Chapter 20
Organization and Specialization of Early Mining and Metal Technologies in Anatolia

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Introduction

This chapter is a retrospective of current developments in the field of Anatolian archaeometallurgy. Since the 2000 publication of *The Domestication of Metals* (Yener 2000), a number of new field- and laboratory-based projects and international conferences have provided new data that challenge old assumptions about the development of metallurgy and other complex pyrotechnologies. Frequent conference proceedings dedicated to mining and metallurgy in Anatolia (Yalçın 2000a, 2002, 2005, 2008; Yalçın et al. 2008) demonstrate the diversity and importance of this craft. Perhaps the most salient theme is the role of localized processes in the development of early complex metallurgy and ore extraction, both as a cascade of technological innovation (Schiffer 2005) and as an understanding of the organization of production and trade (see, for example, Hauptmann et al. 2002; Ramage and Craddock 2000).

Archaeologists are now becoming increasingly aware that these highland zones were areas of intense technological and social innovation. For example, excavations at Göbekli Tepe (Schmidt 2000, 2006), located on the southern plains directly adjacent to the Taurus Mountains, have revealed at least two phases of monumental architecture dating to the tenth and ninth millennium BC. These structures with richly adorned monolithic pillars demonstrate the presence of specialized institutions and societal inequality before the regional adoption of agriculture and increasingly sedentary lifeways. The development of complex technologies like metallurgy may also follow a similar trajectory, where technological innovation and adoption correlate to socioeconomic and political structures.

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When past scholars assumed that the development of social complexity and the demand for metal raw materials was a lowland Mesopotamian causation (e.g., Childe 1930), they did not take into account the potential for autonomous social institutions and cultural development in the periphery of powerful states and empires (Stein 1999). In addition, the discovery of production debris in the Balkans dating to before 5000 cal. BC (Radivojević et al. 2010) suggests that the development of metallurgy is likely unrelated to the emergence of complex political economy in Syro-Mesopotamia. The emergence of early complex technologies must take into account the potential for indigenous developments and the structure of interregional interaction.

Today, Anatolia is known to be one of the earliest regions where communities participated in complex metallurgical traditions (see Bachmann 2008 for a history of early research; de Jesus 1980; Muhly 2011; Müller-Karpe 1994; Nieling 2009; Pernicka 1990; Przeworski 1939; Yener 2000). With access to a diverse material base, Anatolia was witness to the early production of a wide variety of nonferrous alloys, surface treatments, and intricate cast/hammered forms. While the time and place of these innovations lack a high degree of chronological and spatial precision, early Anatolian metallurgy shares broad technological developments with the Near East and southeastern Europe. That being said, recent research in prehistoric archaeology over the past 20 years has generated a body of data which indicates that developmental trajectories of complex technologies occurred at varied rates and in regional contexts, with a probable origin in Southwest Asia (Roberts et al. 2009). Research in this region, therefore, has the potential to evaluate longstanding assumptions about not only the origins of metallurgy but also the relationships among social complexity, technology, and long-distance trade.

Regional traditions of metal production and consumption seem to emerge in areas where mineral and native metal resources were relatively abundant (Hauptmann 2007, p. 255; Roberts et al. 2009, pp. 1013–1014; Yener 2000, pp. 18–25). However, geographic proximity to resources and technological proficiency alone cannot generate interest in producing and developing costly materials. There must also be social and economic incentives. Social differentiation and inequality often necessitated the use of scarce resources and complex technologies to display and communicate social heterogeneity or homogeneity (Vidale and Miller 2000). Metal production, a unique pyrotechnological development involving both rare materials and complex technologies, provides a way for some groups to manage access to wealth, which was used to differentiate social groups (Brumfiel and Earle 1987; Helms 1993). Once metal became an indicator of wealth, disparities in access to raw materials and production technologies promoted varying degrees of cooperation and competition among producer and consumer groups. Empirical evidence, especially from textual sources and modern frameworks of urban growth, suggests that interregional cooperative alliances develop out of the potential to increase wealth and surplus, where scale economies promote specialization and economic expansion promotes diversification (see Algaze 2008: 30–39). It is therefore likely that well adapted economic strategies often helped integrate a heterogenous cultural and natural geography between the highlands and lowlands.

Through the assessment of archaeological materials from Anatolia, with a particular focus on data from central and eastern Anatolia, we reexamine some of the main theoretical facets posed in earlier work. After discussing important issues in the heterogeneous distribution and variation in ore resources across Anatolia, we formulate a geographically salient theoretical framework, which is used to explore long-term changes in the metallurgy of the region. Here, we also focus on how a technological organization is socially networked and indivisible from local culture-historical developments.

Highland Geography in Anatolia and the Distribution of Raw Materials

The landscape of Anatolia, modern-day Turkey, is extraordinarily complex. Anatolia is a large peninsular landmass that is surrounded by three seas: the Black Sea to the north, the Aegean to the west, and the Mediterranean to the southwest. The landmass is primarily composed of a series of high mountain ranges and steppes as a result of relict continental agglomeration, tectonic activity, and volcanism that took place during most of the Phanerozoic (Okay 2008). Turkey is composed geologically of three main tectonic units including the Pontide, the Anatolide-Tauride Block, and the Arabian Platform. Resting in between the Pontide and Anatolide-Tauride Block, the central Anatolian crystalline complex stretches from modern Kırıkkale to Sivas, and is composed of mostly metamorphic and plutonic rocks dating to the Cretaceous. Anatolia is also highly varied in terms of climate, with arid regions to the south and southeast along the Syro-Mesopotamian plains and subtropical rainforests in the northeast along the Black Sea. Many of the mountainous regions are heavily wooded, including most of the Pontide belt and western Anatolia. Relict forests that have survived several different periods of deforestation can be found in different areas of the central Anatolian plateau (Miller 1999; Willcox 1974, 2002).

The highlands of Anatolia, a varied mountainous and steppe landscape, are endowed with pockets rich in metal-bearing mineral concentrations (Fig. 20.1). As part of a larger metallogenic belt within the Alpine–Himalayan orogenic system (Okay 2008), Anatolia has extensive polymetallic deposits of copper, iron, lead, silver (often in the form of argentiferous lead), and zinc, in addition to rarer deposits of antimony, arsenic, nickel, gold, and tin (Bayburtoğlu and Yıldırım 2008; Çağatay et al. 1979, 1989; Çağatay and Pehlivan 1988; de Jesus 1980; Maden Tetkik ve Arama Enstitüsü 1970, 1971, 1972; Öztürk and Hanilçi 2009; Sarp and Cerny 2005). The three largest massive sulfide ore bodies include the metallogenic zones of Ergani in the eastern Taurus and Küre and Murgul/GöktaşŸ along the central and eastern Pontide belt (Wagner and Öztunalı 2000). The geological history of the Anatolian landmass resulted in mineralizations of different ages, which is a decisive factor in the success of extensive lead isotope research conducted in Anatolia (Begemann and Schmitt-Strecker 2008).

