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Cooperation, the Craft Economy, and Metal Technology during the Bronze and Iron Ages in Central Anatolia

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by

Joseph William Lehner

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ABSTRACT OF THE DISSERTATION

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Doctor of Philosophy in Archaeology
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Abstract

One of the most important transitions in human evolutionary history is the emergence and development of large-scale complex societies. The role of copper and bronze in the context of the emergence of Bronze and Iron Age states in the Near East is poorly understood due to a relative lack of comprehensive analysis of diachronic archaeometallurgical data. Excavations from Boğazköy and Kerkenes Dağ in central Anatolia have recovered one of the largest, diverse, and stratified corpora of copper objects and metal production debris, spanning the period from the Early Bronze Age, ca. 2300 BC, until the Late Iron Age, mid-5th century BC. Analysis of over 1100 objects employing energy dispersive X-ray fluorescence (EDXRF), in field portable X-ray fluorescence (pXRF), and select lead isotope analyses using multiple collector inductively coupled plasma mass spectrometry (MC-ICPMS) demonstrate that the rise of political complexity is closely tied to increases in trade and the management of commodity chains. Textual evidence illustrates how the Hittite state in particular managed the mobilization of metal commodities and finished goods as taxes, gifts, and payments for labor. Metal trade is further linked to state finance systems to explain how production and trade are tied to strategies of economic integration and interregional networking in Anatolia and beyond in the Near East and Mediterranean regions.

The dissertation of Joseph William Lehner is approved.

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In memory of WJL

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CHAPTER 1: COOPERATION, CRAFT ECONOMY, AND METAL TECHNOLOGY

1.1 Introduction and background

One of the most important transitions in human evolutionary history is the emergence and development of large-scale complex societies. Several cross-cultural examples in many areas of the world demonstrate how the transition from small, dispersed, and autonomous villages to highly integrated larger towns and cities is further marked by substantial changes in how individuals and groups within these polities interacted and organized (Blanton and Fargher 2008; Flannery and Marcus 2012; Johnson and Earle 1987; Stein 2001). These changes include social, economic, political, and ideological transformations which may permit or support novel organizational types or strategies. More specifically, among the most important markers of this transformation is the reorganization of labor and long-distance trade (Algaze 2008; Arnold 1996), intensification of agricultural production to create a surplus (Marston 2012), higher degrees of interdependence and orders of interaction (Spencer 2010), and scaled manifestations of ideological power (DeMarrais, et al. 1996). Distinctly complex and multilineal, this transitionary process is further characterized by the periodic and dynamic "rise and fall" of sociopolitical entities as groups competed for resources and status (Marcus 1998). In many known cases, this dynamic process of political and economic cycling within a region led to the formation of states through the related strategies of war and trade (Levine, et al. 2013; Redmond and Spencer 2012; Spencer 2003, 2010; Stanish and Levine 2011).

The region of central Anatolia presents an excellent example of this process. The increasing complexity and diversity of socioeconomic and political networks in this region during the Bronze and Iron Ages are key characteristics in the development of state societies and empires (Alcock, et al. 2001; Goldstone and Haldon 2009). Archaic states have a marked economic patterning that is largely shaped by the structure and intensity of the trade relationships that were constructed and maintained to enable the dynamic operations among urban cores and resource areas (Algaze 1993, 2005, 2008; Stein 1999). People in these societies often used materials, technologies and artistic styles as forms of communication to develop and maintain social relations and long-term political alliances across great distances (Feldman 2006). This research will primarily examine how social groups within the Hittite Empire (ca. 1650-1200 BC) and the later political regime at Kerkenes Dağ (ca. 650-550 BC) structured copper metal technology and trade to form cooperative relations. Metal production and trade are particularly sensitive to changes in state fiscal and political strategies, and as such their analysis provides an important proxy into global economic processes. I argue that the expansion and decline of states in the region during this time period is particularly marked by the adoption and structuring of metal trade as part of wider state fiscal strategies in staple and wealth finance. Further, economic activities involved in metal production and trade show significant topological shifts, shedding light onto the network parameters associated with the evolution of cooperation in Anatolia.

Beginning during at least the Early Bronze Age II period (ca. 2600-2300 BC), parallel developments in long-distance trade and conflict appear in an unprecedented scale (Selover 2015). Together with the innovations in technologies of conflict, including elaborate alloyed copper weapons and fortification systems, evidence for increased levels of cooperation include the diversifications of settlements systems, corporate architecture, highly developed divisions of labor, and structured trade in exotic materials (Düring 2011: 270).

The diversity, scale, and intensity of all these developments increase during later periods of the Bronze Age, which culminated with the development of the Hittite Empire ca. 1650 BC. The Hittite Empire was arguably the first expansionist state to develop in central Anatolia. Archaeological and textual evidence demonstrates that its capital Hattuša developed into regional center around 2000 BC and, following the "Middle Chronology," the state began its rapid expansion under the reign of Hattušili I ca. 1650 – 1620 BC (Bryce 2005; Klengel 1998; Schachner 2009a). According to the *Proclamation of Telipinu*, a Hittite historical text, an organized military force under the reign of Mursili I ca. 1620 – 1590 successfully sacked Aleppo, capital of the north Syrian kingdom of Yamhad, and Babylon in southern Mesopotamia ca. 1595 BC, entering the Hittites into large scale interregional interaction (Bryce 2005: 70-72). The greatest extent of the Hittite state arguably occurred from ca. 1400 BC to 1200 BC.

The transition from large territorial states of the Late Bronze Age to the subsequent rise of regional Iron Age kingdoms in the Near East and Anatolia is marked by one of the most empirically visible changes in the archaeological record (Bachhuber and Roberts 2009; Harrison 2008; Yener 2013). Late Bronze Age sites from across the Near East, Anatolia, and Aegean reflect large-scale destructions and abandonment, material culture appears to become rapidly regionalized, and environmental proxies demonstrate periods of climatic shift and anthropogenic degradation. These data have been variously interpreted together to help explain the processes and causes of rapid social and cultural change across the region. While scientific consensus generally appreciates the complexity of the sociopolitical cycling and cultural responses we observe more globally (eg. Butzer 2012), the difficulty to model complex past dynamics has led many scholars to reduce causation to only a few explanatory variables, including but not limited to prolonged climatic stress (Drake 2012; Kaniewski, et al. 2013), environmental degradation

(Chew 2001), warfare (Drews 1993), and pronounced shifts in established economic networks and core regions (Frank 1993).

In central Anatolia, the distinct millennium-long political and economic tradition of the Bronze Age began to decline during the end of the 13th century BC with the gradual deterioration of the administrative, economic, and religious infrastructure that was fundamental to the operation of the Hittite state (Seeher 2010: 220-221). By the end of the 13th and beginning of the 12th century BC, the capital Hattuša was probably composed mostly of waning temple and palace infrastructure (Seeher 2001), especially after the relocation of the residence of the ruling family and sanctuaries to the southeastern polities. The decline of the Hittite state also happened within the context of growing competition among neighboring states (Hawkins 2002: 151). While the historical events and processes that caused the decline of state institutions and the subsequent reorganization of communities in central Anatolia are unknown, empirical evidence is consistent with continuous occupation of the region even though it seems that communities dispersed and population densities appear to have decreased (Seeher 2010: 221).

The rapid cultural change from Hittite Anatolia to the Early Iron Age (ca. 1200-900 BC) is often attributed to migration and diffusion of social groups into north central Anatolia who introduced novel forms of social, economic, and political organization in the region (Seeher 2010: 222; Voigt and Henrickson 2000a: 46; Voigt and Henrickson 2000b). This interpretation is based on the appearance of new kinds of material culture and architecture in the region, yet there is little theoretical consensus concerning precisely the processes by which these changes happened, resulting most likely from the high fragmentary nature of the present data (Genz 2003, 2011). Evidence from Boğazköy, Gordion, and Çadır Höyük all attest to these significant discontinuities in cultural practices; however it is yet quite unclear how these changes reflect cultural transmission due to cultural or demic diffusion (exogenous change) versus other aspects of cultural development inherent to localized internal processes (endogenous change).

The situation is somewhat clearer in regions to the south and southeast of the Bronze Age Hittite core, where the selective adoption of Hittite elite institutions demonstrates some continuity (Mora and d'Alfonso 2012). The current picture suggests that the development of these new political formations on the southern and southeastern periphery of the old Hittite core were established from Bronze Age dynastic lineages (Hawkins 1995). Conversely in north central Anatolia, the subsequent reemergence of polities appears to operate with greater continuity of earlier Iron Age cultures which are quite distinct from the so-called Neo-Hittite states to the southeast (Summers 2009). The Mid to Late Iron Age in central Anatolia can be characterized as a myriad network of small competing kingdoms and states, and there is little evidence to suggest powerful control over the entire region by any one polity over any extended period of time (Genz 2011: 360). Evidence from Gordion demonstrates that the development of a prominent state and its associated polities occurred only slightly later during the late 10th and early 9th centuries BC (Sams and Voigt 2011: 159) . Gordion developed into a large urban center with monumental architecture, an expansive lower city, and a tradition of monumental tumulus burials, which attest to the existence of a ruling class of kings. A related regional center at Boğazköy during the 9th-7th centuries BC further east confirm the reemergence of polity within the bend of the Kızılırmak, where a complex settlement of fortified structures and monumental buildings demonstrate how this former Hittite capital redevelops as a central place. More regionally, the emergence of these larger political entities developed within the framework of secondary state formation across the Mediterranean and Near East, including the emergence of an enmeshed network and diversity of powerful states such as Assyria, Urartu, Tabal, and Syro-

Phoenicia (Joffe 2002; Sherratt and Sherratt 1993). Towards the late 7th and 6th centuries BC, the west Anatolian Lydian Empire briefly expanded into Central Anatolia from their capital of Sardis near to the Aegean coast, exacting tribute from the Phrygian capital at Gordion.

Perhaps related to the Lydian expansion east, the late7th/early 6th century foundation of a large new urban center on the low mountain of Kerkenes Dağ southeast of Boğazköy marks the emergence of a new political regime with cultural, linguistic, and political affinities with Phrygian Anatolia (Summers 2006b, 2009). Kerkenes Dağ remains the largest Iron Age city in Anatolia and is comprised of a dense organization of urban blocks, monumental architecture, an expansive city wall, and numerous large tumuli that are likely the burials of the leaders of the polity. The city on Kerkenes Dağ seems to have flourished not only during the Lydian expansion eastward into the Phrygian core, but also during the Median expansion westward into Urartu and likely as far as the eastern limits of the Kızılırmak and the Neo-Babylonians northwards into the previously occupied Late Assyrian territories (Wittke 2004). These developments occurred just after the dissolution of the kingdoms of Tabal south of the Kızılırmak in modern Cappadocia (Hawkins 2000: 425-433). Only after several decades since its urban foundation, the city was abandoned and destroyed during the mid-6th century BC as a result of what is interpreted to be scaled warfare between the expanding powers of Lydia and Achaemenid Persia (Summers 1997). Shortly after the destruction of the city on Kerkenes Dağ, the Achaemenid Empire occupied much of Anatolia and the Near East, uniting all of Central Anatolia into a single satrapy called Kapatka, whose central city was Mazaca or modern day Kayseri .

I theorize that the political economy in Central Anatolia during the Bronze Age and Iron Age is marked by cyclical periods of economic expansion and contraction. These cyclical periods had a profound impact on the ways resources were acquired by states. Economic expansion is marked by increases in the geographic scope of cooperation networks resulting in the further integration of producer and consumer communities. Spencer (2010: 7120) notes that expansion processes necessarily involve the adoption of novel bureaucracies or social institutions for their maintenance, and therefore parallel administrative institutions are expected to develop alongside large-scale expansions in trade. Economic contraction is marked by the disintegration of specific cooperation networks and institutions that once linked elite groups to foci of production and resources and are subsequently selected out of the repertoire of interactions. In a contracting economic environment where metal is a vitally important technology, social groups will sponsor select resource areas and production foci. A resulting pattern of intensive production may also increase the likelihood for cooperation networks to vertically integrate. In other words, the commodity chains associated with the production of value-added metal goods will likely centralize where values are particularly high, such as with the production of gold, silver, and tin bronze.

Table 1.1: Periodization of cultural developments in central Anatolia. Adapted from (Düring (2011); Sagona and Zimansky (2009); Summers (2008)). 1). Periods of focus in this dissertation in bold.

Time Period	Date (BC)	Characteristics
Chalcolithic	6000 - 3000	Dispersed autonomous village societies; ranked societies
Early Bronze Age	**3000 - 2000**	**Complex chiefdoms, kingdoms, earliest state level societies**
Middle Bronze Age	**2000 - 1750**	**Competing states, Old Assyrian Trade**
Late Bronze Age	**1750 - 1200**	**Early Hittite State, Hittite Empire**
Early Iron Age	**1200 - 900**	**Political decline; dispersed villages, ranked societies**
Middle Iron Age	**900 - 700**	**Second urbanism, Phrygian state**
Late Iron Age	**700 - *ca.* 547**	**Kerkenes Dağ, Lydian expansion**
Persian	*ca.* 547 - 330	Achaemenid (Persian) Period
Hellenistic	330 – 100	Decline of major urban centers

1.2 Cooperation and the Craft Economy

Early metal production is understood here to be part of a broader craft economy. The craft economy can be defined as the acquisition, manufacture, distribution, and consumption of crafted materials and finished goods. 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: 20). 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). One reasonable explanation for these relationships to evolve on a large scale is the opportunity for cooperating partners or polities to produce greater returns and wealth that would not be possible without specialization and interdependence (Brumfiel and Earle 1987; Clark and Parry 1990; Costin 1991, 2001). 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, et al. 2012). High degrees of cooperation, which is associated with the development of social complexity, also often leave a distinct signature in the archaeological record (see papers in Carballo 2013; Vidale and Miller 2000). 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 scaled production and standardization of utilitarian goods is also a marker of high degrees of cooperation and specialization (Rice 1981: 220).

The increasing returns to scale associated with agglomeration economies in early complex societies in Anatolia and the Near East suggest that population density, cooperation, and location were key elements (Algaze 2008: 28-39) – a process similar to emerging industries more generally (Boschma and Frenken 2011; Krugman 1991a, 1991b; Potter and Watts 2011). Fujita, Krugman, and Venables formally theorized that the centripetal forces of market size are opposed by the centrifugal forces of dispersed natural resources (1999: 9), thereby creating basins of substantially integrated economic activity in space. This logic is mirrored by Costin (2001: 313), who argues that production and consumption processes themselves can serve to integrate social groups through the benefits of cooperation, while also reinforcing difference through differential participation. Furthermore, the costs associated with transportation, production, and competition are often substantial in highland environments, and these factors likely influenced how production activities were both geographically situated and integrated. Highland environments often promote highly adapted and specialized sociocultural solutions to this problem (Aldenderfer 1998; Ehlers and Kreutzmann 2000; Körner 2004; Wilkinson 2003b; Zimansky 1985). Indeed, highland environments contain roughly half of the currently defined biodiversity hotspots on land even though they define up to a quarter of the land area (Kohler and Maselli 2009). This fundamental dynamic likely influenced much of the organization of production in Anatolia. The basic principle behind this pattern in Anatolia is that the topographically diverse highland ecologies profoundly affected the political and economic strategies of Anatolian populations.

Yener (2000) first described this process in the rise of complex metal industries in Anatolia in what she calls the highland production model. This model differs considerably from previous models that explain the rise of metallurgy based on data from the southern Levant or Europe (Strahm and Hauptmann 2009; Thornton 2009). Contrary to the development of cultural knowledge and technological innovations in the lowlands, Yener argues that metallurgical traditions develop out of a "balkanized technological horizon" during the Chalcolithic (ca. 4500 – 3500 BC), when Anatolian societies evolved a spectrum of highly regionalized political and economic systems (Düring 2011: 200-256; Schoop 2005), some of which, particularly in the upper Euphrates region, appear to have aspects of early urbanism. These regionalized polities across Anatolia functioned as multiple foci of production, where patterns of shared sealing traditions, ceramics, architecture, and other forms of materials culture are not observed in the distinctive metallurgical traditions (Yener 2000: 30-66).

Intrinsic to early metallurgy in Anatolia are the primary production strategies which differed from production models well known to the southern Levant. Primary production in metallurgy, which consists of the suite of technologies involved in the reduction of ores into metal through smelting (see Craddock 1995), has its likely origins in the Near East (cf. Radivojević and Rehren 2015; Radivojević, et al. 2010; Roberts 2011; Roberts, et al. 2009). The production of so-called "natural" or unintentional alloys as the result of prolific experimentation in smelting during the Chalcolithic (Strahm 1988; Strahm and Hauptmann 2009) may equally likely be associated with a well-adapted and fully intentional technology. Rather than smelting relatively homogenous iron- or manganese-rich copper ores, which are common to the Feinan and Timna sources of the southern Levant (Genz and Hauptmann 2002; Hauptmann, et al. 1992), Anatolian producers appear to have utilized a wide range of naturally available polymetallic ore types. The smelting of polymetallic ores or mixed smelting of select ores can result in the production of a wide variety of locally available copper alloys (Özbal, et al. 2002a; Özbal, et al. 2008; Radivojević and Rehren 2015; Radivojević, et al. 2013). Diverse alloy types can be found in much of the literature on Anatolian metallurgy. For example, metals like Cu-As, Ag-Cu, and Cu-As-Ni Late Chalcolithic / Early Bronze Age Arslantepe (Hauptmann, et al. 2002b; Palmieri and Di Nocera 2000) and Cu-Ni alloys from Late Bronze Age Boğazköy-Hattuša (Lehner 2011, 2014b) and Kaman Kalehöyük (Hirao and Enomoto 1997) demonstrate the prolonged practice of smelting mixed ore types in Anatolia.

