alloyed with arsenic. Tin ranges from measurements below the detection limit to around 10.0 wt% tin bronze which was the upper limit of detection. Lead appears in minor or trace amounts in many of the analyzed objects, ranging from a few ppm up to 3.0 wt%. Because the amount of lead is relatively low, it is difficult to be certain whether or not lead was intentionally added. Lead, like arsenic, is also present in many of the copper ores of Anatolia and it is also a useful additive to smelts to regulate melting temperatures. Therefore, it is likely, however difficult to demonstrate at present, that copper and copper alloys with minor amounts of lead represents a technological preference for ores rich in lead or the intentional addition of lead ores to the smelt.

Esin's data demonstrate the presence of at least three major alloy groups, including copper-arsenic (n=50), copper-tin (n=23), and a ternary alloy of copper with tin and arsenic (n=12). This observation is verified by cluster analysis, which is a method that quantitatively groups samples together based on their compositional similarity (fig. 6). Principle components analysis (fig. 7), which reduces the multidimensionality of the dataset into fewer components, further verifies this observation. Table 2 shows the average weight percentages of the elements in the measured samples based on the groups calculated by cluster analysis. Apparent from the groupings is the relatively similar amount of arsenic across the three different groups, ranging from 0.90 to 1.25 wt%, which suggests that minor concentrations of arsenic derived in part from the smelting process in primary production and/or extensive recycling.

Results of Esin's work indicate that alloys of copper and tin are not rare. However, as one might expect from the importance of tin in the texts, tin bronzes do not dominate the assemblage. In fact, arsenical bronzes seem to be more common. This is significant for two reasons. First, as far as I am aware, there is little to no mention of arsenic in the Kültepe texts. This is a problem that Adams (1978) first mentioned when reviewing M. T. Larsen's synthesis of the Old Assyrian Trading Colony period based on the Kültepe texts (1976). Adams cites the work of Eaton and McKerrell (1976) who were able to demonstrate a more gradual adoption of tin bronzes later into the second half of the second millennium BCE. This observation is consistent with over three hundred analyses of copper alloys from Boghazköy-Hattusa (Lehner 2012) and further analyses of copper alloys at İkiztepe (Özbal, Pehlivan, et al.,

1. Esin's work was part of a larger project based then at the Württembergisches Landesmuseum in Stuttgart (today it is the Archäologisches Landesmuseum Baden-Württemburg). Esin's analyses were conducted using optical emission spectroscopy (OES). Renewed work by Ercanlı (2013) for his dissertation at the Middle Eastern Technical University adds to Esin's contribution. See Pernicka 1984 for issues of accuracy and interlaboratory reproducibility in the Stuttgart data. See also Kuruçayırlı and Özbal 2005 for a comparison of Esin's data and newer analyses of using atomic absorption spectrometry. I am personally thankful to Ernst Pernicka and the Curt-Engelhorn-Zentrum Archäometrie in Mannheim for providing access to the Stuttgart database.

Table 2. Average compositional values for each alloy group produced by cluster analysis.

Alloy Type	Cu	Sn	Pb	As	Sb	Ag	Ni	Bi	Zn	Co	Fe
Cu-As	98	0.15	0.17	1.25	0.08	0.05	0.10	0.01	0.02	0	0.18
Cu-Sn	89	9.46	0.30	0.90	0.03	0.04	0.14	0	0.02	0	0.16
Cu-As-Sn	92	5.07	1.08	1.15	0.08	0.04	0.19	0.01	0	0	0.09