The geographic distribution of ore bodies roughly follows the contours of the Pontide and Tauride orogenic belts in northern and southern Turkey. Polymetallic

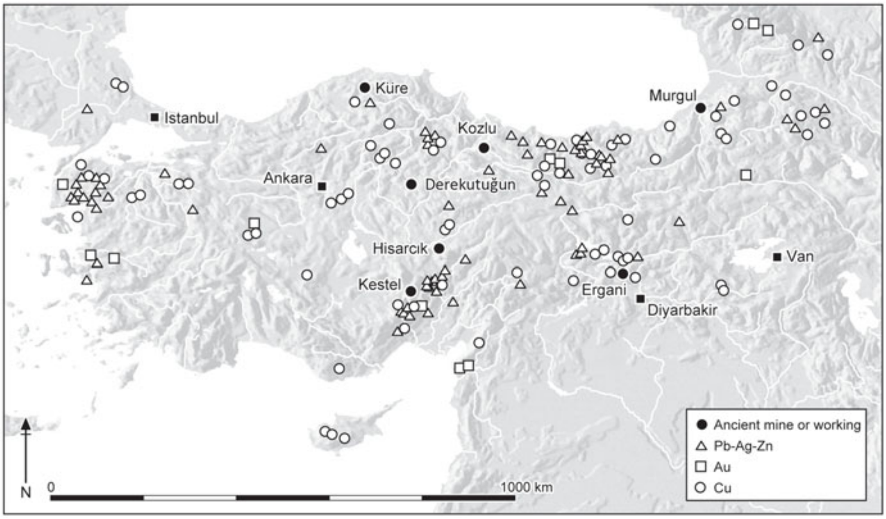

Fig. 20.1 Known major ore sources. Important ancient mining or old working sites noted

copper and lead–zinc–silver ores are particularly abundant in the eastern sectors of these regions (Seeliger et al. 1985; Wagner et al. 1989). Arsenic and antimony-rich ores of the fahlerz-type are evident in both Pontide and Tauride sources (Özbal et al. 1999; Özbal et al. 2002a, b; Özbal et al. 2001; Özbal et al. 2008) and from fourth-millennium BC archaeological deposits at Norşuntepe (Seeliger et al. 1985; Zwicker 1980) and Arslantepe (Palmieri et al. 1993) along the Upper Euphrates. A major copper–nickel sulfide deposit near modern Bitlis in eastern Turkey has also been reported (Çağatay 1987). The Bolkardağ mining district of the central Taurus and immediately north of Cilicia includes mostly iron, argentiferous lead, copper-lead-zinc ores, and smaller occurrences of gold and tin (Pehlivan and Alpan 1986; Yener and Özbal 1986; Yener et al. 1991). More specifically, cassiterite, a tin-oxide, has been observed in floor debris at the ancient mining site of Kestel and also nearby alluvial deposits (Yener et al. 1989). Cassiterite has also been observed together with oxides of iron, arsenic, and antimony north of the Bolkardağ on the northeastern slopes of Erciyes Dağ at Hisarcık (Yazgan 2005; Sarp and Cerny 2005). In the northwest, the Troad sources reveal a diverse array of complex ore deposits, including copper, lead, silver, and gold (Pernicka et al. 2003; Pernicka et al. 1984; Wagner et al. 1985). Arsenic-bearing ore bodies are unknown in this metallogenic zone. The central Anatolian highland, an arid steppe environment bounded to the north and south by high mountains, 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.

A key pattern in the distribution of raw materials and environments in highland regions like Anatolia, Transcaucasia, and Iran is their heterogeneous and uneven characters (Wilkinson 2003). Despite a relative abundance of ore sources, their spotty

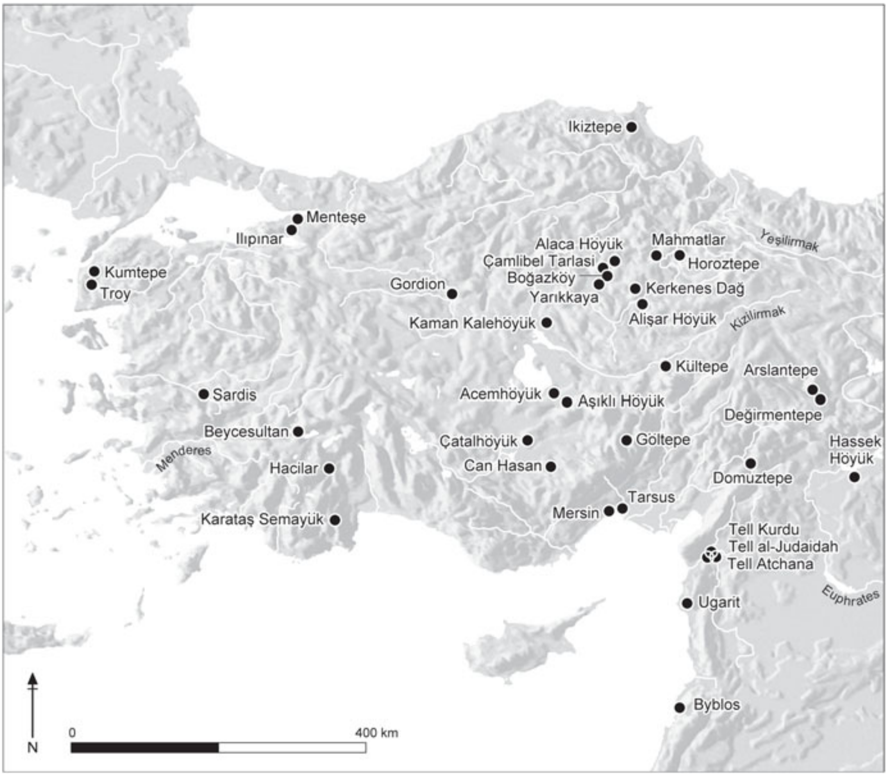

Fig. 20.2 Map of western and central Anatolia with sites mentioned in this text

distribution created special stresses that influenced how they were extracted, refined, smelted, and transported (Craddock 1995). In other words, geographic and social parameters of mining regions had significant influence on technological organization and socioeconomic process (Knapp 1998). Distance from the raw materials to fuel and food supplies, as well as seasonal weather conditions, were key factors in how they were utilized. The dynamic and costly ventures of mining and smelting activities often had considerable impact on the environment, leading to deforestation, alterations of drainage routes, and other problems (Monna et al. 2004). Transportation is often limited to navigable rivers and wide intermontane valleys, and even then it was largely a seasonal enterprise. As the Kültepe-Kanesh texts tell us, movement of goods across central Anatolia was often abruptly postponed due to poor weather, and this likely had significant effects on trade relations and the exchange rates of metal types (Dercksen 1996).