A third important aspect of Yener's highland model is the development of what she calls a "multi-tiered" or hierarchical organization of production. Contemporaneous with the first urbanization in Anatolia during the Early Bronze Age ca 3000-2000 BC, specialized mining and smelting communities developed in highland regions near to ore resources (e.g. Göltepe). This pattern is noted also in the southern Levant and in Europe for varying reasons, but generally seem to be associated with parallel developments in social complexity. At the site of Göltepe in the central Taurus ca. 2880–2175 BC, people were engaged in the labor intensive benefaction of low grade tin ores rich in iron (Adriaens, et al. 1999a; Yener, et al. 2003) for the smelting of tin (Adriaens, et al. 1996; Earl and Özbal 1996; Yener and Vandiver 1993). Unfortunately intensive investigations of highland primary production sites like Göltepe are few in Anatolia. Recent research at the Early Bronze Age copper mining site of Derekutuğun in modern Çorum province proves to be an important exception (Yalçın and İpek 2011; Yalçın and Maass 2013). Additionally, we have little data about primary production sites in Anatolia after the Early Bronze Age, yet we can infer from the Kültepe texts (Dercksen 1996), Hittite texts (Siegelová 2005, 2008; Siegelová and Tsumoto 2011), and from secondary production workshops at sites across Anatolia that they must exist (see Müller-Karpe 1994). Further intensive archaeological research in resource rich highland regions is obviously needed to help answer this problem (ex. Kaptan 1986; Kaptan 1990).

This observation implies that mining sites and many other specialized activities involved in raw material procurement and preparation developed out of increasing interaction and integration with lowland societies. However, the degree of actual autonomy that highland producers had is yet unknown. The degree of integration highland producers they themselves sponsored during changes in the political and economic organization of lowland societies likely served as an important determining factor. Simplistically, integration could function by means of market processes known to the Kültepe texts (Adams 1974; Larsen 1976; Lumsden 2008; Veenhof 1997), for example, or through redistributive processes and control on the other (Earle 2010, 2011; Oka and Kusimba 2008; Smith 2004). Specifically to central Anatolia, the shift from the emergence of centralized estates in the late Early and Middle Bronze Age to the territorially integrated Hittite state of the Late Bronze Age likely had a notable effect not only on the exchange and redistribution of metals but also therefore their production (Cherry 1986; Liverani 1987, 2014 [1988]).

This challenge also makes it difficult to assess precisely how early highland metallurgists were integrated into the broader craft economy during the Bronze Age. It is further difficult to examine empirically because very little archaeological data for the Middle and Late Bronze Age exists for the primary production of metal in Anatolia during this crucial formative time period. Evidence for secondary production activities is much more prevalent because they often occur in urban contexts which have been the focus of archaeological research for the last several decades. Research at the ancient Bronze Age urban center of Kültepe-Kaneš, for example, demonstrates that urban producers were almost entirely limited to secondary metallurgy and were variably organized by authoritative leadership (Lehner and Yener 2014). This is particularly evident because metal workshops seem to be limited to households in the lower town rather than concentrated in closed contexts more indicative of attachment to state institutions like palaces or temples (Müller-Karpe 1994: 49-66). Ingots of copper and silver were recovered in workshops (Özgüç 1986a), which links the lowland urban and highland producers, however we know from texts that this linkage could be based on an extensive exchange system involving several interest groups rather than simplistic relationships between highland and lowland metallurgists alone (Dercksen 1996).

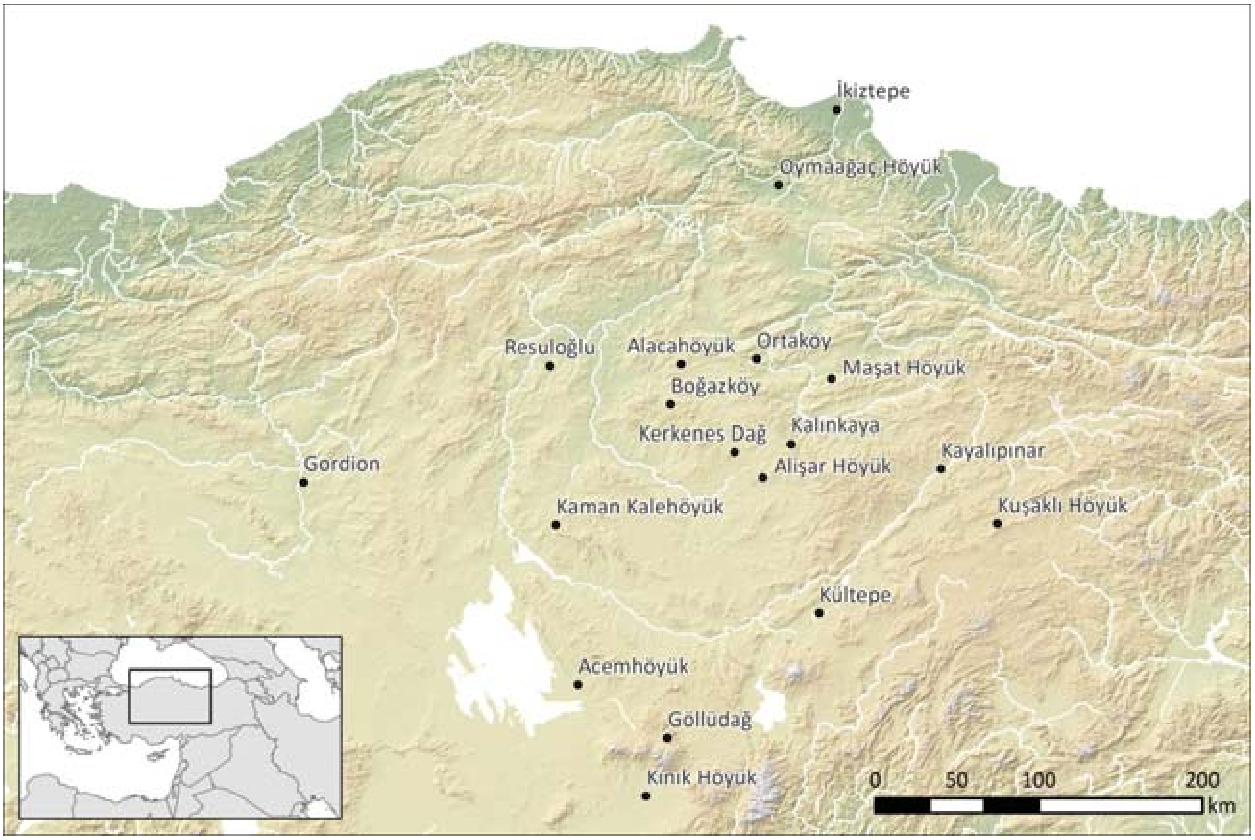

Figure 1.1 Location of prominent archaeological sites in north central Anatolia mentioned in this dissertation.

These three aspects of the highland production model, namely localized traditions of production, the early use of a diverse resource base including a wide variety of ore types, and the development of specialized primary metallurgy sites like Göltepe and Derekutuğun, encapsulate a generalized pattern that is theorized to characterize early metallurgy in highland regions like Anatolia (Lehner and Yener 2014), the Caucasus (Courcier 2014; Schachner 2002), and Iran (Thornton 2009). Yener's work in particular focused on the early formative periods of development from the Neolithic to the Early Bronze Age, however little is known how these patterns developed in the later periods when highly networked state-level political strategies dominate as a primary means of political integration. The organization and control of the craft economy is certainly linked to these developments in later periods. During both the Middle and

Late Bronze Age in central Anatolia, the long-distance exchange of commodities, prestige objects, and knowledge is evident across the Near East, Aegean, and eastern Mediterranean. By the Late Bronze Age in particular, the craft economy functioned not only as a means to produce a wealth surplus more locally, but also as a means of alliance formation, cooperation, and diplomacy between competing regions (Feldman 2006; Liverani 2001).

1.3 Theoretical perspective on cooperation and commodity chains

This dissertation combines economic geography and theory in the evolution of cooperation as a way to understand changes in human behavioral strategies in state level societies. In so doing, I assume individuals and corporate groups interact within a framework of contingency and bounded logic (Bowles and Gintis 2011; Boyd and Richerson 2009; Gintis, et al. 2005; Henrich, et al. 2004; Henrich, et al. 2001), rather than rational in the classic economic sense of the word. Cooperation is defined here as an act of reciprocity, direct or indirect, whose stability is contingent upon a history of interaction and anticipated future outcomes in what is essentially an evolutionary process (Axelrod 1984; Axelrod and Hamilton 1981). Cooperation can occur between two or more individuals and between corporate social groups of any size (McElreath and Boyd 2007: 123-166). Under the right ecological conditions, social complexity (structured social diversity, hierarchies, etc.) can evolve through the self-interested interactions of individuals and groups (Nowak 2012).

Large-scale societies may differ drastically in the way cooperative networks are structured and maintained. One of the largest limiting factors to large-scale cooperation, especially among polities cyclically expanding through resource acquisition feedback mechanisms described by Spencer (2010), is geographic distance. Distance related costs, including those incurred through transportation and communication, fundamentally structure the way individuals and corporate groups organize their long-distance activities. Communication networks evolve in changing environments where efficiencies, however measured, mitigate costs relative to the benefits provided by cooperative relations. As such, the geography of archaic states is more accurately characterized as highly structured social networks across space rather than necessarily cohesive aerial units or territories (Adams 1981; Branting, et al. 2013; Smith 2005, 2007; Ur 2010; Wilkinson 2003a).

One of the ways that metal technology tracked onto geographies of large-scale cooperation, was through the social construction of intertwined commodity chains (Earle 2010: 210). More commonly examined explicitly by economists and economic historians (Bair 2009), commodity chains are composed of the sequence of actions and processes inherent to the resource extraction, manufacture, distribution, and consumption. This directly parallels the previously described understanding of a craft economy; however it further focuses on these processes in space and time. How these chains are organized, and where different chains overlap, provide clues to how different communities may have sponsored or controlled them.

From the height of the Bronze Age urbanism in Anatolia to its eventual contraction and rise again during the Iron Age, global economic patterns are known to have shifted significantly in their extent and structure. The actual dynamics of this shift are unknown in Anatolia. I propose that these dynamics can be understood as economic expansions and contractions (Bair 2009). Expanding economies show increases in cooperation network size and complexity, while contracting economies demonstrate the selective abandonment of network ties and institutions. The global structure of cyclical economies, in the sense of expanding and contracting economies, consists of two variables. First, the geographical scope of a global economy, defined here as distance and diversity involved in cooperation networks, should positively correlate with economic cycles. Increasingly expansionist strategies of polities necessarily take in more territories to acquire necessary agricultural surpluses and access to value-added goods like metal. During the Anatolian Bronze Age, the Hittites used combinations of staple and wealth surpluses to finance a coercive military force to integrate strategic regions into their state. These regions were often along important trade corridors, such as the Cilician gates into ancient Kizzuwatna or along the valleys to the metal rich regions of the eastern Pontides. An obvious effect of increased geographic scope in an expanding economy is the use and exploitation of more resource areas, the materials produced from them, and increases in the number of cooperating individuals or groups. This should be reflected in both the diversity of metal technologies and the provenance of their raw materials.

Second, the organization of commodity chains that adapt to an increasing geographic scope should show changes in integration. This can take the form of both vertical and horizontal integration of commodity chains. Social groups involved in the production of materials like metals may aggregate similar production activities horizontally to produce scale up production efficiencies in a region. Spatial clustering of industries is an example of such integration, and this is first observed with the development of regional centers in Anatolia. At sites like Boğazköy and Kültepe, which were central places of large states, similar production activities are located in proximity to one another. Similarly, some social groups may muster the necessary surplus and capital to vertically integrate commodity chains, integrating several production processes and commodities within a single organizational unit. Evidence of vertical integration is discernable when an attempt is made to centralize many or all aspects of production along a commodity chain. As I will argue in this dissertation, evidence points towards the tendency for Anatolian states to horizontally integrate aspects of secondary metal production in regional centers as a way to manage the production of high value finished goods.

1.4 Organization of the dissertation

Following this introduction, Chapter 2 outlines the general theory and interpretive methods associated with metal technology. This includes a necessary description in a highly simplified commodity chain organized through the three major production sequences, raw material acquisition, primary production, and secondary production. All three of these processes leave determinative archaeological markers and their presence or absence at any particular site aids in the description and interpretation of the commodity chain involved. The second part of this chapter discusses the environmental parameters of Anatolia specifically pertaining to the geology of Asia Minor and the distribution of scientifically described metal resources. This then leads into an assessment of the cultural history of metal production leading up to the Early Bronze Age. Chapter 3 describes the state of the art concerning Bronze and Iron Age metal production and trade. This chapter focuses on the published archaeological and textual remains of Kültepe and Boğazköy to empirical generate a model capable of describing the organization of metal production and trade at these sites. Because the Iron Age in central Anatolia is data poor, this chapter describes and postulates why there is a lack of knowledge and how to explain this pattern. While Chapter 4 describes the chronological and contextual information of all samples analyzed in this study, Chapter 5 presents the results of the methods and analyses. Chapter 6 concludes the study with a discussion of state fiscal systems, dichotomized here as wealth and staple finance systems, as they relate to the production and trade of metal in Anatolia.

CHAPTER 2: THE SOCIAL EVOLUTION OF METAL TECHNOLOGY IN ANATOLIA

2.1 Introduction

Regional traditions of metal production and consumption seem to emerge in areas where mineral and native metal resources were relatively abundant (Golden 2009: 34-47; Hauptmann 2007: 255; Roberts, et al. 2009: 1013-1014; Yener 2000: 18-25). However, it is well known that 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 used to differentiate social groups (Brumfiel and Earle 1987; Helms 1993). Once metal became locked into a cultural system as an indicator of wealth, disparities in access to these resources necessitated varying degrees of cooperation among producer and consumer groups. These relations often linked distant groups together into cooperative agreements based on economies of scale. Therefore, metal technologies are embedded in complex networks and institutions of production, exchange, and consumption that effectively unite disparate highland resource areas and lowland regions.

In this chapter, I consider metallurgy and its related technologies as integral to the craft economy present in the archaic societies of Anatolia. Here I develop the necessary framework to help understand the principles of the craft and how various stages of production can be reorganized to adapt to overarching social and cultural changes. Then I discuss the geology and distribution of raw materials used in the production of metal in Anatolia before considering how they were acquired and used over time up until the end of the Early Bronze Age. These data form a necessary background to aid in the interpretation of compositional data found in Chapter 5.

2.2 Metallurgy and the Craft Economy

Metal technology is an important proxy of highly cooperative behavior in a craft economy because as a technology it often requires a high amount of labor, knowledge of a variety of related technologies, and access to highly dispersed resources. In many ways, an efficient metal technology requires cooperation. However, the evolution of this technology over time in highlands of Anatolia and Iran has resulted in several different regional configurations, suggesting that there is no single optimal strategy in metal production (Thornton 2009: 320; Yener 2000: 4-10). Rather, empirical evidence suggests that people produced a wide variety of metals by intentionally utilizing a diverse resource and knowledge base that evolved in in the context of distinct natural and cultural ecologies.

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 (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 BC) to a more diversified, large-scale, and centralized production that took place outside of habitation areas during the EB II–III (ca. 3000–2300 BC) (Genz and Hauptmann 2002; Levy 1995), where ingots of metal were imported rather than locally produced (Golden, et al. 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; Kohl 1987; Stein 2005; Stein 1999).

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 semi-finished 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 BC). 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 BC 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 BC), is one such example (Yener and Vandiver 1993). Additionally, data indicates 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.

2.2.1 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 in urban cultures of Bronze Age and Iron Age Anatolia. 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 (eg. 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.

2.2.2 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 BC), 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 non-weathered 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 4th and early 3th millennium BC, evident at Derekutuğun in Çorum (Yalçın and Maass 2013), Kozlu in Tokat (Giles and Kuijpers 1974), and Kestel in the Taurus (Yener, et al. 1989). However, numerous types of polymetallic, oxidic, and sulphidic ores have been identified at a number of 5th and 4th millennium settlements such as Değirmentepe (Esin 1985; Özbal 1985) and Arslantepe (Hauptmann, et al. 2002b; Palmieri, et al. 1993) along the Upper Euphrates, and Çamlıbel Tarlası in modern Çorum province (Schoop 2010, 2011), 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 BC). 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.