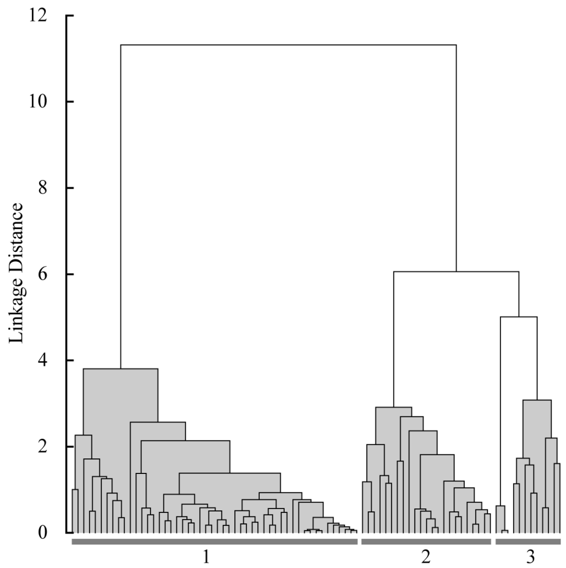

Fig. 6. Cluster analysis dendrogram produced from eighty-five separate samples using the unweighted pair group average method with Euclidean distance. Results indicate the presence of three major alloy types: [1] Cu-As, [2] Cu-Sn, and [3] Cu-As-Sn.

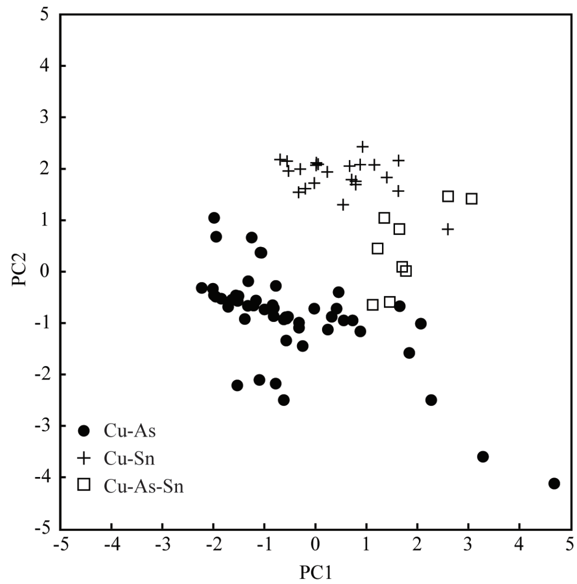

Fig. 7. Principal components analysis of eighty-five samples including major constituents Cu, Sn, As, and Pb in addition to traces of Ag, Bi, Co, Fe, Ni, Sb, and Zn.

2002). Tin is almost certainly to be identified with the *annuku*-metal of the Kültepe texts, but this leaves arsenic as a curiously unmentioned alloy constituent.

Second, this lack of arsenic in the texts may in fact relate to how arsenical copper is produced. As mentioned earlier, most arsenical bronzes in excess of 1.0 wt% arsenic were not produced from the melting of pure copper and arsenic together, but rather from a much more complex process of mixed or co-smelting, which involved the selection of appropriate copper and arsenic minerals together in a smelting process (Lechtman and Klein 1999; Lechtman 1991). Copper metal could have also been melted together with iron arsenide called speiss, which was demonstrated to be intentionally produced at the third-millennium BCE site of Arisman in Northwest Iran (Rehren, Boscher, and Pernicka 2012). Arsenic contents below 1.0 wt% could very well have been introduced as part of a fluxing agent such as an iron oxide or in the copper ores themselves. Additionally, the high volatility of arsenic at high temperatures in oxidizing atmospheres would also decrease the concentration of arsenic as copper alloys were further refined or recycled with tin bronzes. Many of the copper-tin alloys at Kültepe do have arsenic in excess of 1.0 wt% (see fig. 8), which suggests that either ternary copper-tin alloys with arsenic were an inten-