The clustered distribution and diverse mineralogical characteristics of these metal resources no doubt influenced their availability over time. Disparities in proximate access to these resources and regional competition for material use created incentives for long-distance cooperation among some individuals and communities, while

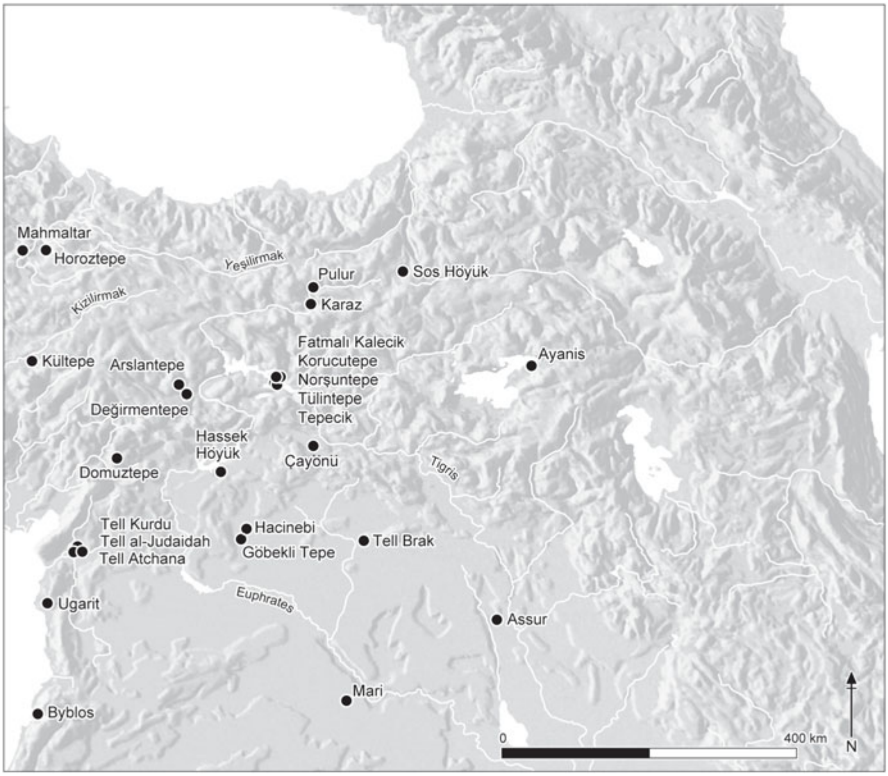

Fig. 20.3 Map of **e**astern Anatolia with sites mentioned in this text

providing leveraging power to others. As will be argued later in this chapter, economic specialization and diversification in mining, and extraction technologies and strategies, were not only the result of an increased demand for metals and finished forms but also the result of innovations in labor organization. Increased sophistication in technological organization ensured a predictable supply of important materials necessary for the regular maintenance of social relations while at the same time generating potential for significant social inequality. Diverse alloys and technologies are well represented in many fourth- and third-millennium BC burial contexts in Anatolia. For example, the well-known collections of decorated copper alloy swords and spearheads from the Early Bronze Age "Royal Tomb" at Arslantepe (Hauptmann et al. 2002; Palmieri and Di Nocera 2000), and the elaborate Alacahöyük, Kalınkaya, and Horoztepe cast tin bronze standards and figurines (Arik 1937; Koşay 1938; Özgüç 1964; Yıldırım and Zimmermann 2006; Zimmermann and Yıldırım 2007), indicate metal resources and technologies were associated with disparities among social groups.

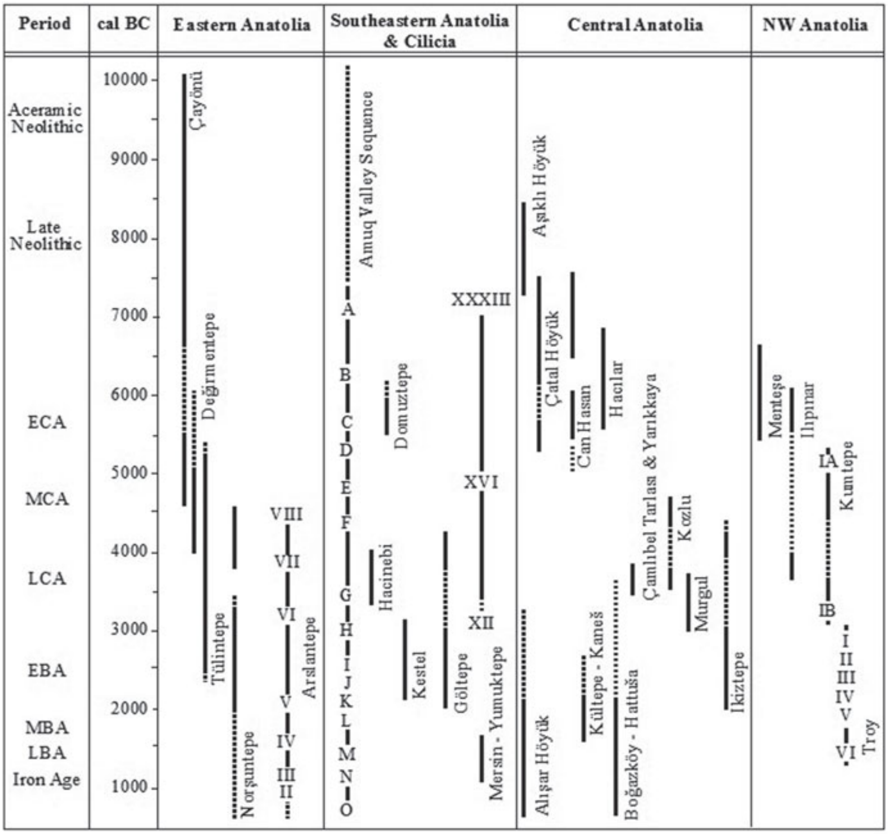

Fig. 20.4 Calibrated radiocarbon dates and relative chronology of important sites mentioned in this text. *Solid lines* are C14 dated sequences. *Dotted lines* are inferred occupations without absolute chronological control

Intellectual Framework

The model of highland Anatolia and lowland Syro-Mesopotamia as a core–periphery relationship in which lowland predominantly urban cultures extract highland raw materials is of course simplistic. While archaeologists continue to refer to Anatolia as a highland region, it should be stressed that the dichotomy between highland and lowland regions is somewhat problematic because, as Yener (2000) and Thornton (2009, p. 305) point out, the Near Eastern highland regions are internally highly variable. They constitute a series of interlocked highland intermontane and lowland valleys and plateaus. Nevertheless, Anatolia is a distinct region that warrants discussion of both broad diachronic changes in the organization metal technologies and localized traditions of metallurgical practice.

The framework for this discussion is divided into two parts. First, we will discuss how perceptions of the role of ancient Anatolia in the Near East are changing with respect to complex technologies. As a corollary to this and in agreement with Thornton (2009), we will then offer an alternative view which suggests that Anatolia and other resource-rich regions in the Near East were regions of indigenous technological and social innovation. This is apparent because organized mining and metal production exist before apparent large-scale Mesopotamian involvement in Anatolia. Second, we discuss how metal production is coordinated over long distances to mitigate disparities in access to rare materials and technologies. Changes in the organization of metal technology coordinate with socioeconomic shifts in the way metal resources are acquired and distributed, which results in the emergence of a multi-tier hierarchy of mining and metal production.