2.2.3 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 2nd millennium BC 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 at 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 3rd and 2nd millennium silver in the Near East contain around 0.1 wt% lead or suggesting cupellation was widely used to produce silver (Moorey 1994: 323-240)

. The earliest examples of silver extraction through cupellation date to the late 4th millennium BC from Fatmalı-Kalecik (Hess, et al. 1998) and Habuba Kabira (Pernicka, et al. 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, the earliest evidence of which dates to the 6th century BC at Sardis located in western Anatolia (Bachmann 1999; Ramage and Craddock 2000).

Iron production also deserves some mention for the Anatolian Bronze Age. Re-dating of the Alaca Höyük irons, including the iron dagger with gold handle, places them firmly with the later part of the 3rd millennium BC (Yalçın 2010). In addition, numerous iron objects from Kaman-Kalehöyük Stratum III dating to the early second millennium BC 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: 27-29; Maxwell-Hyslop 1972). Additionally, amorphous iron lumps discovered in a large house from the lower city at Kültepe (Müller-Karpe 1994: 55; 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 a byproduct result of copper smelting (Akanuma 2006). However some opinion persists to explain 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 Pernicka 1990: 60-63; Waldbaum 1999). 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, evident both at Kültepe and Acemhöyük, are bun-shaped and bar-shaped ingots (Özgüç 1995). 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, et al. 2002a), 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 re-melt 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 1991, 1996; Lechtman and Klein 1999) 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, et al. 2012; Thornton, et al. 2009). Arsenic is highly volatile at high temperatures, so it is difficult to mutually control arsenic and copper in a single environment. Producers likely developed specific ways to carefully time the addition of arsenic 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 BC (Kuruçayırlı 2011; Kuruçayırlı and Özbal 2005; Lehner 2011, 2014b).

2.2.4 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 re-melting 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 elite residences and palaces (Lehner 2014a).

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 Late 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 (Lechtman 1996), 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).

2.3 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 sub-tropical 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 (Figure 4.1). 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; Yalçın and Özbal 2009; Yener, et al. 2015). Prior to any larger archaeometallurgy research programs, the characterization of these ore bodies was accomplished by the Turkish General Directorate of Mineral Research and Exploration (MTA). While most of this original exploratory work was aimed at defining the economic potential and modern industrial interpretation of the ores, the extensive placement of major ore bodies and smaller metal occurrences throughout the Anatolian peninsula provided the necessary environment for the development of early metallurgy. De Jesus (de Jesus 1980) compiled much of this early work and analyses of archaeological metal, mostly conducted by Ufuk Esin (Esin 1969), in the first major synthesis of Anatolian archaeometallurgy and resource use based on scientific data.

In addition to the fundamental exploratory work of the MTA, a series of later surveys in the 80s and 90s geared towards understanding how these resources related to ancient societies further generated a large archaeometallurgical dataset. These data characterized the elemental and isotopic composition of hundreds of ore sources and occurrences across Anatolia. This work includes the Heidelberg-Mainz surveys across Anatolia in the 1980s (see Wagner, et al. 2003: , and references therein), later surveys lead by A. Yener in the Bolkardağ mining district of the central Taurus (Yener 1986; Yener and Özbal 1986), and analyses of ore samples from the Taurus and across central Anatolia by the Japanese expedition to Kaman Kalehöyük (Hirao, et al. 1995). Much of this work was accomplished in the context of extensive analyses of ore sources across the Mediterranean, as scholars sought to define and explain the origins of metallurgy in the Old World, the nature of metals trade, and the provenance of copper, tin, silver, and lead metal more generally (for Anatolia and the Near East more specifically, see Pernicka 1990; Yener 2000).

The three largest massive copper sulphide ore bodies in Anatolia include the metallogenic zones of Ergani in the eastern Taurus and Küre and Murgul/Göktaş along the central and eastern Pontide belt (Wagner and Öztunalı 2000). The geological age of these mineralizations also varies in relation to ongoing tectonic and geothermal activity throughout peninsular Turkey – a determining factor in the success of extensive lead isotope research conducted in the greater Anatolian region (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 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 ore of the fahlerz type are evident in both Pontide and Tauride sources (Özbal, et al. 1999; 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 sulphide deposit near modern Bitlis in eastern Turkey has also been reported (Çağatay 1987), while further smaller sources of copper-nickel sulphides have been reported from within the major iron-bearing ore zones of Divriği-Sivas (Harada, et al. 1971). The Bolkardağ mining district of the central Taurus and immediately north of Cilicia includes mostly iron, argentiferous lead, copper-lead-zinc ores and also oxides and sulfides of tin including stannite and cassiterite (Pehlivan and Alpan 1986; Yener and Özbal 1987; Yener, et al. 1989). More recently, a tin occurrence at Hisarcık in Kayseri province, located north of the Bolkardağ, was found associated with scores of mines (Yener, et al. 2015). 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 are their heterogeneous and uneven distribution (Wilkinson 2003b). Despite a relative abundance of ore sources, their spotty distribution and diverse characteristics influenced how they were extracted, refined, smelted and transported (Craddock 1995). The geographic and social parameters of mining regions had significant influence on technological organization, socioeconomic processes, and interregional relations

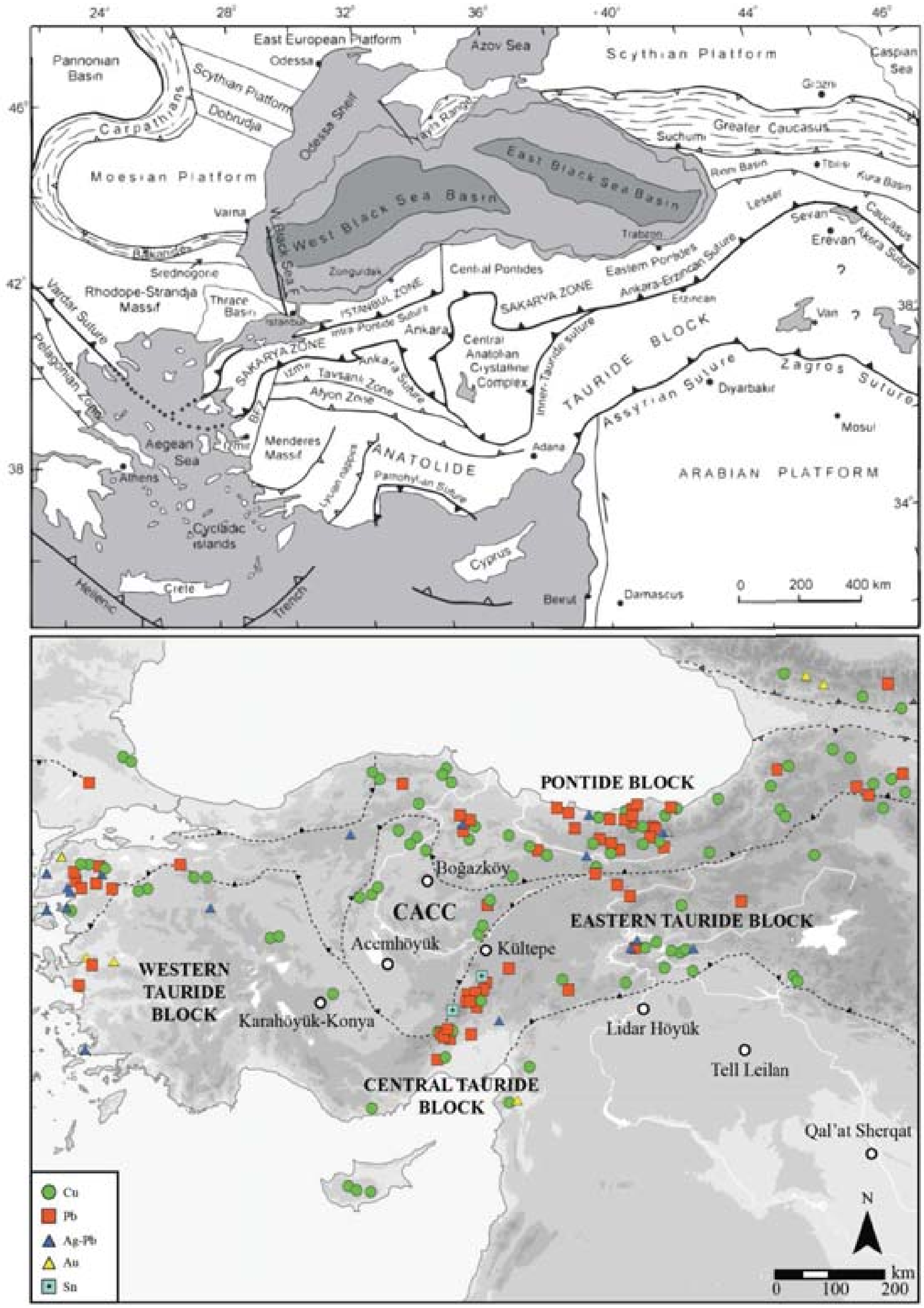

Figure 2.1: Top: structural geology of the Anatolian peninsula highlighting major faults and geological zones or blocks (adapted from Okay 2008: 21, Fig. 3). Bottom: the tectonic and lithological development of the Anatolian peninsula have determinative effects on the distribution of known metal bearing regions, which can be characterized by their placement in major blocks.

(Knapp 1998). Distance from the raw materials to fuel and food supplies, as well as seasonal weather conditions, would have been key factors in how they were accessed. Production and transportation to and from the highland resource areas was almost certainly restricted by seasonal conditions due to harsh prohibitive winters. Furthermore, economic transportation routes were most often limited to navigable rivers and intermontane valleys. Patterns associated with climatic and social events, such as poor weather, trade embargos, and regional warfare, further constrained access. As the Kültepe demonstrate, movement of goods across central Anatolia was often abruptly postponed due to poor weather and war, and this likely had significant effects on trade relations and the exchange values of metal types (Barjamovic 2011: 28-29; Dercksen 1996). Furthermore, the dynamic and costly ventures of mining and smelting activities often had considerable impact on the environment, leading to deforestation and alterations of drainage routes (Monna, et al. 2004).

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 providing leveraging power to others. As will be argued later, economic specialization and diversification in mining, and extraction technologies, 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. Suffice to say for now, 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. 2002b; 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; Zimmermann, et al. 2009), indicate metal resources and technologies were associated with disparities among social groups.

2.4 The earliest emergence of metallurgy in Anatolia

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 (2009:305) point out, the Near Eastern highland regions are internally variable. They constitute a series of interlocked highland intermontane and lowland valleys and plateaus. However within the greater Near East, Anatolian physical geography is distinctive, providing not only important resources in the formation of complementary links with the Syro-Mesopotamian plains but also naturally defensible environments. Nevertheless, Anatolia is a distinct region that warrants discussion of both broad diachronic changes in the organization of metal technologies and localized traditions of metallurgical practice.

The framework for this discussion is divided into two parts. First, I 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), I 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 exists before apparent large scale Mesopotamian involvement in Anatolia. Second, I discuss how metal production is coordinated over long distances in order 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. This organizational trajectory sets the stage for metal production and consumption that we observe during the Late Bronze Age (ca. 1550 – 1200 BC) and Middle/Late Iron Age (ca. 800-500 BC), which are political optima in terms of polity size and the foci periods of this dissertation.

2.4.1 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 tended to view archaeological problems in terms of the regions that surround Anatolia, including the Aegean and Mesopotamia. It was usually assumed that novel social, political, and technological forms originated elsewhere, outside the frontier highlands of the Anatolian. It was V. Gordon Childe who suggested that metallurgy was central to cultural diffusion in the region, where ‘itinerant metalsmiths’ contributed to the rise of social elites and complex societies across the Near East (Childe 1930, 1944). It logically followed that traditions of metallurgy diffused from the Near East, specifically Mesopotamia and the Levant, into other regions including Anatolia and the Aegean. Criticism of this simple model came first from Europe, where scholars used radiocarbon dates to challenge the claim, suggesting an independent development of metallurgy in southeastern Europe (Renfrew 1969, 1973). Empirical evidence to date further demonstrates complex social processes of technological innovation associated with the origins of metallurgy occurred not within the lowland resource poor regions of the Near East, but within the resource diverse regions in Anatolia and Iran (Roberts, et al. 2009). Rather, we can now expect innovations in metallurgy to occur as a distinctive relationship between resource availability and cultural transmission. It is most likely that Mesopotamia did not need to develop novel primary production technologies, but instead social groups found new ways to organize labor and technologies associated with secondary production and distribution strategies. Anatolia, on the other hand, had proximate resources and different social systems, and therefore we can expect innovations to occur both in primary and secondary production strategies.

In a review of the intellectual history and rhetorical devices used to describe the Anatolian peninsula, particularly as a region of analysis, 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 2007:219). 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: 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 *ex oriente lux*.

The suggestion that highland regions promote diversity is not a novel concept. Aldenderfer (1998), Ehlers and Kreutzmann (2000) and Körner (2003, 2004) 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.

2.5 Metal production and consumption 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). In addition, access to raw materials during formative periods of emergent complexity help generate temporally-resilient acquisition networks important to many later complex technologies. As early as the 11th 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, et al. 2004; Solecki 1969). Evidence for the regional occurrence of cold-worked native copper begins during the 9th – 7th millennia 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 9th to the 7th millennia 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). 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).

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 promoted 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.

2.6 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 (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, is 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 2000). 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 (<0.005-0.01 wt%) (Yalçın 2000: 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, furnace 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 5th and beginning of the 4th millennia BC (Esin and Harmankaya 1988; Yener 2000: 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. 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 indicate 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 analysis 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 dating to the Late Chalcolithic (period VIA) contained several rooms for storage, which suggest that the building was the center of a local power and possibly 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 (1999) defines 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 sulphides 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. 2002b).

A hoard of 21 metal alloy weapons dating to the VIA period contain almost predominantly copper-arsenic alloys ranging from 2.57-6.08 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. 2002b: 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 non-utilitarian 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. 2002b; 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. 1999: 145) indicate that alloying strategies may have involved the

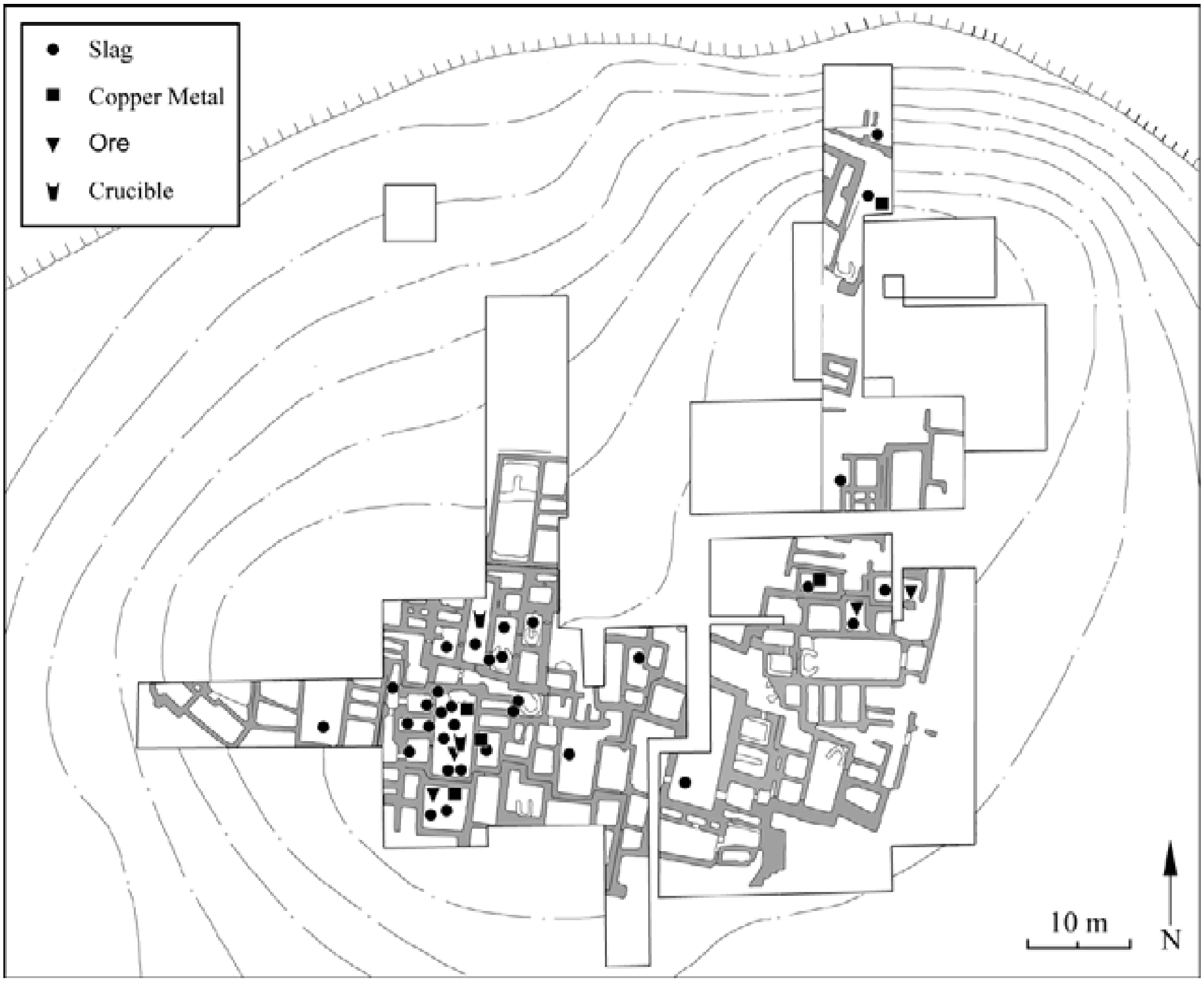

Figure 2.2: Değirmentepe with metallurgical remains which demonstrate both primary and secondary production technologies existing together (Lehner and Yener 2014: Fig. 20.5, Müller-Karpe 1994: Fig. 4).

production and trade of this special cosmelting product used to produce early copper-arsenic alloys (Rehren, et al. 2012; Thornton, et al. 2009). It may also have been a by-product of smelting copper-nickel-arsenic ores. However, the use of speiss as a necessary ingredient in the production of arsenic alloys may help explain the emergence of high-arsenic copper alloys. Further complex advances in primary smelting is also evinced in the earliest production of silver from the reduction of argentiferous lead ores. 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 in the Near East to date for the reduction of argentiferous lead ores into silver metal using 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, 2011). 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 sulphide 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 sulphide 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, indicates that producer communities in North-Central Anatolia lived in small household aggregates composed of part-time specialists.