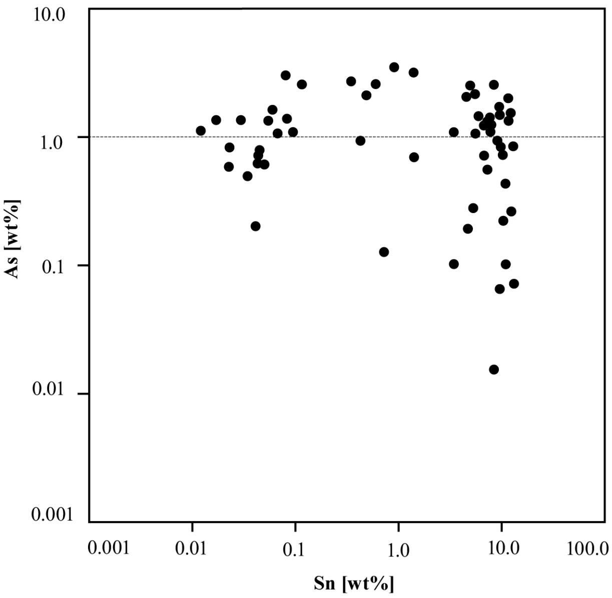

Fig. 8. Binary chart comparing Sn and As compositions across the entire analyzed Kültepe assemblage. Two clusters are apparent, showing the presence of at Cu-As alloys and Cu-Sn alloys with trace As. Note that 1.0% As is given as an arbitrary point for intentional alloying.

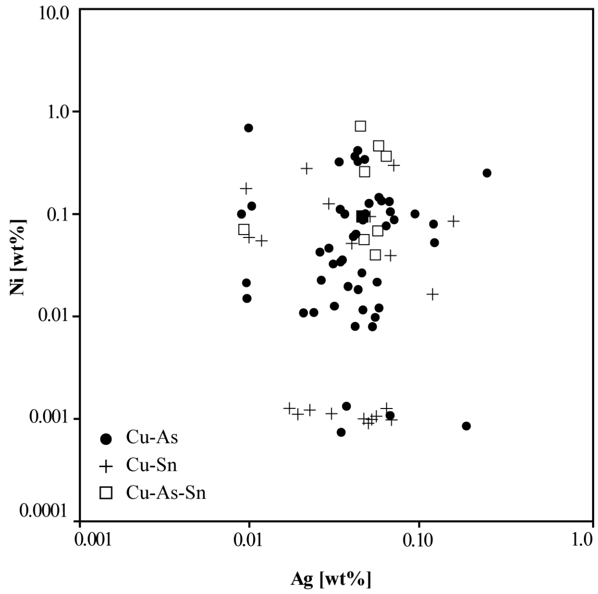

Fig. 9. Binary chart comparing compositions of Ag and Ni compared across alloy types.

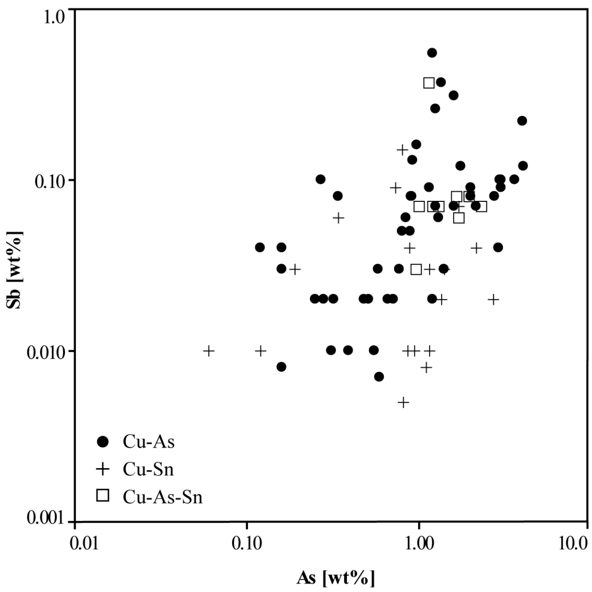

Fig. 10. Binary chart comparing trace composition of As and Sb compared across alloy types.

tional alloy type, or that copper-tin alloys were produced from the alloying of copper containing arsenic. Figures 9 and 10 demonstrate that there is little difference among alloy types in relation to the composition of the minor elements silver, antimony, and nickel. This suggests that producers did not discriminate between ore types, which vary in these trace elements, in the production of different alloy types. These significant overlaps are also consistent with the possibility that the recycling and remelting of copper alloys was an extensive practice.