Anatolia as a Region of Innovation

An increasingly sophisticated understanding of cultural and historical process in Anatolia is changing our conceptualization of this region as a focus of analysis (Düring 2011; Mathews 2011; Sagona and Zimansky 2009). Past researchers tend to view archaeological problems in terms of the regions that surround Anatolia, including Greece and Mesopotamia. It is usually assumed that novel social, political, and technological forms originated elsewhere, outside the frontier highlands of the Anatolian peninsula.

In a review of the intellectual history and rhetorical devices used to describe the Anatolian peninsula, Yazıcıoğlu (2007) examines the origins and pitfalls of the conception of Anatolia as a "land bridge," most notably as a conduit of knowledge rather than a landscape of innovation unto itself. Yazıcıoğlu argues against the conceptualization of Anatolia as a land bridge because this metaphorical simplification "hampers a thorough understanding of the material culture of Anatolia and skews our perspective, especially in analyzing trade and exchange relations or processes of diffusion and/or migration" (Yazıcıoğlu 2007, p. 219). In effect, she argues that this perspective generates an emphasis on the movement of people, things, and ideas through the region, while downplaying the significance of several millennia of regional traditions and cultural practices. As Yener (1995, p. 119) has pointed out, "Anatolia is often presented as a cultural frontier in which it is seen as passive receiver of innovations that emanated from more sophisticated centers." The common metaphor is of Anatolia embodying a land bridge from Mesopotamia to Europe—from the East to the West.

The suggestion that highland regions promote diversity is not a novel concept. Aldenderfer (1998), Ehlers and Kreutzmann (2000), and Körner (2003) all argue that various challenges inherent in highland environments promote behavioral specialization. Human communities adapted to these local environments to facilitate predictable access to their unique resources, including pastureland, food sources, and raw materials used in the manufacture of tools and ornaments. Highland regions, rather than impeding transportation, guided trade and exchange routes by way of valleys and mountain passes. Central to the question of Anatolia as a region of innovation are the resources of its diverse natural environments and the close proximity of its ecotones that were the necessary preconditions for the emergence of metallurgy and its rapid success in the region.

Regional environments and resource distributions in the Anatolian highlands influenced diverse institutions of production and specialization that otherwise would not be feasible in the lowland plains of Mesopotamia. Highland mining communities are one subset of these specialized institutions. These communities seemed to emerge with the greater demand for resources used in the creation of utilitarian and wealth objects, during the mid-fourth millennium BC.

Technological Organization as Social Organization

The procedural stages to metal technology need not be repeated here; see Craddock (1995), Miller (2007a, pp. 144–166), and Rehren and Pernicka (2008) for detailed descriptions of production and manufacturing techniques. Key steps in these procedures allow for a wide variety of variations in smelting techniques, alloy recipes, and final forms and shapes. For the purposes of this chapter, we argue that production and manufacturing strategies have clear spatial components that are necessary to grasp in the understanding of technological organization (e.g., Stöllner 2003). In this sense, technologies are theorized to track and focus on these various elements of the production chain (Earle 2010), from the acquisition of raw materials and smelting to the melting, casting, and manufacturing of finished products.

To define how we approach the technological organization of metal production, it is important to embrace a holistic perspective of craft production in the context of mutual technological developments across regions and assemblages (Shimada 2007). In this aspect, we try to view metal working regions and specialized production activities in terms of their technological, socioeconomic, spatial, and ideological dimensions (Hanks and Doonan 2009; Knapp 1998; Levy 1993; Linduff 2004; Linduff and Mei 2009; Topping and Lynott 2005). Sites across the highlands of Anatolia demonstrate unique adaptations to highland environments; thus, it is essential to view specialized technological process "in concert with the social coordination of labor" (Pfaffenberger 1992, p. 497). Labor specialization, either part time or full time, occurred as a series of cooperative social arrangements among an economically diversified demographic. Following Costin (1991, p. 43), we define specialization as "differential participation in specific economic activities," where metallurgical activities necessitated at least part-time dedication to production.

The precise location and context of change are intrinsic components to long-term changes in the organization of activities (Miller 2007b). Depending on the social and spatial infrastructure in which ancient communities interacted, whether in urban or interregional contexts, many crafts were located in specific areas to regulate relations among associated technologies, materials, and socioeconomic outcomes. The emergent pattern is that technological organization often maps onto social organization (Nelson 1991).

The degree to which metal technological organization in Anatolia was controlled during different periods of time is debatable. The evidence is inconclusive whether lowland centers cooperated in reciprocal networks of exchange with highland production zones or whether they effectively controlled these regions by politically integrating them. While it is clear that some finished forms were signifiers of status, including alloy vessels, swords, and spearheads, there is very little evidence for the systematic control of their production and distribution without evidence from texts. Elite control of trade does seem to be exercised to some degree during the Middle Bronze Age 2000–1750 BC, as is evident from numerous Akkadian texts known from Anatolia (Dercksen 1996, pp. 162–178). The emerging picture from these texts is that Mesopotamian and Anatolian merchants were actively vying for control of trade in a competition of merchant coalitions and palatial bureaucracies.

Artifacts of Wealth and Prestige—Metal During the Anatolian Neolithic

The use of native metals and metalliferous minerals (e.g., malachite $Cu_2CO_3(OH)_2$, hematite Fe_2O_3, and galena PbS), during the Anatolian Neolithic demonstrates a high degree of technological sophistication and familiarity before the development of formal smelting techniques (Schoop 1995, 1999; Pernicka 1990). In addition, access to raw materials during formative periods of emergent complexity helped generate temporally resilient acquisition networks important to many later complex technologies. As early as the eleventh millennium BC, metalliferous minerals were used as raw materials for pigments and ornaments, such as a perforated pendant possibly made of malachite from Shanidar in Iraq and green stone beads from Rosh Horesha in Israel (Bar-Yosef Mayer and Porat 2008; Solecki 1969; Solecki et al. 2004). Evidence for the regional occurrence of cold-worked native copper begins during the ninth to seventh millennium BC in the form of ornaments (Schoop 1995).

Substantial evidence for the working of native copper comes from the Neolithic site of Çayönü in southeastern Turkey (Özdoğan and Özdoğan 1999). Dating from the ninth to seventh millennium BC, successive occupational strata at Çayönü provide key evidence for the emergence of complex societies that partake in agricultural economies and specialized technologies in the Near East (Özdoğan 1999). Located in a highland setting, near to the Tigris river valley and approximately 20 km from Ergani Maden, one of the largest copper sources in Turkey, materials from all occupation layers demonstrate the use of native copper metal and minerals. Parallel traditions in working lithic and metal minerals include the production of perforated stone beads and cold-hammered and annealed metal beads rolled into small tubes (Maddin et al. 1999). Similar use of metal minerals and annealed and hammered native copper beads has been noted in central Anatolia at the sites of Aşıklı Höyük (Esin 1995, 1999; Yalçın and Pernicka 1999) and Çatalhöyük (Mellaart 1964; Birch et al. 2013). Two native silver tube beads from Domuztepe in modern Kahramanmaraş date to the mid-sixth millennium BC and show evidence of annealing and hammering (Carter et al. 2003; Yener et al. in prep.).