Published analyses of a few finished artifacts from Çamlıbel Tarlası demonstrate that the metals used are arsenical copper (Rehren and Radivojević 2010: 215). 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, 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 regards 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 north-western Anatolia (Begemann, et al. 1994) and Ikiztepe near to the Black Sea (Bilgi 1984, 1990; Özbal, et al. 2002a; Özbal, et al. 2008), means that while divergent patterns of metal production were localized, some metallurgical techniques, perhaps utilizing speiss, were shared across very long distances.

2.7 The Development of Tin Bronze and Specialized Mining Communities

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 possibly extended as far east as modern Afghanistan (Delmas and Casanova 1990; Muhly 1973a, 1973b; Muhly and Wertime 1973). 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: 109-173). Second, the organization of production shifted from site-centered metallurgy to a multi-tiered hierarchy of production (Yener 2000: 67-70) allowing for the development of large scale industrial systems to evolve for the first time in Anatolia.

The earliest bronze alloys occur in the Near East during the late 4th and early 3rd millennia BC (generally the Late Chalcolithic and EB I), whereas the wide spread consumption of bronze can be dated to the mid-3rd millennium BC and extends from the Persian Gulf to the Aegean (Pare 2000; Pernicka 1998; Weeks 2004). Many of the earliest bronzes come from early excavations whose exact contexts and dates cannot be directly confirmed using independent absolute dating techniques[1]. Furthermore, analytical sensitivity has improved considerably for both lower and upper limits of detection of important elements relating to metal technology. Given these uncertainties we are still presented with plausible evidence for a range of early tin bronzes whose adoption in the Near East can be confidently dated to at least the early 3rd millennium BC. Examples of copper tin alloys across Mesopotamia include several objects

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[1] See Buchholz (1967), de Jesus (1980), Esin (1969), and Muhly (1973a) for a comprehensive discussion of these older analyses and the references therein.

dating to the early 3rd millennium BC from Tepe Gawra (Hauptmann and Pernicka 2004: no. 267, 289) the Y cemetery at Kish (Hauptmann and Pernicka 2004: no. 8, 10, 18; Müller-Karpe 1989; Stech 1999), Tell Razuk (Hauptmann and Pernicka 2004: no. 723), and Tell Agrab (Hauptmann and Pernicka 2004: no. 45). Several more examples from a burial dating to the EB I in northern Syria at Tell Qara Quzaq along the Middle Euphrates show appreciable evidence for the use of copper tin alloys (Montero Fenollós 1995, 1997, 2000, 2004).

Among the earliest examples of copper tin alloys in the Near East include a group of ornaments from Kalleh Nisar (northwestern Iran) with tin contents ranging from 3.5% to 14.8% and are considered to be purposefully alloyed. These ornaments come from a burial excavated by Louis Vanden Berghe in the 1960s and date to the EB I in Luristan, which is roughly contemporary with the Jamdet Nasr to Early Dynastic I (ED I) periods in Mesopotamia (Fleming, et al. 2005; Vanden Berghe 1970). Although not scientifically tested, it is likely that the tin for these early tin bronzes in the Iranian highlands was derived from the small occurrences of tin located in the Astaneh-Sarband region (Nezafati, et al. 2008, 2009, 2011). Further examples of early tin bronzes and possible tin occurrences are noted in the Caucuses in Dagestan (Kohl 2002), Armenia (Meliksetian, et al. 2003), and Georgia (Erb-Satullo, et al. in press).

Along the northwestern bend of the eastern Mediterranean at sites in Cilicia and within the Amuq Valley, early copper tin alloys are first observed in early 3rd millennium BC contexts. For example, six figurines from a cache at Tell Judeidah and probably dating to the Amuq G period were produced from a cast copper tin alloy (Braidwood, et al. 1951). Although the date

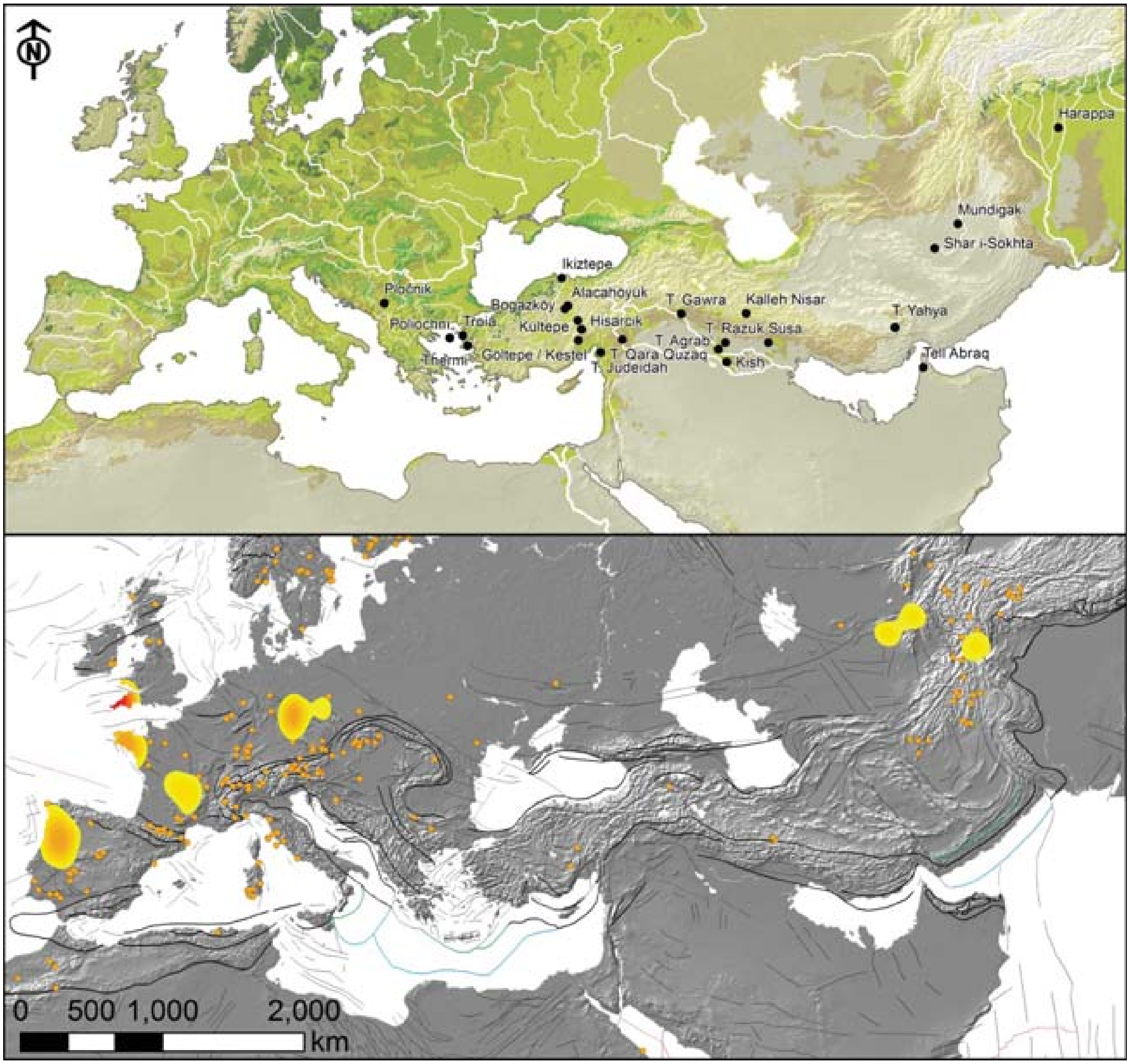

Figure 2.3: The distribution of known tin sources/occurrences and the earliest sites where past communities consumed tin metal across the Near East and Central Asia demonstrates a major geographic disparity. The earliest tin bronzes occur along the piedmont of northern Syro-Mesopotamia and western Iran (above). The largest tin-bearing regions (in gradients) occur in Europe and Central Asia, while smaller occurrences (points) are irregularly distributed throughout the region and tend to be more proximate to larger tin sources (below) (Lehner 2014c).

and context of the figurines has been seriously questioned (Hall and Steadman 1991: 227; Seeden 1980: 8; Yakar 1984: 70), renewed investigations of Amuq G copper alloys and production debris from Tell Judeidah (Adriaens, et al. 2002) and radiocarbon dates from a sounding in 1995 confirming the Amuq G chronology (Yener, et al. 2000: 197) reinforce the evidence for early tin consumption at the site. Early 3rd millennium deposits at Tarsus (EB II) in Cilicia also provide several examples of early copper tin alloys (Esin 1969; Kuruçayırlı and Özbal 2005). Near to modern Gaziantep at the site of Gedikli, analyses confirmed the presence of copper tin alloys from Level III (Bengliyan 1985), which are dated to the EB II with radiocarbon dates bracketing the assemblage between 3060-2500 BC (1σ) (Duru 2006: 206).

Empirical evidence for copper tin alloys in central and eastern Anatolia appears to date somewhat later. It is presently unknown if the adoption of tin use in these regions was a result of a slower technological diffusion rate, because relatively fewer analyses of Late Chalcolithic / EB I metal assemblages have been conducted to date. This is partly due to the relative paucity of contexts in these periods in central Anatolia. An important exception includes the Late Chalcolithic and EB I contexts from İkiztepe and Bekaroğlu in north central Anatolia. Several hundred analyses of weapons, tools, and ornaments demonstrate the prolific consumption of arsenical copper and a near conspicuous absence of copper tin alloys[2] (Bilgi 1984; Özbal, et al. 2008; Özbal, et al. 2002b; Zimmermann and Ipek 2010), which parallels patterns observed in most EBA contexts in Transcaucasia (Edens 1995). Analysis of Late Chalcolithic and EB I fine weapons and ornaments at the site of Arslantepe shows a somewhat different pattern of copper alloy production and consumption without the use of tin. Here we find the production of copper silver alloys and arsenical copper with significant lead, nickel, and antimony contents

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[2] Two exceptions from İkiztepe include a spearhead (İ/93-120) and a dagger (İ/93-043) that date to a later EBIII occupational context and contain 1.05% and 1.25% tin respectively (Özbal, et al. 2008: 68).

(Hauptmann, et al. 2002b). A similar compositional profile from several objects at the roughly contemporary sites Tepecik and Tülintepe have been described, however also including the presence of a single rolled head pin with 5.27% tin (Yalçın and Yalçın 2009: 137). Unfortunately the date of these objects, which were discovered by chance in a hoard found in 1966, cannot be independently verified beyond stylistic comparisons and are therefore unreliable. Nearby at Norşuntepe, select analyses of a long sequence of copper alloys demonstrate that tin bronzes do not appear until levels 8-6 which date to the EB III (Pernicka, et al. 2002: 117).

The well-known metal assemblages associated with the Early Bronze Age burials at Alacahöyük provide some of the earliest examples of a well-developed tin bronze tradition in central Anatolia. Several so-called standards and other copper-based objects were first analyzed by Esin (1969), which demonstrated that cast tin bronzes were consumed alongside with arsenical copper. Recent surface analyses of several objects confirm the presence of tin bronzes, however also demonstrating a remarkable diversity in metal compositions, including alloys of copper silver gold, copper silver, leaded tin bronze, and one example of an antimonial tin bronze figurine (Yalçın 2010, 2012). Stylistically and contextually similar objects from the nearby sites of Horoztepe and Mahmatlar (Esin 1969), Kalınkaya (Yıldırım and Zimmermann 2006; Zimmermann and Geniş 2012), and Resuloğlu (Zimmermann 2012; Zimmermann and Yıldırım 2007; Zimmermann, et al. 2009) all attest to a similar profile of metal consumption.

There is not yet an absolute chronology which defines the central Anatolian Early Bronze Age which is capable of linking these sites and the metallurgical tradition that they collectively represent. It is not out purposes to enter into a discussion of Early Bronze Age chronology in this region, which is very much in dispute, but suffice to say it is now clear that the Alişar sequence, which was developed in the 1930s-1960s, needs to be critically reexamined in light of chronological inconsistencies across the region (Ivanova 2013: 233-237; Schoop 2005: 66). The important ongoing research at nearby Çadır Höyük promises to resolve some of the problems (Steadman, et al. 2013; Steadman, et al. 2008). New work by Spagni at Alişar Höyük and nearby Çadır Höyük, for example, demonstrates that tin bronze consumption develops during the mid-3rd millennium (personal communication 2014). Nevertheless, relative interregional chronologies based on stylistic comparison variously place the Alacahöyük burials in the mid to late 3rd millennium BC (Bachhuber 2008; Gerber 2006; Gürsan-Salzmann 1992). The work at Kalınkaya and Resuloğlu, which has important parallels with EBA Alacahöyük, dates the burials and settlement to the late 3rd millennium BC (Yıldırım 2006; Zimmermann 2007). Recent analyses by Yalçın, however, are beginning to provide an absolute chronology based on three radiocarbon dates derived from charcoal trapped in the corrosion of some of the copper-based objects (2010: 61-62). These dates would conservatively place the burial deposits into the early to mid-third millennium BC, roughly contemporary with Troy I and Amuq H. Further analysis is required before this important data can be interpreted with any probabilistic confidence, answering whether this tradition of bronze production and consumption extended through many centuries in the 3rd millennium, or if this tradition represents a short period of use shortly before the emergence of numerous of regional urban centers across Anatolia.

Evidence for the adoption of tin bronze is comparably better understood in northwest Anatolia, where analyses of materials from the Troad and across the Aegean demonstrate the consumption of tin bronze by the mid-3rd millennium BC. Data from the Troad, primarily from the sites of Troy and Beşiktepe, show that bronze consumption is confirmed in the Troy I period during the first half of the 3rd millennium BC (Begemann, et al. 2003; Pernicka, et al. 1984), and with a rapid adoption in use by the Troy II period (Pernicka, et al. 2003). A similar pattern can be observed in the Aegean at sites like Poliochni on Lemnos (Pernicka, et al. 1990), Thermi on Lesbos (Begemann, et al. 1995), and Kastri on Syros (Stos-Gale, et al. 1984).

Lead isotope analysis of many mid-3rd millennium BC copper tin alloys roughly contemporary with Troy I and II from northwestern Anatolia and the Aegean demonstrate that the copper in the bronze is distinct from many of the copper ores from these regions (Begemann, et al. 2003; Pernicka, et al. 1984). This highly radiogenic lead is probably derived from ores of at least Precambrian age, the rocks of which are almost entirely unknown to the Aegean, Anatolia and the Middle East more generally. Additionally, because placer deposits of cassiterite have little to no trace lead, the lead from the bronzes is most likely derived from the copper. Lead isotope measures from these studies also suggest that the copper used to produce arsenical copper, a much older metallurgical technology, is likely sourced locally. This influx of imported copper is observed elsewhere in the Aegean (e.g. Kastri) and from sites as far as in Oman and the United Arab Emirates (Weeks 1999, 2004), which coincides with the rise of tin bronzes in the region. This combined evidence suggests that the earliest bronzes of northwestern Anatolia and the Aegean regions were imported and not locally produced.