Compositional differences among artifact types in arsenic, lead, and tin are shown in fig. 11. Artifacts were classified as ornaments (n=26), tools (n=52), and other (n=7) for indeterminate objects. There is enough reason to hypothesize that metal smiths chose specific alloys for different object types based specifically on the varying performance characteristics of the materials. However, judging from the frequency of copper-arsenic and copper-tin alloys in either object category, there are no significant differences. This is surprising because copper alloyed with arsenic or tin would have noticeable differences in performance, including characteristics like ductility, hardness, and color (Lechtman 1996; Hosler 1995). These data suggest that copper alloy composition played a decreasing role in the manufacture of finished objects.

Lead isotope analysis by Sayre et al. (2001) of samples from Middle Bronze Age Acemhöyük, Karahöyük-Konya, and Kültepe is consistent with an extensive metal-production network (fig. 12). All samples are consistent with local sources Tauride, Pontide, and central Anatolian sources, including one lead metal sample from Kültepe is consistent with both central Tauride and central Anatolian sources. Two silver objects sampled from Acemhöyük are not consistent with any Anatolian sources, however this likely reflects an inadequate understanding of all the silver-lead ore sources available during the Bronze Age. None of the analyzed samples were consistent with eastern Tauride sources, such as Ergani or the Keban series, which is consistent with textual data (Larsen 1976). Further lead isotope work, such as that at Kaman Kalehöyük (Enomoto and Hirao 2006; Hirao and Enomoto 1994; Hirao et al. 1992) could help determine the raw material diversity and acquisition strategies present in this time that we know almost solely from textual evidence.

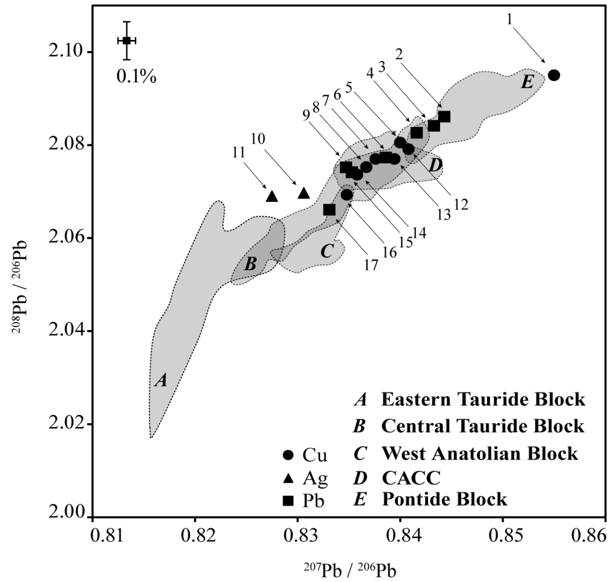

Fig. 12. Lead isotope binary plot comparing ^{207}Pb/^{206}Pb by ^{208}Pb/^{206}Pb of known ore bodies and artifacts dating to the MBA (data from Sayre et al. 2001). 1. AAN 282 Acemhöyük Cu-ingot, 2. AAN 271 Acemhöyük Pb ore nodule, 3. AAN 925 Alisar Pb ring, 4. AAN 008 Acemhöyük Pb pendant, 5. AAN 843 Acemhöyük Cu pin, 6. AAN 199 Kültepe Pb frag, 7. AAN 842 Acemhöyük Cu pin, 8. AAN 17 096 Acemhöyük Cu crucible slag, 9. AAN 924 Alisar Pb ring, 10. AAN184 Acemhöyük Ag frag., 11. AAN 185 Acemhöyük Ag frag., 12. AAN 17 095 Acemhöyük Cu ore nodule, 13. AAN288 Acemhöyük As ore nodule, 14. AAN 2032 Karahöyük-Konya Cu slag, 15. AAN 926 Alisar Pb ring, 16. AAN 286 Acemhöyük Cu ingot, 17. AAN 840 Acemhöyük Pb frag.