The production and consumption patterns related to these materials indicate that they were used to demarcate social boundaries and were also likely indicators of social status. These scarce materials were naturally circumscribed by rugged highland terrain and their technological alteration into ornaments required sufficient specialized knowledge. Later metallurgical traditions correspond to two important patterns that emerge during the Neolithic. First, the establishment of metal materials and technologies as a source of wealth developed alongside the emergence of increasingly complex social institutions. This is best evinced by the presence of scarce materials associated with early monumental architecture at many important Neolithic sites along the Taurus such as Çayönü, Nevalı Çori, and Hallan Çemi (Lichter 2007). Second, the emergence of long-distance trade patterns created path-dependent economies that influenced the way materials were exchanged and distributed. Economic interaction patterns between highland source areas and adjacent lowland agricultural villages established a successful way of accessing and distributing these materials that would have dramatic network effects.

Site-centered Production: Centralization, Nucleation, and Balkanization

Significant socioeconomic reorganization during the Early and Middle Chalcolithic (ca. 6000–4000 BC) created a mosaic of complex cultural regions across Anatolia (Düring 2011; Schoop 2005). Regionalized political affiliations and exchange networks focused largely on local materials, although certain materials (e.g., obsidian) are known to have been transported over very long distances (e.g., Carter et al. 2008; Healey 2007). Important developments in extractive metallurgy occur during this crucial time period in lowland regions that are proximate to highland resource areas such as in the Altınova, in Cilicia, and in the Amuq Valley. As Yener et al. note (1996), these regions are set apart from other sites in northern Mesopotamia by virtue of their direct access to scarce materials, while at the same time sharing similar highly productive agricultural conditions. Interregional patterns of competition and cooperation, and the management of access to lowland centers, are identified by the possible innovation of city walls or enclosures at sites like Hacılar, Kuruçay, Mersin, and Değirmentepe. In addition, the repertoire of metal objects drastically increases during this time period. Ornaments and jewelry were produced with tools and weapons by the Late Chalcolithic period, which provides sound evidence for the diversification of the technology as it was variably adopted in different parts of Anatolia.

Dating to the beginning of the fifth millennium BC, a series of metal axes, chisels, and other tools from Mersin (XVI–XIV) in Cilicia (Garstang 1953) demonstrate the development of casting technologies and the possible smelting of ores into metal (Caneva 2000; Esin 1969; Yalçın 2000b). Unlike objects made from native copper, which is relatively pure, the metal objects from Mersin show significant amounts of antimony (0.032–0.748 wt%), arsenic (< 0.006–0.604 wt%), and tin (< 0.005–0.010 wt%) (Yalçın 2000b, p. 114). The presence of these elements indicates that the metals were derived from the smelting of polymetallic ores, several sources of which have been documented to the north in the central Taurus Mountains (Yener et al. 1991). Problematically, no production debris (e.g., slags, crucibles, and furnace

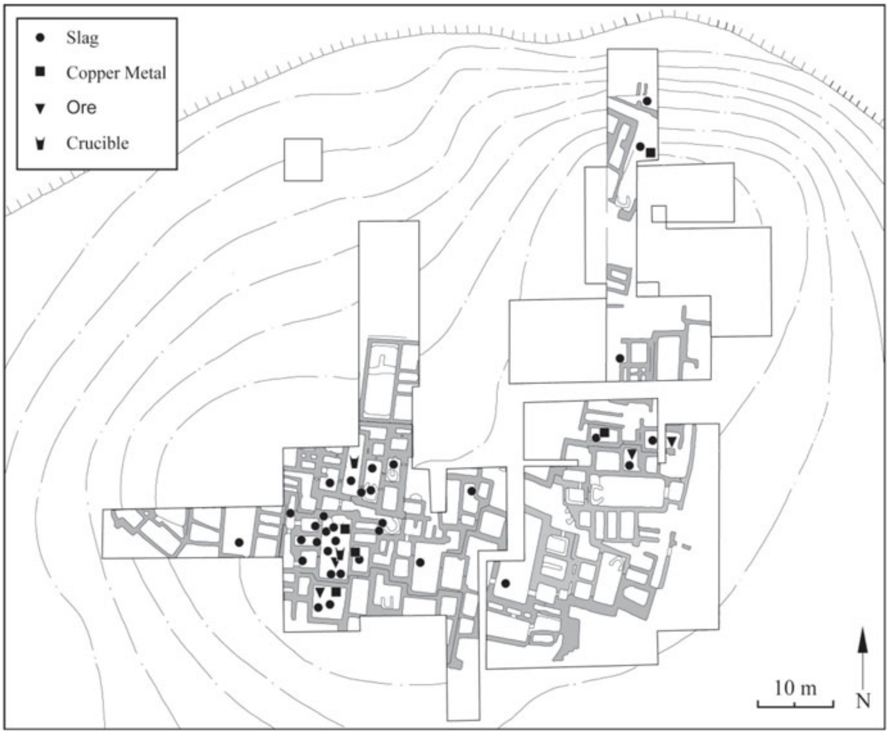

Fig. 20.5 Değirmentepe with metallurgical remains. (Adapted from Müller-Karpe 1994, Fig. 4)

installations) has been discovered at Mersin dating to this early period, so the actual characteristics of extractive metallurgy can only be inferred from these finished products.

Some of the first evidence for the organization of extractive metallurgy comes from the site of Değirmentepe and dates to the end of the fifth and beginning of the fourth millennium BC (Esin and Harmankaya 1988; Yener 2000, pp. 33–44). Değirmentepe is a multi-period village along the Upper Euphrates with a significant Middle and Late Chalcolithic occupation sharing cultural affinities with Ubaid Mesopotamia. Several houses were excavated to reveal that many of the households were involved with many metallurgical activities from ore processing, smelting, and possibly melting and casting (Fig. 20.5). Importantly, many of the households also had evidence of administrative activities, including seals, sealings, tokens, and bullae of local and foreign styles (Esin 1990), and their production (Arsebük 1986).

Several different polymetallic ore sources are known in the region and their use has a long history that starts during this period. Metallurgical debris from the site indicates that the organization of production relied heavily on nearby ore sources. However, it is not clear whether or not mining sites that date to this period took part in smelting activities. The presence of several furnaces and some raw ore materials indicates that primary production was a village activity and that ores could have been transported directly from the source areas and consumed at the village. Parallels for these activities are noted at the nearby sites of Norşuntepe (Hauptmann 1982) and Tepecik (Esin 1982). The analyses of slag debris and slaggy encrustations on crucibles, however, suggest that much of the production may have been the further refinement of copper-rich slags and copper metal in a secondary or final production stage to produce arsenical copper alloys (Kunç and Çukur 1988; Özbal 1985). It is entirely possible that ores and slags were smelted elsewhere and then brought into the village for further working and refinement. Metallurgical production debris is evenly distributed across the site, which suggests that the organization of production may be characterized as an independent household or nucleated workshop-level production.