The second major innovation in the Early Bronze Age is the reorganization of and use of labor to scale up production at second-tier processing sites in mining regions (Yener 2000: 67-68). 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 – 1993 uncovered a total of 1500 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 (Figure 2.3). 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 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; Vandiver, et al. 1992). The relatively high concentration of tin in the prepared ore is evidence that one of the primary activities of the metal-smiths 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 30-90 wt% tin content (Adriaens, et al. 1999a; Adriaens, et al. 1996, 1999b; Adriaens, et al. 1997). Activities involved the intentional production of tin metal by reduction firing of tin oxide in crucibles in a labor-intensive, multi-step process carried out between 800^{o} and 950^{o}C (Özbal 2009; Yener and Vandiver 1993). Metal artifacts from the site, including copper-tin, copper-tin-arsenic, and copper-tin-silver alloys, range from 4.75 – 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).

The recent discovery of central Anatolian tin deposits in the vicinity of Kültepe has ushered in a reinvigorated research program regarding the tin problem. This new deposit of tin, located near the town of Hisarcık along the hilly flanks of the near-4,000-m stratovolcano Erciyes Dağ, is also associated with scores of ancient mining operations (Yener, et al. 2015). The tin deposits were first discovered by the MTA (General Directorate of Mineral Research and Exploration), specifically by geologist Evren Yazgan (Yener, et al. 2015). Initial analyses of select samples from an outcropping demonstrated that cassiterite was associated with iron oxides and a rare iron-arsenic oxide mineral called yazganite. These deposits formed in a subsurface volcanic environment and were deposited on the soft andesitic walls of near-surface fumaroles as hot gases that cooled when they escaped into air. As such, they differ substantially from tin ores more common to Europe and central Asia, which primarily derive from hard granitic lithologies.

The concurrence of tin and iron would have presented significant challenges to ancient smelters hoping to reduce tin metal from these ores. Tin and iron oxides have a similar reducibility, and in order to control for the amount of iron as an impurity in the tin metal, ancient smelters would have faced a trade-off (Smith 1996). Under low reducing conditions, nonmetallic tin would be trapped in slags, effectively reducing the efficiency of the smelt, even if metallic prills of tin could be retrieved. Conversely, tin metal extraction could be increased through high reducing conditions, a process which would also admit significant quantities of undesirable iron. This results in a product called hardhead, an iron-tin alloy. Additionally, these natural deposits could have been used in a co-smelting or mixed-smelting technique, whereby smelters reduced the tin ores together with copper ores or directly in molten copper through a cementation process. Preliminary archaeological surveys in the region, led by Fikri Kulakoğlu, Ryoichi Kontani, Yuichi Hayakawa, and Aslıhan Yener, also identified industrial sites and ancient mining operations in the region of the tin deposits. One such site, called Teknekayası Höyük, has been dated to the third millennium BC by associated pottery, suggesting that many of the ancient mining operations in the area may be related (Yener et al. 2015: 605).

If the current interpretation of the region holds, then along with the Bolkardağ occurrences this would be the second known tin occurrence associated with Bronze Age industries in Anatolia. These results suggest that early metallurgy, especially given the highly dispersed nature of resources intrinsic to the craft, developed from the utilization of a diversity of deposit types, including smaller occurrences of metal deposits, many of which could have been totally exhausted. These results also have direct impact on the hypotheses of bronze adoption in the region. We must now consider the role of small deposits of local tin in the earliest innovation and adoption of bronzes in the Near East; however, it is also important to remember that these results do not necessarily falsify the standard model, which is based on second millennium BC textual and archaeological data. Local small-scale production of tin during the third millennium BC could have conceivably operated alongside the importation of exotic tin produced from distant operations elsewhere in the Old World. 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.

2.8 Conclusion

In this chapter, I first described briefly the geological background and distribution of ore resources in Anatolia. The distribution of these resources ultimately influenced the extent to which distant lowland agrarian communities conducted trade relations with highland resources areas. One of the most distinctive characteristics of Anatolia, and even highland Iran, is the incredible diversity of metal resources, including the increasing likelihood of tangible, though small tin occurrences. Unlike the southern Levant, Anatolian deposits are characterized by their polymetallic nature, though punctuated by just a few massive sulphide deposits like Ergani and Küre. I first argued first 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 or Mesopotamia (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, I argued for the development of specialized labor evinced by 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.

As will become apparent, evidence for metal production and consumption is poorly studied for later periods, despite the fact that some types of data are available. The history of metallurgy is generally left with the adoption of tin bronze, however we know very little about how and precisely where this technology was adopted. Furthermore, tin bronze does not appear to replace arsenical copper rapidly, but rather these two different technologies, which required very different sets of working knowledge and economic bases, are used in parallel for more than a millennium. Yener's work on Early Bronze Age metal production is only assumed to continue during these later periods, however this has never been tested (however, see Lehner 2014a, 2014b; Lehner and Schachner in press). In the following chapters, I provide new evidence for a sequence of production strategies that further highlight the role of localized traditions, despite periods of political and economic expansion.

CHAPTER 3: METAL PRODUCTION AND TRADE DURING THE BRONZE AND IRON AGES IN CENTRAL ANATOLIA

3.1 Introduction

In order to understand the organization of metal production and trade during the rise Boğazköy and Kerkenes Dağ as regional centers, it is first necessary to examine the development of regional polities in central Anatolia more generally. In the previous chapter, I argued that by the Early Bronze Age (EBA) in Anatolia (ca. 3000 – 2000 BC), metal technologies evolved in a landscape of increasing increasingly complex societies. During the EBA, empirical evidence demonstrates that individuals and coalitions opted to select strategies of diversification and specialization to not only overcome the organizational problems of large-scale cooperation but also to benefit from it. These interrelated strategies included the development of regionalized ways of primary and secondary production, an increased reliance on long-distance trade for raw materials, and finally the development of a "multi-tiered" organization of production (Yener 2000).

In this chapter, I examine how these strategies were further developed during the 2nd and first half of the 1st millennia BC. During the Middle Bronze Age (ca. 2000-1750 BC), small competing states eventually gave way to the rise of the Hittite Empire, which strategically sought to integrate much of central Anatolia and parts of western Anatolia and northern Syria. The integration of central Anatolia into the Hittite Empire was financed in part by the control of high value commodities through a system of tribute, levies and sponsorship of markets. I argue that the diversification and specialization of metal technologies during the EBA led to the elaborate and highly organized system of production and trade that we observe during these successive periods of increased political and economic integration. I use empirical evidence from both archaeological excavations and the analyses of Old Assyrian and Hittite texts to understand the complex though fundamental relationship that producers, traders, and state institutions all had with metal materials and technologies. The increasing efforts of political entities to integrate developed polities had profound effects on the nature in which metal commodities flowed into regional centers. After several centuries of competition among smaller polities in central Anatolia, at least one sector of metal trade and production was loosely integrated into state institutions visible archaeologically and textually at the capital Hattuša.

The geographic dispersion of raw materials effectively limited how state officials, traders, and producers alike managed their access and transport to regional centers. Conversely, segments of production activities that added increasing value to copper, from refining processes to the skilled production of finished goods, appear to be often integrated into regional centers. One trajectory of this development is explained by ecological processes associated with industrial production, such as economies of scale, transport costs, and social network effects (Fujita, et al. 1999). Yet another compatible explanation for this development is the role of elite individuals and institutions that directly sponsored or controlled metal industries and trade. We now know that the specialized production activities involved in secondary metallurgy, especially in urban contexts, promoted the clustering of metal industries in regional centers like Kültepe (Lehner 2014a). These metal workshops were primarily devoted to the specialized production of various finished goods and the workshops cut across social contexts in cities of central Anatolia. By the height of the Hittite Empire during the later half of the 2nd millennium BC, texts demonstrate that temple and palace officials would commission the production of a range of objects in gold, silver, and bronze that would be distributed to local elites as a form of wealth finance (Siegelová 1986: 110-121); however, there is no evidence to suggest that most workshops were exclusively or directly attached to the palaces or temples themselves. Rather, both textual and archaeological data are more consistent with the hypothesis that state institutions periodically sponsored specialists and workshops involved in copper production, but the working and provisioning of precious metals like gold and possibly iron likely happened directly under the control of the state.

During the Iron Age in central Anatolia, much less is known because few production contexts have ever been excavated and there is a lack of textual evidence. After the disintegration of the Hittite Empire and the abandonment of its state institutions in central Anatolia, the subsequent emergence of Iron Age polities in the region appears to have involved novel political and economic strategies (Genz 2011; Grave, et al. 2009; Grave, et al. 2012; Kealhofer, et al. 2009; Kealhofer, et al. 2010; Voigt and Henrickson 2000a). There is a resounding lack of data and theoretical discussion on precisely how these new polities organized the domestic and long-distance trade of metal and its production. Virtually all data is derived primarily from roughly contemporary cultural contexts outside of central Anatolia.

The conclusion of this chapter reiterates the original research questions to be tested in the following chapters. The archaeological and textual evidence of the 2nd and 1st millennia provide valuable insight into the relatively rapid rise and fall of complex polities. Metal commodities effectively track these processes.

3.2 Metal and markets: the evolution of the regional center in central Anatolia during the EBIII and MBA

The EBII – EBIII (mid to end of the 3^{rd} millennium BC) in central Anatolia is characterized by incipient state formation (Düring 2011: 257-299). Multiple lines of evidence indicate this, including 1) the development of dispersed urban centers and settlement hierarchies in regions associated with the largest sites (Kontani, et al. 2014a; Kontani, et al. 2014b; Kulakoğlu 2011); 2) pronounced status differentiation (Zimmermann 2009); 3) monumental residential, religious, and defensive architecture (Ezer 2014); 4) administrative technology (Kulakoğlu and Öztürk 2015); 5) craft specialization (Lehner and Yener 2014) and 6) long-distance trade (Aruz 2006; Kulakoğlu and Öztürk 2015; Lehner, et al. 2015; Özgüç 1986b; Zimmermann 2006). These developments in central Anatolia had far reaching effects on the organization of metal production and trade, as was demonstrated in Chapter 2 specifically concerning the development of pronounced divisions of labor across primary and secondary metallurgy operations.

Beginning sometime around 1975 BC until 1725 BC, textual evidence deriving from the archives of Mesopotamian entrepreneurs and their companies at Kültepe points to the immediate presence of a variety of small states interlocked into an extensive and complex political economy (Larsen 1976). Merchants from northern Mesopotamia (most from the city-state of Aššur) developed cooperative enterprises partially based on kinship, long-distance exchange, and regional market integration to trade tin and textile commodities for gold and silver originating in Anatolia at high profit margins (Larsen 1976; Veenhof 2008). Once in Anatolia, merchants participated in a highly developed and indigenous copper exchange system to build a further surplus of silver and gold to transport back to Aššur (Dercksen 1996). The texts and archaeological evidence demonstrate that by the early second millennium BC, just as the first enterprises were developed in Anatolia, highly competitive polities in central Anatolia, the largest of which was *Kaniš*, had already established a complex political economy based on rain-fed agriculture, pastoralism, and the long-distance trade of high value materials and objects often produced of metal. The well-documented existence of complex economic institutions and long-distance trade in Anatolia during the early second millennium suggests that an extensive exchange network was already in place during the Early Bronze Age (Şahoğlu 2005). Following the work of Sherratt and Sherratt (1991) and Helms (1993), Bachhuber (2011) theorizes that the development of long-distance exchange in central Anatolia happened because of the increased interest among competing resident elite social groups to acquire exotic materials, including most importantly metal and textiles. This pattern is recognized cross-culturally in periods of early formative chiefdoms and states in many parts of the world (Marcus 2008).

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; Dercksen 1996; Larsen 1967, 1976; Veenhof 2008). The production and exchange of copper, tin, gold, and silver according to the texts, which has been scrutinized in some detail by Dercksen (1996, 2005) and Veenhof (2014), 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. Donkey caravans with 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 regional centers like *Kaneš* and *Purušhaddum* in exchange for silver to be reinvested in the copper trade or sent back to Assur to purchase more tin and textiles.

One of the distinguishing characteristics of this commodities trade represented by the Kültepe texts was the ubiquity of silver weights used as an equitable standard of exchange. The use of silver as a standard of exchange has a deep history in greater Mesopotamia, and it is likely that this practice influenced economic strategies of domestic and long-distance trade since at least the early 3rd millennium BC (Helwing 2014; Peyronel 2010; van de Mieroop 2014). The far reaching buying power of silver, in addition to the availability of markets of high value textiles and tin in Mesopotamia, allowed the Assyrian merchants to enter into an extensive trade network in place before their arrival. Favorable prices for commodities in central Anatolia created a lucrative market for entrepreneurial Assyrians, who could return with 100% return on their investments for tin and over 200% for textiles. For metals specifically, textual evidence provides the relative prices of iron, gold, tin and copper relative to silver (Figure 3.1). These data demonstrate how iron, gold, and tin were all highly valued commodities relative to copper. The exchange value of copper presumably did not offset the costs of its transport south of the Taurus to *Aššur,* which is one of the reasons the Assyrian merchants chose not to return to Assur with it.

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 3.1 lists some of the Old Assyrian words and their respective translations according to Dercksen. Technologically, the meanings embedded in the categories of qualities used by the Assyrian merchants demonstrates 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 (1996: 43-45, 154-157), which is consistent with a hierarchical 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 *Purušaddum*) or *Tišmurnāyum* (from *Tišmurna*), 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 *Wahšušana*, *Durhumit*, *Purušhaddum* and, of course, *Kaniš*. There is also an observable relationship between sites known textually for poor quality copper and a close proximity to copper sources (Figure 3.2).

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 (Barjamovic 2011: 242-267; Dercksen 1996: 154-155; Michel 1991). Satellite sites, perhaps *Kunanamit* and *Tišmurna*, 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).

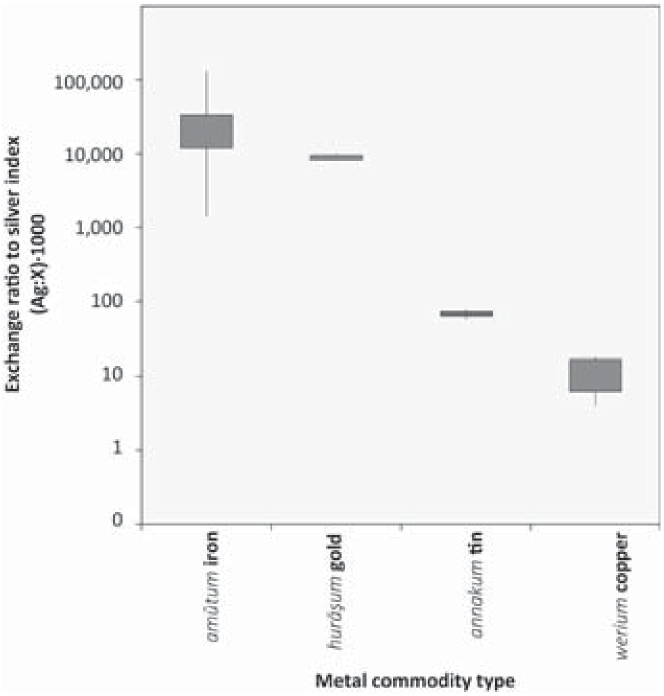


Figure 3.1: Exchange equivalencies of iron, tin, gold, and copper relative to silver in Anatolia, irrespective of quality descriptors. Comparison is possible by creating an exchange ratio index which is the ratio of silver to the commodity multiplied by 1000 and then transformed to a log-scale. Boxes and whiskers represent quartiles of equivalency data from Old Assyrian texts dating to the 20th-19th centuries BC (equivalencies from Dercksen 1996 and 2005).

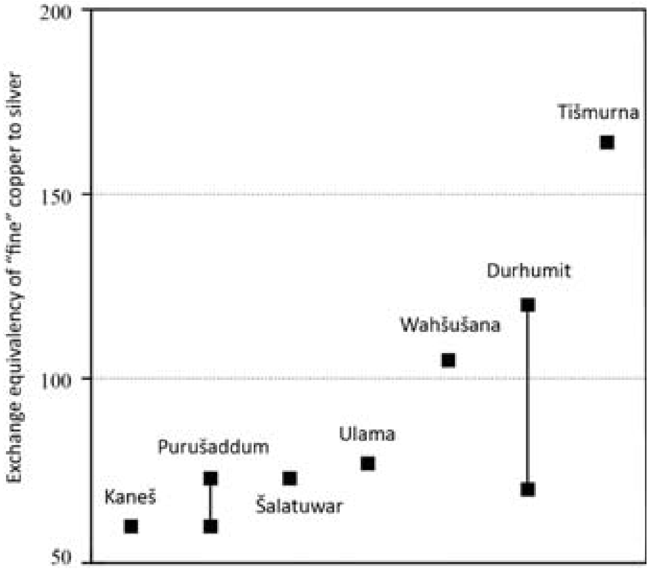


Figure 3.2: Exchange equivalencies of "fine" copper to silver recorded at different localities according to the Kültepe texts ca. 1950-1750 BC; abscissae indicate known ranges in prices (Lehner 2014: 143, fig. 2; data from Dercksen 1996).

Table 3.1: 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 also with silver and tin
	sallāmum	black
	ša masā'im	copper that requires refining

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 Figure 3.1, one can observe from ranked exchange equivalencies between high quality copper and silver that a rough 100% profit is gained when a direct exchange from the source areas to the urban centers of either *Kaniš* or *Purušhaddum* occurred. 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 demonstrates a significant degree of economic integration into at least two regional centers at both *Kaniš* and *Purušhaddum*, at least during the Karum II period ca. 1950 – 1836 BC (Veenhof 2003: 57).