Conclusion

Empirical evidence for the production and exchange of metals during the early second millennium BCE in Anatolia demonstrates that they are an extension and intensification of earlier economic strategies and technological styles developed during the fourth and third millennia BCE. This continuity is in part related to how metal is produced but also to how early Anatolian societies used it. Metal materials functioned, for example, as items of wealth and indicators of status, as tools and weapons, or as a fungible medium of exchange. As the demand for metals increased, beginning during the third millennium BCE, so too did the proliferation and virtuosity of metallurgy as an industry and a craft. The "balkanization" of metal technologies during the Chalcolithic and Early Bronze Age led to a more interregional and interconnected tradition marked by extensive long-distance trade, economic specialization, and highly organized interregional production strategies. By the

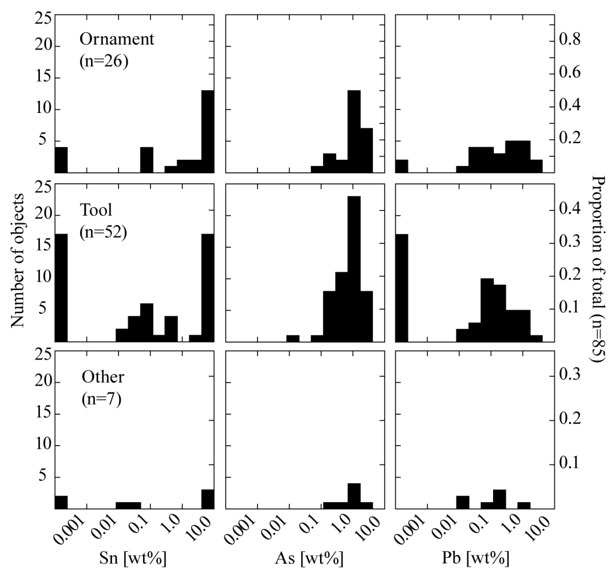

Fig. 11. Histograms of major alloy constituents by number of objects and their proportion to the total assemblage of measure artifacts (n=85).

early second millennium BCE in Anatolia, metal industries and materials were interwoven and structured within extra-kin networks of reciprocity and became commodified as a standard media of exchange. At the same time, empirical evidence from archaeological excavations and texts indicate that metal industries were diversified and highly specialized, in which the clustered network of production was likely predicated on the "centripetal" pull in the evolution of cooperation and the "centrifugal" force of dispersed natural resources (e.g., Fujita, Krugman, and Venables 1999, 9).

I have argued that despite the elaboration and sophistication of metal production and exchange strategies in Anatolia, many of the workshops at Kültepe are relatively decentralized and not directly attached to the palace known to exist at that time. Rather, the workshops may be part of an indirectly controlled household-unit production where part-time specialists worked in cooperation with the urban population of which they were a part. This is evidenced by the presence of a palace functionary who regulated metal production. Evidence that the metal smiths also crafted items of stone, including cylinder seals, stamp seals, and beads (T. Özgüç 1986, 50) suggests that the metal smiths were employed in other crafts to a degree of unknown extent. That being said, there is evidence for a degree of specialization and control of raw materials that suggests the existence of attachment to the palace directly, including the storing and working of copper, high-grade obsidian, rock crystal, and ivory (Çukur and Kunç 1990, 33; T. Özgüç 1986, 50).

The production of finished metal products at Kültepe represents some of the last steps in a long chain of exchange from primary processing sites in the polymetallic highlands of north-central Anatolia to varying refining centers along the Kızılırmak. The economic integration of central Anatolia during the Middle Bronze Age provided the necessary conditions for an elaborate and regionally extensive period of metal production. Metallurgical evidence at Kültepe provides ample evidence for a high degree of specialization and complementarity with highland resource regions. It is the economic conditions, and the craft specialists who ultimately depend on the elaborate raw materials network, that preclude the political developments which lead to the formation of the Hittite state only a century later ca. 1650 BCE.

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