The Late Chalcolithic site of Arslantepe, near to modern Malatya along the Upper Euphrates, provides an excellent contrast to the organization of metal production at Değirmentepe. Arslantepe was the center of a large network of Late Chalcolithic villages during the so-called Uruk period of Mesopotamia. This period is particularly known for the intrusive activities of Mesopotamian communities into regions outside their political and cultural core in southern Iraq. Algaze (2005), Stein (1999), Rothman (2001), and Frangipane (2001a) have argued for different forms of interaction among communities in Anatolia and Mesopotamia during this period. It is clear that Mesopotamian communities, at this time, sourced metal materials and finished products from the Taurus and Zagros, although the nature of those interactions, as based on symmetrical or asymmetrical relations, is hotly debated. Excavations at Arslantepe indicate a certain degree of interaction with Uruk Mesopotamia, but there was also a local elite presence independent of Uruk control. A large monumental structure in the Late Chalcolithic (period VIA) contained several rooms for storage which together suggest that the building was the seat of a local power or a redistributive center (Frangipane 1997).

Frangipane (2001b) notes two opposing forms of power at Arslantepe in this period—a local kingdom and a later intrusive power related to Transcaucasian migrations into southeastern Anatolia and Syro-Palestine—both of which correspond to developments in Mesopotamia. Metallurgical traditions and the economic networks inferred from the analyses of the raw materials, production debris, and finished goods differ significantly between these two periods. Palmieri et al. (1999) notes a significant relationship among successive periods (VII ca. 3700–3400 BC, VIA ca. 3400–3000 BC, and VIB 3000–2900 BC) and the types of alloys and ores. During the Late Chalcolithic (period VIA), communities used polymetallic ores with varying quantities of arsenic, antimony, silver, bismuth, and nickel. Ore selection changes to the predominant use of copper–iron sulfides during the Early Bronze Age (period VIB), which indicates possible shifts in trade networks and metallurgical traditions. Finished artifacts also reflect these variations with a predominance of copper–arsenic alloys but also alloys of copper–silver and copper–arsenic–nickel (Hauptmann et al. 2002).

A hoard of 21 metal alloy weapons dating to the VIA period contain almost predominantly copper–arsenic alloys, ranging from 2.57 to 6.08 wt% arsenic. Intriguingly, lead isotope analysis (LIA) of the objects suggests they originate from several likely sources in the northeastern Pontides near to the Black Sea (Hauptmann et al. 2002, pp. 61–62). In contrast, metals from a large tomb dating to the VIB period, contemporary with large-scale changes in material culture related to the Kura–Araxes culture of Transcaucasia, demonstrate a change in alloy preference and provenance. In addition to copper–arsenic alloys, several nonutilitarian objects made of a silver–copper alloy and objects made of a copper–arsenic–nickel alloy reflect gross changes in ore consumption and alloy preferences. LIA of the copper–arsenic alloys from Period VIB suggest a similar provenience to those from the earlier period VIA, but the copper–arsenic–nickel alloys may reflect a more local source or one potentially to the north-east in Transcaucasia or the central Taurus. The copper–silver alloys have a unique isotopic signature that does not allow their identification with any known ore source, but does match with other artifacts from central Anatolia (Hauptmann et al. 2002; Sayre et al. 2001).

Slag analyses from the site suggest a wide-ranging technological variety of extractive metallurgy. Perhaps most significantly, a class of slags, containing prills of an arsenic–nickel–iron speiss (Palmieri et al. 2000, p. 145), indicate that alloying strategies may have involved the production and trade of this special co-smelting product used to produce early copper–arsenic alloys (Thornton et al. 2009). It may also have been a by-product of smelting copper–nickel–arsenic ores. However, the use of speiss as an ingredient in the production of arsenic alloys, as suggested by Thornton et al. (2009) and Rehren et al. (2012), may help explain the emergence of high-arsenic copper alloys. At the sites of Habuba Kabira and Fatmalı-Kalecik, both dating to the Late Chalcolithic, the presence of lead-rich litharge provides the earliest evidence for the reduction of argentiferous lead ores into refined silver metal through cupellation (Hess et al. 1998; Pernicka et al. 1998).

Recent excavations at Çamlıbel Tarlası have explored in detail the activities of a small Chalcolithic village in central Anatolia that thrived ca. 3590–3470 cal. BC (Schoop 2008, 2009, 2010). Four occupational phases (CBT I–IV) of rectangular architecture with stone foundations and rammed earth revealed a range of activities, including different stages of stone tool and metal production. All phases show the presence of metallurgical slags, ores, pounding stones, crucible fragments, a diagnostic ring-idol mold, and finished metal objects. Analyses of the slags by Rehren and Radivojević (2010) demonstrated that the primary reduction of sulfide and oxide ores into pure copper metal was an activity on site. This explains the presence of pounding stones, which were used in the benefaction of ore materials for their preparation in a smelt. Fieldwork within the vicinity of the site discovered a large outcropping of sulfide and oxide ore minerals (Marsh 2010) that seem to correlate with the slag analyses. Near to Çamlıbel Tarlası, the Late Chalcolithic site of Yarıkkaya demonstrates a similar household-level production of metal (Hauptmann 1969; Schoop 2005). Production debris, including several crucibles with a thin layer of encrusted metalliferous residues (Fig. 20.6), indicates that producer communities in north-central Anatolia lived in small household aggregates composed of part-time specialists.

Analyses of a few finished artifacts from Çamlıbel Tarlası by Rehren and Radivojević (2010, p. 215) demonstrate that the metals used are arsenical copper alloys.

Fig. 20.6 Crucible from Yarıkkaya, north-central Anatolia. (See Schoop 2005, Plate 30.1)

As the current analyses of slags from the site do not show any presence of arsenic in the copper nor iron–arsenic–nickel speiss, it is not clear whence the arsenic derived. Recent surveys by Özbal and his colleagues (Özbal et al. 2008) discovered a range of arsenical minerals to the north of Çamlıbel along the Pontide belt. These resources may have been used in the production of the arsenical copper found at Çamlıbel, although direct evidence for this has yet to be demonstrated.

The emergence of complex metallurgy, as highlighted above, is clearly a reflection of the availability of necessary resources, appropriate technologies, and the ability to free up labor for specialized production. The regionalism and localization of political entities that occur with urbanism, as highlighted with the administrative technologies and monumental architecture of Arslantepe, allowed for constrained networks of production. It is not clear how groups acquired the necessary raw materials for the various technologies examined above. During these periods along the Upper Euphrates, it is clear that many stages of metal production occurred perhaps simultaneously and in the same location. The sites in this region can be characterized as having in-site production with nucleated production areas. Similar patterns are recognized for other regions in regard to finished materials with the caveat that local alloying traditions likely remained a conservative tradition often unique to the area in which it was produced (Yakar 1984, 1985; Yener 2000). Ores were purposely chosen for their properties and alloys were produced from a range of complex and divergent traditions that likely reflected the local socioeconomic and political networks of production. The presence of arsenical copper alloys across Anatolia, for example, at Ilıpınar in northwestern Anatolia (Begemann et al. 1994) and Ikiztepe near to the Black Sea (Bilgi 1984, 1990; Özbal et al. 2008; Özbal et al. 2002a, b), means that while divergent patterns of metal production were localized, some metallurgical techniques, perhaps utilizing speiss, were shared across very long distances.