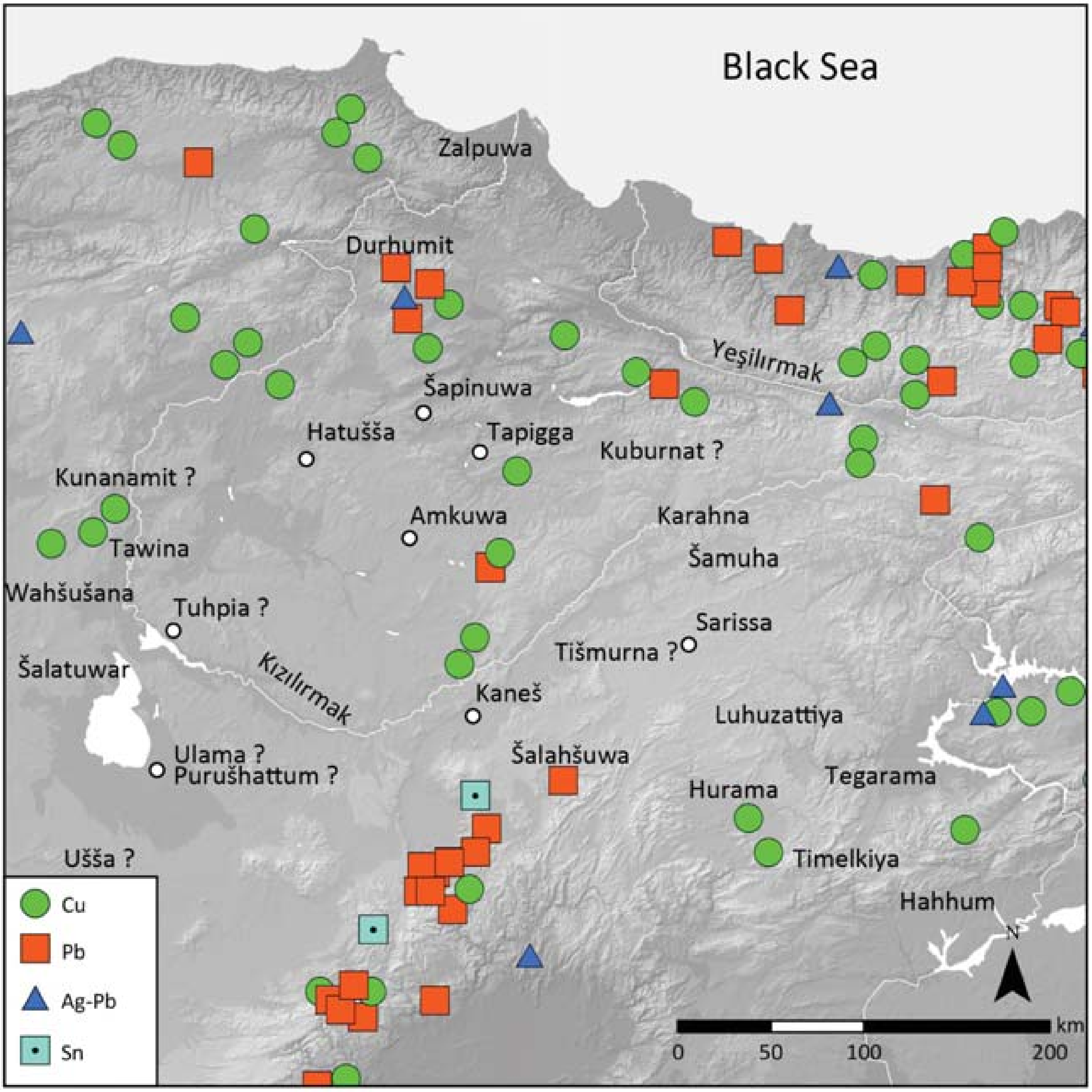


Figure 3.3: Middle Bronze Age urban geography relative to known major metal deposits. Locations marked with a point are known or probably designations, while other locations are based on geographic inferences from texts. Location data of cities adapted from Veenhof 2008.

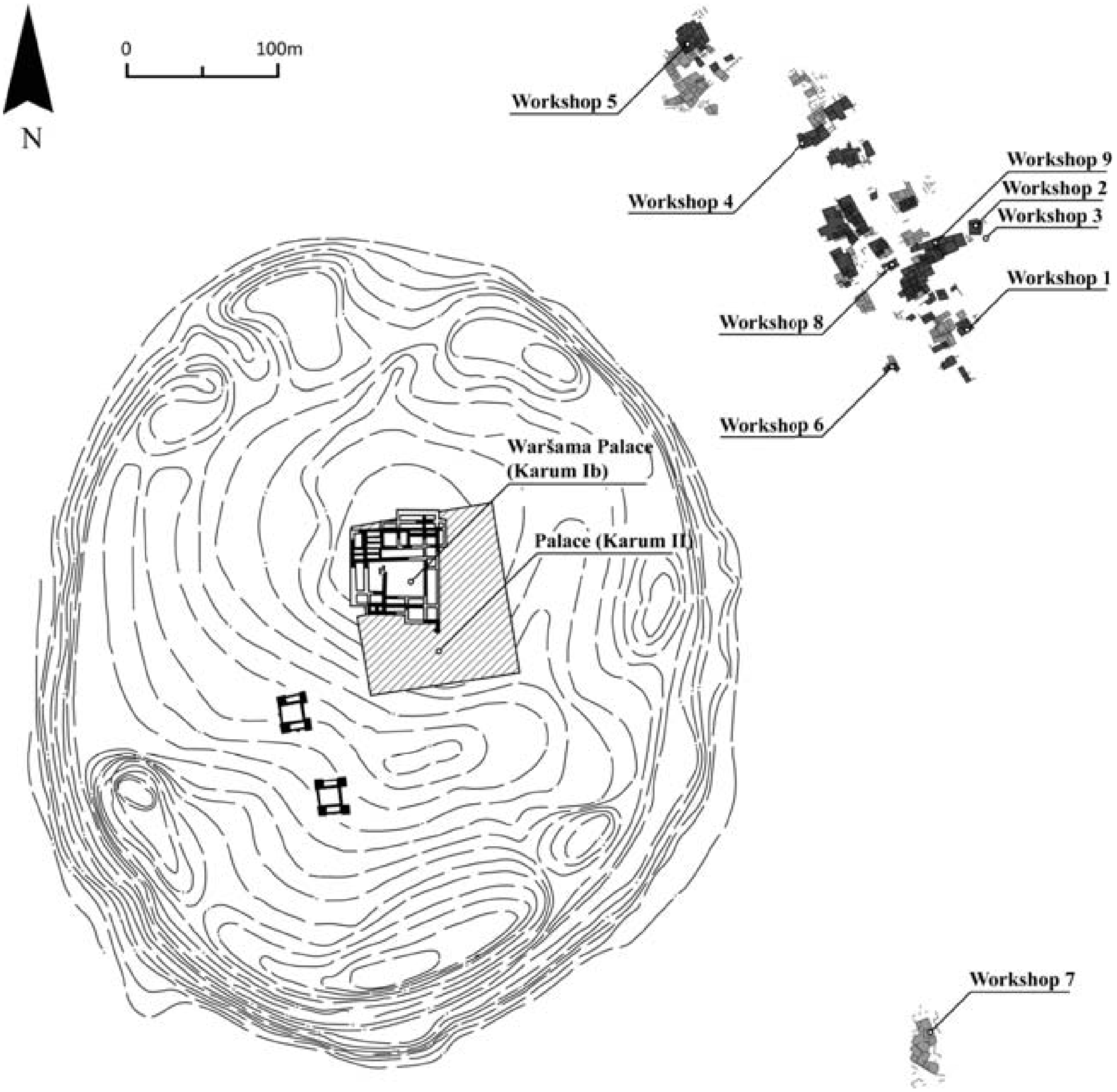


Figure 3.4: Map of Kültepe-Kaneš showing the mound with select MBA architecture and the lower city excavations with known metal workshops (Lehner 2014: 144, fig. 3; adapted from Müller-Karpe 1994: figs. 28, 36)

In addition to describing indirectly the interregional economic environment associated with metal materials, the Kültepe texts also provide evidence for craft organization at the level of the individual and workshop. In the Kültepe excavation reports, Özgüç (1955, 1986a) 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-Kaniš* 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 Old Assyrian. The exact role of this functionary is not entirely understood, 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 or nominally managing metal workshops within the city (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-Kaniš* was codified in the Kültepe tablets.

3.2.1 Archaeological context of metal production at Kültepe

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-Kaniš* near to the end of the metal production cycle and commodity chain. Archaeological evidence from the lower city at Kültepe does in fact indicate that secondary production was the most important metallurgical technology at the site (Figure 3.4).

At least three workshops were excavated from the Karum 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 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 about this workshop are the 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 are nominally similar 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 Karum 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 14-roomed building several slaggy deposits in addition to possible crucibles were discovered (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, 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 (Balkan 1955: 21; Özgüç 1959: 36).

The preservation of at least six excavated workshops from Karum Ib is considerably poorer than those excavated from the previous level Karum II. 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 Karum 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 Karum, however, had a substantial diversity of finds (workshop four). This workshop had a minimum of five rooms, some of which were probably storage rooms (Özgüç 1986a). In a corner next to a furnace 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 (Emre 1971), attests to the central role metallurgy had in everyday economic life at the city. However, contrary to large-scale industrial societies, there is 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.

3.2.2 Compositional and isotopic analyses of copper from Kültepe

Compositional analyses of 86 samples from Kültepe by Esin (1967) and 25 by Lehner et al. (2015) confirm our understanding of tin and bronze consumption in addition to the prolific consumption of arsenical copper. These samples 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. 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.

The compositional data demonstrate the presence of at least three major alloy groups, including copper-arsenic, tin bronze, and a ternary alloy of copper with tin and arsenic. This observation is verified by cluster analysis and principle components analysis by Lehner (2014), which is a method that quantitatively groups samples together based on their compositional similarity. The relatively similar amount of arsenic across the three different groups (ranging from 0.90 – 1.25 wt%) suggest that minor concentrations of arsenic derived in part from the smelting process in primary production and/or extensive recycling.

Alloys of copper and tin were 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 copper seems to be more common. This observation was further verified by a recent study of EBIII and karum period copper alloys from Kültepe (Lehner, et al. 2015). This is significant for two reasons. First 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). Adam's 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 2nd millennium BC. This observation is consistent with over 300 analyses of copper alloys from Boğazköy-Hattuša (Lehner 2012) and further analyses of copper alloys at İkiztepe (Özbal, Pehlivan, et al. 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 of different copper and arsenic minerals, which often involved the direct selection of appropriate ores together in a smelting process (Lechtman 1991; Lechtman and Klein 1999). Copper metal could have also been melted together with the secondary product calledspeiss, an iron-arsenide, which was demonstrated to be intentionally produced at the 3rd millennium BC site of Arisman in North-West Iran (Rehren, et al. 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%, which suggests that either ternary copper-tin alloys with arsenic were an intentional alloy type, or that copper-tin alloys were produced from the alloying of copper containing arsenic.

Lead isotope analysis by Sayre et al. (2001) of samples from large Middle Bronze Age centers Acemhöyük, Karahöyük-Konya, and Kültepe is consistent with an extensive metal production network (Figure 3.5). All samples are consistent with regional sources Tauride, Pontide and Central Anatolian sources, including one lead metal sample from Kültepe is consistent with both central Tauride and Central Anatolian sources (see Chapter 2 for a brief description of these geological regions). 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 are consistent with southeastern Tauride sources, such as Ergani or the Keban series, although a southern source would be most consistent with the textual data (Dercksen 1996: 16). These data are mutually consistent with the texts, attesting to the presence of a large copper trade originating in part by the use of Pontide copper. Unknown to the texts, however, is the simultaneous use of central Tauride sources to the south. The use of the copper and silver producing regions in the Taurus points to a long continuous patter of exploitation through all periods of political development.

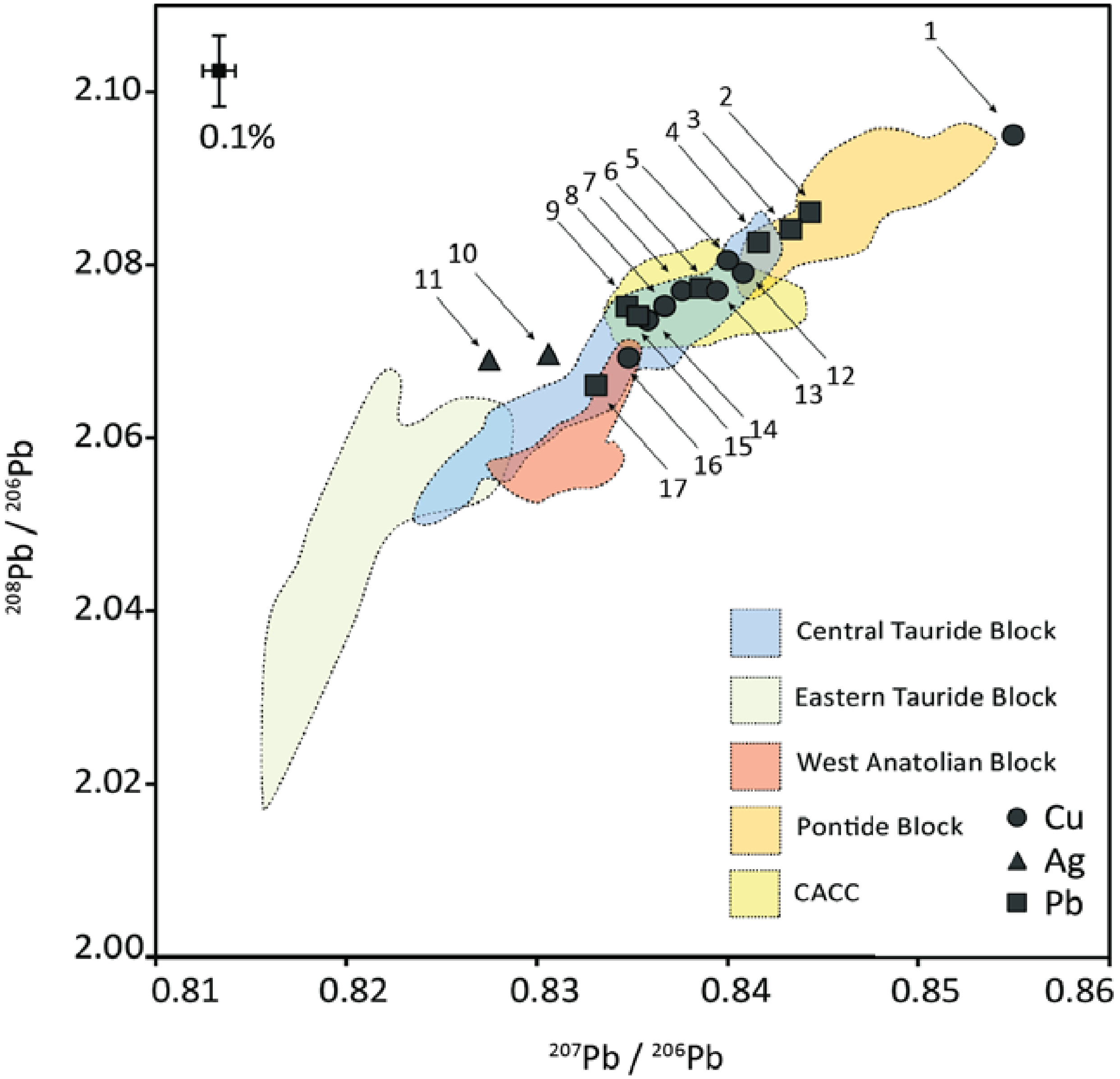


Figure 3.5: Lead isotope binary plot comparing ^{207}Pb/^{206}Pb by ^{208}Pb/^{206}Pb of known ore bodies and artifacts dating to the MBA (adapted from Lehner 2014: 149, fig. 12; object data from Sayre et al. 2001; ore data from Wagner et al. 2003 and references therein). 1. AAN 282 Acemhöyük Cu-ingot, 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. AAN185 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.

3.3 Strategies of tribute, levies and tax, and domestic trade of metal during the rise of the Hittite Empire

For historical reasons that are yet quite unclear, the Middle Bronze Age state polities declined during the 17th century BC (Kulakoğlu 2014). The largest polities in central Anatolia, including the sites of Kültepe, Acemhöyük and Karahöyük (Konya), all exhibit significant conflagration without immediate phases of rebuilding and were abandoned. The likely scenario points towards a periodic episode of intense competition leading to the formation of a novel form of state organization and scale of political integration evinced by the subsequent emergence of the territorial Hittite state centered at Hattuša. The following several generations, approximately 1725 – 1650 BC, have been seldom studied due to a lack of data and preservation of archaeological remains; however analysis based on later historical texts have permitted important interpretations of the historical events, military strategy, and processes of political integration that likely occurred (Forlanini 2008). These Hittite historical texts, namely the so-called Anitta Text (Neu 1974), the Annals and Testament of Hattušili I (de Martino 2003; Melchert 1978; Sommer and Falkenstein 1938), and the Proclamation of Telipinu (Hoffmann 1984), refer to these critical moments and military exploits leading to the formation of the Hittite state. By ca. 1650 BC, well organized elites strategically transformed central Anatolia from a mosaic of small states present during the MBA into the beginning of a large territorial empire, whose capital was founded at Boğazköy-Hattuša.