Specialized Mining Communities and the Development of Tin Bronze

During the Early Bronze Age (ca. 3000–2000 BC), several regional polities across central Anatolia and regions south of the Taurus began to participate in long-distance trade for materials like lapis lazuli and tin that extended as far east as modern Afghanistan (Delmas and Casanova 1990; Muhly 1973a, b). Two major innovations in copper metallurgy during this time period altered the way metal technology was organized. First is the advent of an intentional copper–tin alloy (i.e., tin bronze). The alloying of tin and copper hardens the metal, alters casting properties, and changes its color to yellowy–gold if the correct amount of tin is incorporated (Scott 2011, pp. 109–173). The earliest tin bronzes in Anatolia occur in the northeastern bend of the Mediterranean Sea near to the Taurus, specifically in Cilicia and the Amuq during the Late Chalcolithic ca. 3000 BC (Yener 2009).

This pivotal area, linking the coastal Mediterranean with the cultures of Syro-Anatolia, has immediate relevance to the early production of tin metal from Tauride sources such as Kestel, Bolkardağ, and Hisarcık. The site of Tell Judaidah in the northeastern passes of the Amuq valley in southern Turkey yielded an assemblage of tin bronze artifacts that were found to contain up to 9.74 wt% tin content from Phase G levels (Braidwood et al. 1951). The highest quantity of tin measured was from a crucible fragment encrusted with a green slag from Phase G. Bronze droplets entrapped in the crucible slag yielded multiple phases of Cu–Sn metal rich in tin (35–75 wt% Sn, 15–60 wt% Cu), with the noted presence of 1.49 wt% Ni and 1.80 wt% As (Adriaens et al. 2002: 275). The heterogeneity of the crucible slag led the authors of the study to conclude that this crucible was not used for the re-melting of scrap tin bronzes, but that it was used to prepare a copper–tin alloy from raw materials. From the same context at Judaidah came ten tin bronze pins, chisels, and awl fragments, which had been previously tested, and new analyses again confirmed that they contained appreciable tin content. Copper alloy figurines from Tell Judaidah, which were excavated from sounding TT20 in a well documented context just above floor XIV-3 and dated to Phase G, were analyzed by Friedman et al. (1999) who confirmed that the figurines contained up to 10 wt% tin. Lead isotope analysis of the silver helmet of one of these figurines, as well as other materials from the Amuq, linked the materials to the central Taurus ore sources (Yener et al. 1991).

Further evidence of an early technological breakthrough in bronze alloys comes from Gaziantep in southeastern Turkey, during the Early Bronze (EB) II period (Duru 2006, p. 206). Level III radiocarbon dates range 3090–2500 cal. BC. The analyses of 96 copper-based objects (mostly pins) from burials at the site of Gedikli were determined to be tin bronzes, with an average tin content of 6.33 wt% (Bengliyan 1985). Tell Qara Quzaq, situated in the north Syrian Euphrates region, yielded tin bronzes dating to ca. 2900–2750 BC, contemporary to Phase G in the Amuq. Two chisels and 14 pins had tin contents from 1.47 to 19.07 wt%, the latter of which is an exceptionally high level of tin which indicates the actual alloying of tin and copper metal and not mixed ore smelting (Montero Fenollós 1996). Other sites in northern Syria also show a preponderance of copper–tin alloys dating to the same period (Montero Fenollós 1995, 1997, 2000). Throughout the third millennium BC, during the florescence of Kestel mine operations, Tell Tayinat (Snow 2005) and Tell Judaidah in the Amuq valley, Tarsus in Cilicia southern Turkey (Kuruçayırlı and Özbal 2005), northern Syrian sites, as well as central Anatolian settlements (see summaries in Kuruçayırlı 2007) continued to use tin in the production of bronzes. Further east, early tin bronze spear-points from Tülintepe near to modern Elaziğ date to the Arslantepe VIA-B period (Yalçın and Yalçın 2009).

The second major innovation in the Early Bronze Age is the development of second-tier processing sites in mining regions. Increased urbanization and a diversified means of acquiring important subsistence resources, through pastoralism and improved agricultural practices, helped create a social environment in which economically specialized settlements emerged to mediate access to metal resources. The development of second-tier processing sites occurred as economic alliances grew larger and more complex, effectively networking multiple regions together to hedge against the uncertainty of access. This uncertainty was derived from several variables, including seasonality, finite availability, and sudden shifts in political and economic networks.

Yener and her colleagues began a survey of the Bolkardağ mining district in the early 1980s to examine the economic and technological components of one of the earliest known mining regions (Yener 1986; Yener and Özbal 1986; Yener et al. 1989). Several small sites along the valley suggested that much of the activity in this region was the seasonal extraction of ores. Excavations at the Early Bronze Age mining village of Göltepe and the Kestel mining complex demonstrated that these communities were actively involved in the intensive and sophisticated extraction of polymetallic ores and the reduction of these ores into raw metal.

The site of Göltepe was a mining village situated on top of a large natural hill facing the Kestel mine complex. The hill measures close to 60 hectares and is fortified at the summit with a circuit wall. Excavations from 1990 to 1993 uncovered a total of 1,500 m^2 of the settlement dating to the Late Chalcolithic through to the EB III phase (from ca. 4375–3750 BC to 2880–2175 BC). Habitation structures in period 3 (EBII) are semi-subterranean to fully subterranean and would have had superstructures of wattle and daub (Fig. 20.7). One house in particular had a full range of metallurgical production paraphernalia including crushers, mortars, a crucible, and kilos of ground ore and ore nodules. The house contained large EBA burnished orange-ware jars full