Judging from available archaeological data, Glatz (2009) theorizes that the Hittite state emerged through a selective and regionalized process of political domination represented by four important imperial strategies. These are evinced by the development of at least four suites of ceramic assemblages which predominate in the political core and decay in frequency with distance. This pattern has been variously interpreted as the extension of imperial control or influence on the domestic craft economy (Glatz 2012; Gunter 2006; Postgate 2007). Second, settlement trends show a four-tiered hierarchy within central Anatolia with Boğazköy-Hattuša being the largest (ca. 180 ha). Furthermore, regional analysis of the settlement history reveals a depopulation of peripheral regions in western-central Anatolia and the Pontic region and the resettlement of those regions that were previously dominated by the large MBA regional centers (Table 3.2, adapted from Glatz 2009: 133, Table 1). Third, the use of distinctly stylized glyptic, including titles and professions of officials in Luwian hieroglyphs, in palace/temple contexts within regions peripheral to the core of the Hittite state demonstrates a networked elite interaction based on the administration of these regions by the Hittite state. Fourth, a category of monuments in carved stone, which normally show a Hittite king with an associated Luwian inscription, are distributed throughout Anatolia with particular concentrations on the periphery of the imperial territories. These relief carvings are thought to demonstrate attempts of state hegemony in the borderlands or in those regions of intense political interaction (Glatz and Plourde 2011), including far western Anatolia (ex. Karabel, Akpınar, and Suratkaya). Additional rock carvings more central to the Hittite core, including those near to Boğazköy at Yazılıkaya and others at Fraktin, further connect kingly iconography with Luwian inscriptions.

Schachner (2009a) further describes the important role of distinct innovations of the cities of the core of the Hittite state. The emergence of LBA cities in north central Anatolia, including again the capital Boğazköy-Hattuša and regional centers Kuşaklı-Sarissa, Alacahöyük, Oymaağaç-Nerik, Ortaköy-Šapinuwa, and Kaman-Kalehöyük, variously include the monumental architecture associated with state administration and storage of a scale that was previously unobserved in earlier periods. According to Schachner, these structures include grain storage

Table 3.2: Administrative and spatial scope of known Hittite regional centers (adapted from Glatz 2009: 132, table 1).

Admin. scope	Official role	Hittite name	Modern name	Size (ha)
State/empire	Imperial capital	*Hattuša*	Boğazköy	180
Region	Capital 'Upper Land'	*Samuha*	Kayalıpınar	20
Subregion	Cult center	*Sarissa*	Kuşaklı	18.2
~District	Seat of provincial officials (AGRIG and BEL MADGALTI)	*Tapikka*	Maşat Höyük	~8

silos and sunken water reservoirs that were designed to provision the city and possibly also neighboring settlements with less risk. Schachner argues on the basis of radiocarbon dating that these structures date to the early 16th century BC, precisely within a couple generations of the formation of the Hittite state itself. Like Glatz, Schachner recognizes the role of the state in the production of these important structures, especially since they are located in key settlements within the core of the state itself.

As mentioned above, patterns of pottery consumption, settlement patterns, administrative technologies, landscape monuments, and distinct urban architecture all show important overlapping imperial strategies involved in the transformation of Hittite Anatolia into a territorial state. By the middle of the 16th century BC, elites centered at Boğazköy-Hattuša integrated much of central Anatolia into a novel form of sociopolitical organization (Schachner 2009a, 2011b, 2012), which also extended networks of imperial power into populous neighboring regions to extract tribute and facilitate trade. While certain elements of tribute and levies were adopted during the preceding period (Dercksen 2007), the geographic scope and centralization of the tribute and levy system increases in scale and operation during Hittite rule (Beckman 1995; Imparati 2002; Klengel 1975, 2005; van den Hout 2006).

Metals as ingots or finished goods, and their producers, functioned intimately within this system, and they provide an appropriate proxy and a second line of evidence for the functioning of the imperial system. In the following, I examine briefly three groups of Hittite texts to examine how metal fit into the economy, both in terms of regional domestic and long-distance trade. The domestic economy of central Anatolia during the Hittite Empire may be contrasted with the economic activity associated with long-distance trade, which was typically linked to the transport of exotic materials and high value-added finished products (e.g., tribute and gifts between elites). Contrary to our understanding of economy from the Kültepe texts, which is strictly biased from the point of view of the archives of Mesopotamian merchants who operated in part within the geographic bounds of central Anatolia, data from Hittite texts do not provide direct evidence of mercantile activity among individuals and institutions. Among the thousands of texts known to Hittite Anatolia, none of them are economic texts from the private archives of merchants (Klengel 1979). The texts are composed of state archives located primarily in the capital Boğazköy-Hattuša, Maşat Höyük (Alp 1980), Ortaköy-Šapinuwa (Süel 1992), and Kuşaklı-Sarissa (Wilhelm 1997). Despite the lack of private economic records among merchants, texts concerning the administration of the state, namely palace/temple inventory lists, tax lists, and legal texts, all provide data concerning the organization of metal production and trade.

3.3.1 Hittite legal texts and the domestic economy

The Hittite Laws are a collection of texts that codified norms of punishment and fairness, often into an equitable system of exchange or compensation (Hoffner 1997; Imparati 1964). Like all legal texts, the Hittite laws contain provisions suggesting reforms of earlier practice; however, the reality of such reforms is debated. For example, later versions of most laws are notably compensatory in nature, many of which had exacted corporal punishment in previous times (Hoffner 1997: 7). In Hoffner's critical edition, he lists at least 25 different categories of laws based on common subjects, including but not limited to homicide, theft, marriage, land tenure, breach of contracts, wages, sexual offences, and commodity prices (1997: 13-14, table 6).

The legal texts demonstrate two fundamental characteristics of the domestic economy. First, according to the tariff lists in the legal texts (§§178-186), silver was the main standard of compensation, and it was exchanged on the basis of the weight of shekels (approximately 11.75g in Hatti, 9.4g in Ugarit, 7.83g in Mesopotamia), minas (40 shekels in Hatti, 60 in Mesopotamia), and talents (60 minas). Second, standard weights of cereals like barley were also used as compensation, most often when equivalencies in silver were too small or the recipient had more use for cereal grains (Floreano 2001: 232). The fungibility and market liquidity of silver and grains fostered a remarkable flexibility in exchange across a wide geography, range, and scale of goods and services (for discussion on fungibility and measure in a cross-cultural context, see Renfrew 2012).

Floreano (2001: 210-221) makes the intriguing argument that regulated barter is evident in the tariff lists, even though these lists report exclusive equivalency in silver. Among the lists, the minimum reported value is 1/8 shekel (a copper axe), the maximum is 40 shekels (a mule or 3600m^2 of vineyard), but the mode compensation value is simply 1 shekel for a surprising amount and diversity of goods and services. The apparently extensive purchasing power of a single shekel suggests that the amount was a heuristic value allowing wide equivalency across several commodity types. Since 1 shekel of silver was equivalent to 1 sheep, 3 *PARISU* (150 liters) of wheat, and 4 minas (160 shekels) of copper, most commonly used commodities in daily life could be used both as a means of exchange and a way of payment. If indeed the fungibility of commodities operated in such a fashion, then the price lists in the legal texts functioned as a sort of price control on common goods and a basis of fair exchange in the wider market present at the time. Furthermore, considering that 1 shekel of silver could purchase a single sheep, 2 shekels of silver is the price of a calf, and 3 shekels for $3600m^2$ of irrigated land, the circulation of silver for most daily encounters and needs would have proved unsuitable for most purchases of reduced quantities (Floreano 2001: 212).

Metals and metallurgy are thus placed in an important position within the laws. On the one hand, the ubiquitous use of silver in the texts demonstrates the traditional use of this scarce metal as a means of exchange. The use of silver in this context was a well-adapted economic strategy that was adopted in many states through the Bronze and Iron Ages in the Near East (van de Mieroop 2014). On empirical grounds, its capacity for domestic circulation appears to have pervaded most urban contexts and networks, enabling an equitable system of exchange that could facilitate large-scale cooperation. Weights of silver were accepted in exchange for goods and services well beyond central Anatolia, and therefore some sectors of its local production, refining, and bulk exchange was possibly regulated by state officials (Floreano 2001: 232). Copper and bronze are also mentioned, although less frequently, and only in reference to finished goods. From the standpoint of the Hittite laws, the domestic production and trade of copper operated within a less centralized system than did silver. Gold, tin, and iron are not mentioned at all in the legal texts, which suggests that these commodities were traded and stored outside of the domestic context that the laws governed (Hoffner 1997: 11; Siegelová 2005: 36).

Hoffner (2002: 181) notes that there is no evidence among the Hittite texts for a separate merchant or entrepreneurial class that operated outside of the purview of the palace and temple.

As he also observes, the current Hittite textual corpus almost exclusively documents how privileged and protected individuals conducted official long-distance trade missions sponsored by the king of Hattuša. Regional trade and exchange within central Anatolia therefore most likely operated in a similar fashion to exchange mechanisms in earlier periods. There was less need for state bureaucrats to administer trade in Anatolia through textual records than in Mesopotamian communities. This suggestion is also consistent with the idea that writing was limited to a minority of the population, including a specialized scribal class who were nominally attached to elite institutions and were often themselves trained in Syro-Mesopotamia (Beckman 1995: 25; Bryce 2002: 69-70).

Another possibility, expressed recently by Alparslan (Alparslan 2005: 381), speculates that traders would have rather kept records on perishable materials which would not have preserved over time. Supporting this idea are the two well-preserved wooden writing boards (diptych) from the 13th c. BC shipwreck at Uluburun located off the southwestern Anatolian coast (Bass, et al. 1989: 10, fig. 19; Payton 1991: 101-110). Unfortunately, the wax infilling of these boards did not preserve so there is no way of determining without doubt of speculation which language or script was employed.

The commodities represented on the shipwreck, including hundreds of kilos of Cypriote oxhide copper ingots, tin, and cobalt blue glass ingots from Egypt, in addition to finished objects produced from several exotic materials, are also consistent with trade between elites from Egypt to the Aegean, and with materials deriving from locations bracketed by central Asia to the east and possibly the Iberian peninsula to the west (Bachhuber 2006; Matthäus 2005; Pulak 2005). We cannot assume the trade network and economic strategies evinced by the Uluburun data operated the same way in central Anatolia, which was mostly limited to over-land transportation.

Rather it appears that select and seasonal segments of the Mediterranean trade network entered into central Anatolia, presumably via the port cities and hinterlands of Cilicia (Bronze Age *Kizzuwatna*, Iron Age *Hiyawa*/*Que*) and the northern Levant, carrying tribute and exotic commodities such as gold, silver, tin, glass, and ivory in addition to bulk quantities of copper. More recently, compositional analyses of Red Lustrous Ware from Temple contexts at Boğazköy, and across the Eastern Mediterranean, appear to have been produced in Cyprus (Grave et al. 2014). Imperial Hittite impact on the southern coast has been well documented at the site of Kinet Höyük, where the ceramic production and potmarks are consistent with state sponsorship (Gates 2001).State sanctioned transportation of staple goods is also known but seems to be limited to the transport of surplus from Egypt to supply redistributive institutions in the Hittite heartland to avert severe food shortages in a period of famine (Bryce 2005: 331-332).

3.3.2 Inventory and tax lists

The palace and temple institutions of Hattuša also kept meticulous administrative accounts recording both the palace and temple inventories and the incoming taxes levied as tribute of staple and wealth goods, including vast quantities of metal. Editions of these texts have been published by Košak (1982) and Siegelova (1986), in which the authors describe the relation of the textual information with the administration of the state. Where there is information concerning provenance, most texts discovered at Boğazköy were found among the palace archives at Büyükkale, rooms within the *Haus am Hang*, and from within the precincts of Temple 1. The data within these texts underscore the efforts that state institutions required to not only administer effectively their territories, but also to finance the state rituals and expansion. Siegelová (1986) characterizes the tax lists into two functional though related types. The first are so-called *arka(m)man(n)-,* MADATTU/MANDATU (Akk.) lists (levies or taxes) and IGI.DU$_8$.A (required gifts, tribute), both of which typically identify the act of paying tribute and/or tax from a location to a central palace or temple institution. Apart from the tax lists are the so-called inventory lists, which date primarily to the Empire Period (Hazenbos 2003). These lists took account of the holdings of the palace or temples and included for the most part high value added goods and exotic materials. The tax lists and inventory texts therefore effectively account the incoming flow of goods and their storage, although contextually biased from the point of view of state institutions.

Discussed in further detail by Müller-Karpe (Müller-Karpe 1994: 76-79), these lists demonstrate an important differential use of metal. Treating all objects equal, whether ingots or finished goods, there is a clear tendency for most incoming tribute and tax to be collected in copper or bronze (ca. 60% of all metal mentioned) and much less so of tin, silver, iron, and gold. Table 3.4 lists supplier locations of tributaries from which these metal commodities were sent. Although these locations do not necessarily indicate the provenance of the raw materials, the place names are nevertheless informative concerning the formality of tribute, and the places are associated with the objects by the Hittite state bureaucracy. Only a few of the locations have been positively identified, including *Kizzuwatna* (Cilicia), *Alašiya* (Cyprus), *Ugarit*, all three of which were important actors on the periphery of the Hittite Empire and were periodically under Hittite control. The fact that copper and tin were known imports from these locations within the Eastern Mediterranean region gives more strength to the data from the Uluburun and Cape Gelidonya shipwrecks.

Table 3.3: Metal commodity types and supplier locations according to 13th century BC tax lists (data from Siegelová 1986, 1993, 2005; Siegelová and Tsumoto 2011).

Metal Commodity	Supplier Location	Source
Copper URUDU *kuwanan-/kunnan-*	Hen[-, -]hira	KUB 42.29 II 4’, 12’, 15’-16’ V 18’
	Arpuzziia	
	Šawatta	
	Kurkuriša	KUB 42.28 + III 4’, 8’, IV 6’, 7’, 14’, 19’
	Kuenma/zuliia	
	Mizamizana	
	Huwar[-	
	Šar[-	
	Tuššimna	
	Šapla	KUB 26.67, right col. 3’, 13’
	Tetum[-	
	Kapittat[-	KBo 18.162 I 6’, 13’
	Munna[-	
	Šahhu[-	KBo 7.24 II 14’, IV 1’
	Ar[x]huz[i-	
	Luli[-	KBo 18.161 rev. 8, 13, 16
	Ank[uwa (?)	
	Anzilatašši	
	Parnašši	
	Zarar[a-	KUB 42.28 + IV 17’, KUB 26.67, right col. 6’
	Kizzuwatna	
	Ugarit	
	Alašiya	
Tin NAGGA *arzili- (?)*	Awan[a-	KBo 18.164, right col. 5’
	Tetum[-	KUB 26.67 KUB 26.67, right col. 3’, 13’
	Kapittat[-	
	Munna[-	KBo 18.162 I 6’, 13’
	Šahhu[-	
	Ar[x]huz[i-	KBo 7.24 II 4’, IV 1’
	Luli[-	
	Kizzuwatna	KUB 26.67 right col. 6’
	Alašiya	KUB 36.98 b rev. 14’
Gold GUŠKIN	*Alašiya*	KBo 12.38 I 5’; KBo 12.38 I 13’, 15’; KUB 36.98 b rev. 14’
	Amurru	KBo 10.12 I 9’
	Ugarit	RS 17.227, 20-21; RS 17.340, 23
Silver KU$_3$.BABBAR *harkanza-* (?)	DU [-	KBo 18.155
	Ḫadduna	
	Ḫilammattiia	
	[K]ašuliya	
	Alašiya	KUB 36.98 b rev. 14’
	Ugarit	RS 17.227, 20-21

To examine the divisions in how tribute and institutional storage treated metal as a commodity as opposed to as a value added finished product, isolating mentions of primary metal ingots (PAD) by metal type is first necessary. Figure 3.6 displays the relative frequency of these primary metal commodity types. Among the taxed items, again the majority are composed of copper and bronze, and then silver, followed by tin with only a couple examples of gold. This demonstrates that, at least according to the official texts, raw copper functioned as one of the most frequent metal forms of tax. That we should also discern ingots of tin and silver is consistent with past analyses, especially given that tin was traded almost exclusively in its pure form and that unalloyed silver was used as a money standard. Among the inventories, silver ingots dominate with around 90% of the mentions, the remainder consisting of ingots of gold and one of iron. This pattern corresponds with what we understand about the domestic trade of silver from the legal texts.