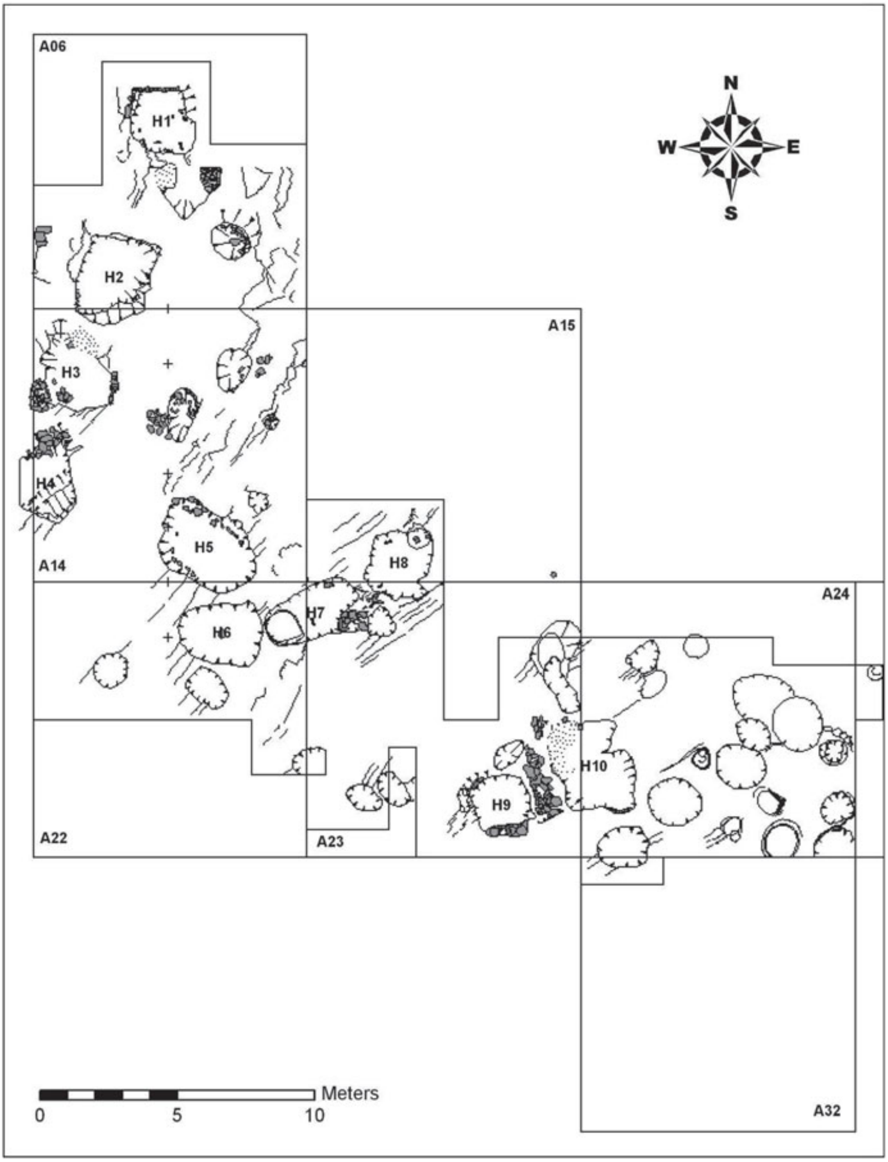

Fig. 20.7 Göltepe site plan, Area A

of ground and refined ore and processed waste materials containing 0.28–3.65 wt% tin, 6.90–41.00 wt% iron, plus minor amounts of arsenic (Adriaens et al. 1999a, b; Vandiver et al. 1992). The relatively high concentration of tin in the prepared ore is evidence that one of the primary activities of the metalsmiths at Göltepe was the preparation of tin metal. The single most significant find at Göltepe relating to the processing of tin has been discovery of over one ton of vitrified earthenware bowl furnaces or crucibles with a glassy slag accretion rich in tin. Constructed with a coarse straw- and grit-tempered ware, they range in rim size from 6 to 50 cm in diameter and have vitrified surfaces containing between 30 and 90 wt% tin content (Adriaens et al. 1996, 1997, 1999a, b). Activities involved the intentional production of tin metal by reduction firing of tin oxide in crucibles in a labor-intensive, multistep process carried out between 800° and 950°C (Yener and Vandiver 1993a, Özbal 2009; Earl and Özbal 1996). Lead isotope analysis of one of the Göltepe crucibles provided complimentary evidence that tin ores from the central Taurus were being processed (Lehner et al. 2009). Metal artifacts from the site, including copper–tin, copper–tin–arsenic, and copper–tin–silver alloys, range from 4.75 to 12.3 wt% tin and some have traces of gold (1.23–52.1 ppm), which are comparable with the Kestel ore analyses (Yener et al. 2003).

Prior to the identification of Anatolian tin, scholars hypothesized that tin was necessarily traded in from Central Asia, Egypt, or Europe for consumption in the Near East (see Muhly 1985; 1993; Stöllner 2011; Yener 1993a, b). Rather than explaining the early presence of copper–tin alloys as a product of long-distance exchange, these new alloys were being produced locally by innovations in technological organization that focused on the primary extraction of tin ores (Yener 2009), but also through regional trade networks that linked these regions to other areas of production. Polymetallic ore deposits near modern Hisarcık in central Anatolia (Sarp and Cerny 2005; Yalçın and Özbal 2009; Yazgan 2005), and in the Astaneh-Sarband area in Iran (Nezafati 2006), also show pronounced concentrations of tin that may have been utilized for the production of early tin alloys (Nezafati et al. 2008, 2009).

The early adoption of copper–tin alloys in central Anatolia is also documented at the Early Bronze Age cemetery of Resuloğlu where copper–tin and copper–tin–silver alloys are attested (Yıldırım and Zimmermann 2006; Zimmermann and Yıldırım 2007). Curiously, the Early Bronze Age settlements and mining activities in the Bolkardağ, and elsewhere in the Pontides (Lutz 1990; Lutz et al. 1994), witness a decline in use during the very end of the Early Bronze Age or beginning of the Middle Bronze Age (ca. 2000 BC). During this period, Old Assyrian texts found at Kültepe testify to the presence of a highly organized and sophisticated metals trade that possibly linked tin resources from central Asia (see Boroffka et al. 2002; Parzinger 2002) to central Anatolia by way of Babylonia and Assyria (Dercksen 1996, 2005; Larsen 1976). Interestingly, lead isotope analyses of a silver bracelet from Grave 20 at Assur point to the continuation of Taurus silver sources (Yener et al. 1991), despite the preference for eastern tin supplies as confirmed by the information in the Assyrian tablets.

Conclusion

As a retrospective on Anatolian metallurgical research over the last 10 years, we have argued for two major points in line with *The Domestication of Metals*. First, we argued that Anatolian metal industries and their organization must be seen in light of local developments and patterns. Past views of the organization of production, such as those imported from the southern Levant (see Thornton 2009), do not fit the data in Anatolia. Rather, we see the development of what has been called the "balkanized technological horizon" during the mid-late Chalcolithic (Yener 2000). These developments occurred *before* formal interaction began with Mesopotamian communities south of the Taurus. The effect of these regionalized traditions is the production of many different types of metal products by many, likely yet unidentified, means of production. Not until the Early Bronze Age do we witness the effects of larger-scale interaction networks on technological traditions.

Second, we argue for the development of specialized settlement hierarchies based on a cooperative model that sees production specialization as a way to mitigate uncertainty of access to crucial raw materials and finished goods. The beginnings of this can be seen at the site of Göltepe in the central Taurus, although indications of long-distance exchange have been demonstrated to exist earlier despite a more constrained, site-centered mode of production. These sites demonstrate how the intensive production of locally available materials creates incentives for long-distance exchange of other scarce materials necessary for the production of socially desirable materials, such as copper–arsenic or copper–tin alloys.

The rise of metal industries in the Near East and Anatolia provides an ideal case study into how human societies organize and develop exchange relations over long distances and difficult terrains. The use of metals and their production in these regions demonstrate clearly how these societies constructed economies in relation to changes in urban and political structure. Most importantly, we can see how technological organization is effectively related to social organization, both spatially and structurally.

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