The relationship is somewhat reversed for the relative frequency of finished goods in the tax lists and inventory texts (Figure 3.6). Copper and bronze objects account for nearly all the items described in the tax lists, demonstrating that copper metal and its alloys functioned as an appropriate method of tribute. The tribute lists include different types of tools, weapons, pins, vessels, belts and other unknown objects. Many of these objects could be used functionally or more simply understood in terms of weight, which seems to have been the case for items like axes which have standard weights (Siegelová and Tsumoto 2011: 281). Among the inventories, finished goods comprised mostly of gold objects, such as small commissioned jewelries, palace equipment, votives, and vessels are common. Objects of silver, copper, bronze and iron occur less frequently.

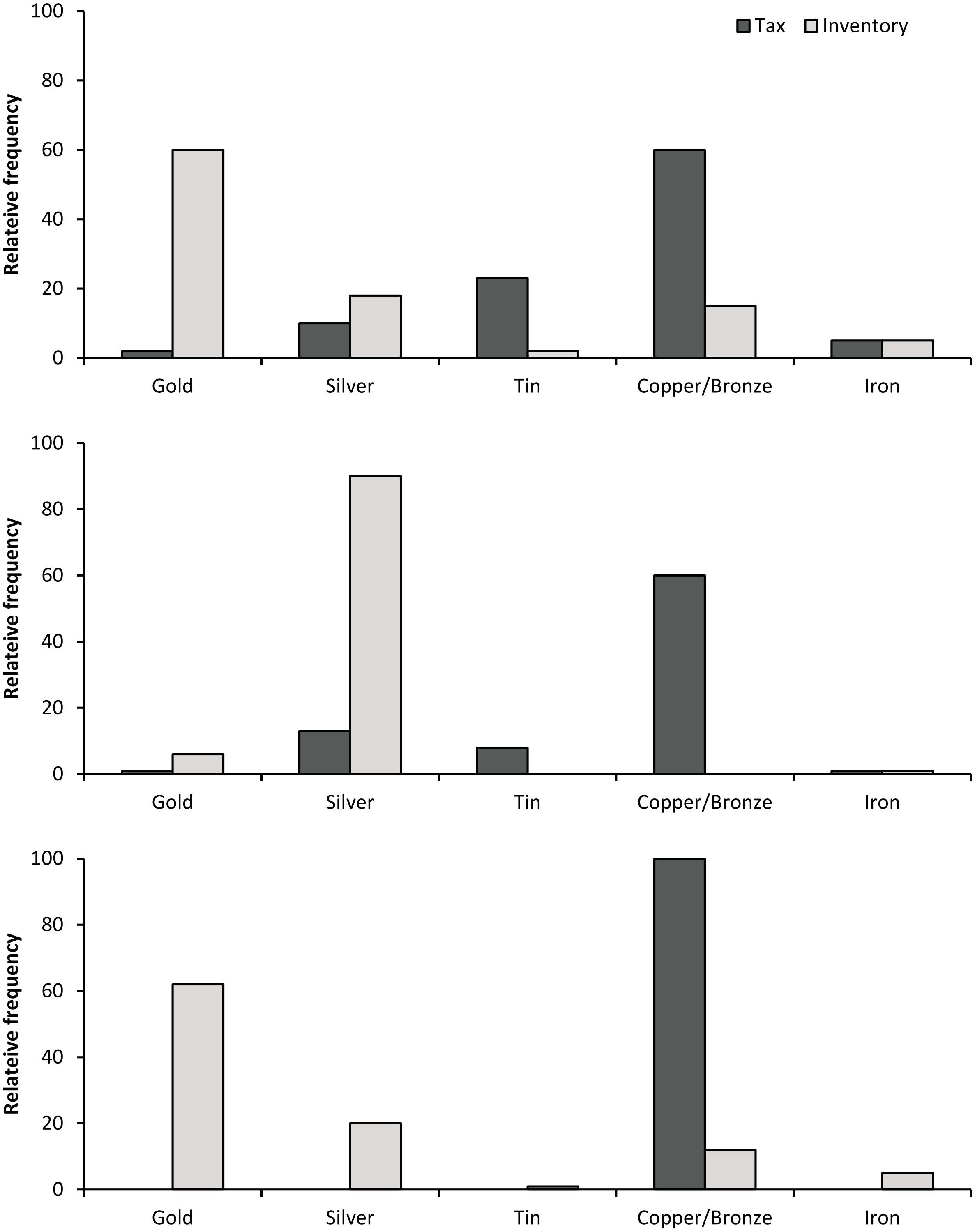


Figure 3.6: (Top) Relative frequency of metal commodity types for all different objects compared against tax and palace/temple inventory lists; (Middle) primary metal commodity types; and (Bottom) metal commodity types for finished goods (data from Siegelová 1986 and Müller-Karpe 1994: 75-76).

3.3.3 Archaeological evidence from Boğazköy

One of the most prominent features of metallurgical production at Boğazköy-Hattuša is that secondary metallurgy is sponsored indirectly by state institutions during the Late Bronze Age (see Figure 3.7). This degree of sponsorship allowed for workshops to be relatively autonomous in production, however textual evidence does suggest that the metal supply was controlled through redistribution and taxation (Siegelová 1986). Specialized craft producers, including textile weavers, ceramicists/potters, seal carvers, stoneworkers, and metal smiths, all appear to have been loosely attached to some degree to state institutions at the site. This can be inferred from material evidence associated with residential architecture in both the lower and upper cities of Hattuša (Müller-Karpe 1994: 66-86). Assemblages of secondary metallurgy are common in these contexts. These include ceramic bellow bowls and tuyères that would have fitted over the top of a range of portable crucibles. The directed heat and exhaust from these configurations would have allowed producers to attain the appropriate temperatures to melt metals and alloys for later casting and working. Metal working tools, including awls, chisels, and piercers, often accompany pyrotechnological workshops suggesting that object finishing occurred alongside melting technologies. Importantly, working tools like these are highly mobile and would have been essential for a number of crafts, suggesting that metal smiths cooperated closely with wood and stone workers, among others.

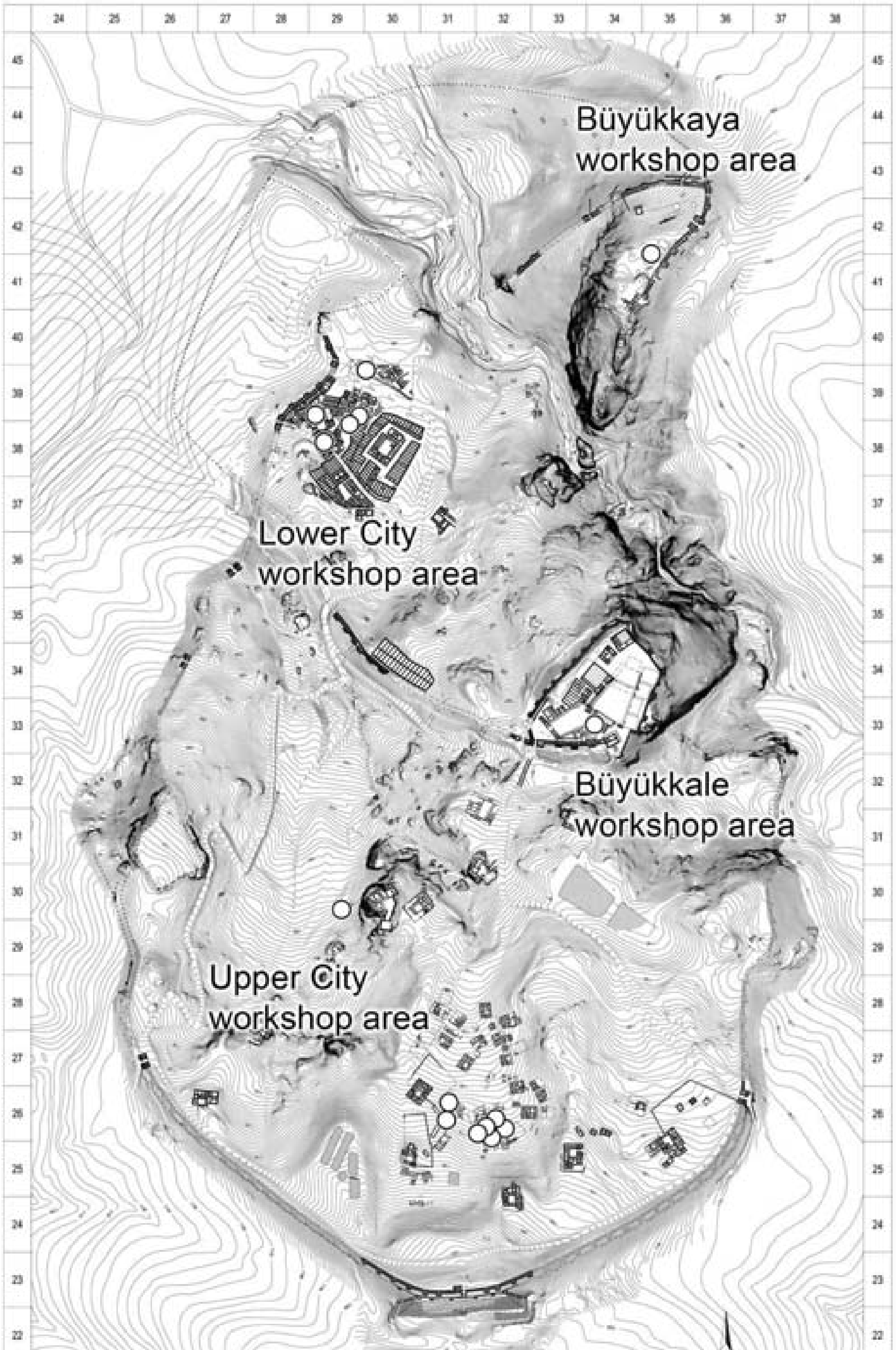


Figure 3.7: Map of the urban layout of Hattusa indicating major workshop (white circles) areas during the Late Bronze Age and Early Iron Age (Büyükkaya) (adapted from Lehner and Schachner in press: fig. 5; Müller-Karpe 1994: 83, fig. 57; Seeher 1995, 2006c).

Figure 3.8: Crucible types from Hattuša. 1. ETD 99/110, 2. ETD 96/218. Adapted from Lehner and Schachner in press (Fig. 9).

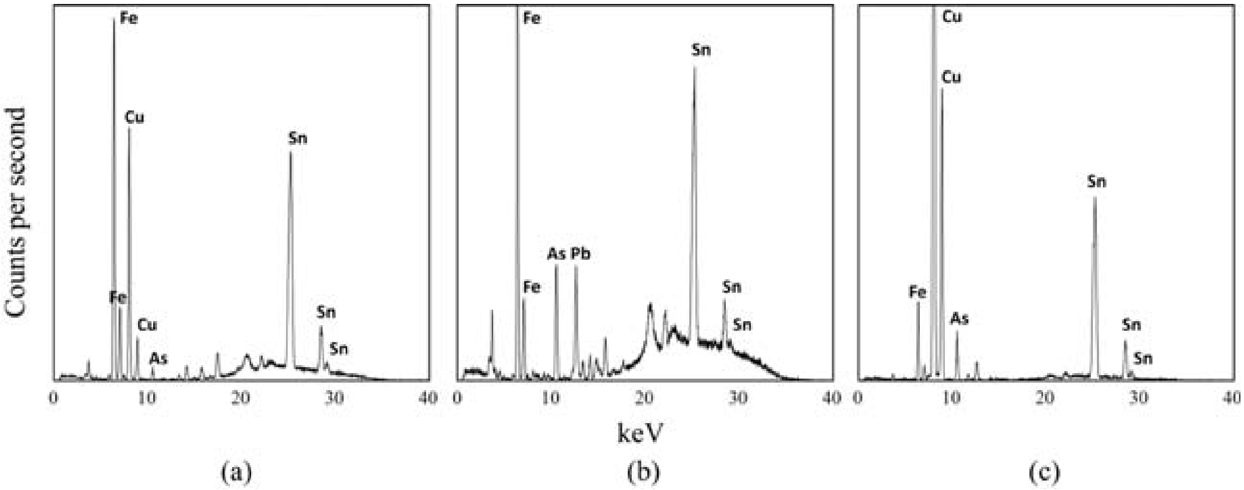


Figure 3.9: X-ray flourescence analysis of crucible residues demonstrates melting and/or recycling practices. (a) Bo 2005: 293/305.263, (b) ETD 99/110, (c) ETD 96/218. Adapted from Lehner and Schachner (in press: fig. 10)

Three such examples of crucibles were available for analysis in 2013 by in-field portable XRF (see Figures 3.10 and 3.11) in order to examine qualitatively their adhering residues. The analysis of metal melting residues is fraught with a number of complex issues (Kearns, et al. 2010), however when used to identify individual elements, it is possible to characterize what materials were being melted but it is impossible with these methods to determine the original production methods and metal ratios. Additionally, these crucibles could have been used more than once; therefore mixed signatures could also result. Spectra for Bo 2005: 293/305.263 and ETD 96/218 show similar patterns with notable peaks in iron, copper, and tin. Traces of arsenic also attest to either multiple use for different alloys, ternary alloy processing, or arsenical impurities reacting preferentially with the ceramic body. Bo 2005: 293/305.263 (no photo) is a highly fragmented bottom portion of the crucible bowl, and was found near to a possible furnace installation in the Sarıkale valley dating to the 15th century (Seeher 2006c: 175). ETD 96/218 probably dates to the Early Iron Age ca. 11-10th century BC and was found alongside other metal production debris at Büyükkaya (Seeher 1997: 327-331). ETD 99/110, which was found in a fill deposit of the east ponds in the Upper City (Baykal-Seeher 2006), shows a lack of copper but enrichments in lead, in addition to major peaks in tin and arsenic. The lack of copper could result from the fact that only the rim of the crucible was analyzable which may allow for this heterogeneous signature. It is unlikely that this crucible was used for the alloying of tin, lead, and arsenic alone as there is no precedent for this.

The crucible data are mutually consistent with both recycling and melting ingots of copper and tin for later casting. Obviously more data is needed from more crucibles to more accurately generalize on production technologies, however from the data so far we can be certain that tin bronze production was a central activity of metal producers at Hattuša. This further suggests that these producers focused on a metal type that held a more interregional quality, which is somewhat contradictory to the known compositional data from finished objects at Hattuša. Tin bronze production at Hattuša therefore lends credence to the value and prestige of this metal type.

Excavations at Boğazköy-Hattuša have further uncovered a total of at least four planoconvex ingots and one oxhide ingot dating to the Middle and Late Bronze Ages (see Figure 3.12). These primary ingots are simply produced from pouring molten metal into a rough form and retain a bubbly ‘blistered’ pattern on the surface where it contacts air upon cooling. The compositions of these reflect relatively unrefined and unalloyed blister copper (see Table 3.3). The compositional ranges of arsenic between 0.01 and 0.32 wt% differ from the range of arsenical copper in analyzed objects which in general have higher arsenic. This is consistent with the later addition of arsenic to produce alloyed metal in finished objects. While theoretically the ingots could have derived from recycling, the lack of common alloying components like arsenic or tin suggests that the copper metal reflects a composition that is close to the original primary smelt. A large planoconvex ingot discovered in 1958 in debris behind the Phrygian East Gate of Büyükkale phase Ia (Boehmer 1972: 74, Nr. 190) is particularly unique in that it has a relatively high composition of the impurity nickel (ca. 1.3 wt.%). This most certainly derived from the original ore source. Bo 11/590, which dates to the early second millennium BC and was uncovered in the karum-period Lower City in 2011 (Schachner 2013: 89-91, fig. 11). The quarter fragment of an oxhide ingot was found in the Upper City (Bo 79/206) and was previously analyzed in Oxford showing compatibility with the Apliki source in Cyprus (Stos-Gale, et al. 1997: 117). These data confirm our existing understanding of second millennium BC metal trade, and they further confirm the well-known southward interests that the Hittite state had according to the tax documents discussed above.

Evidence for silver recycling is evident from a small planoconvex from the Temple Precinct of the Upper City (Bo 87/69). The bulk composition of the ingot demonstrates significant impurities of gold (ca. 7.5 wt.%) and copper (ca. 5.4 wt.%). Values for tin and zinc are likely over estimated in the XRF quantifications due to the x-ray peak overlaps. This ingot was discovered in an insecure context in the temple quarter of the Upper City (Herbordt in prep), however its silver composition is consistent with Bronze Age silver technologies. Impurities of lead and bismuth are consistent with the cupellation of silver from argentiferous lead. This production technology was known in Anatolia and the Near East since at least the fourth millennium BC (Helwing 2014; Hess, et al. 1998; Pernicka, et al. 1998). The presence of gold and copper, which do not naturally occur at such high concentrations in argentiferous lead, suggests that the gold and copper was unintentionally added to the silver as a recycling impurity. It is possible that silver objects with gold plating, or silver alloyed with copper, were later melted down into ingots for transportation and reworking.

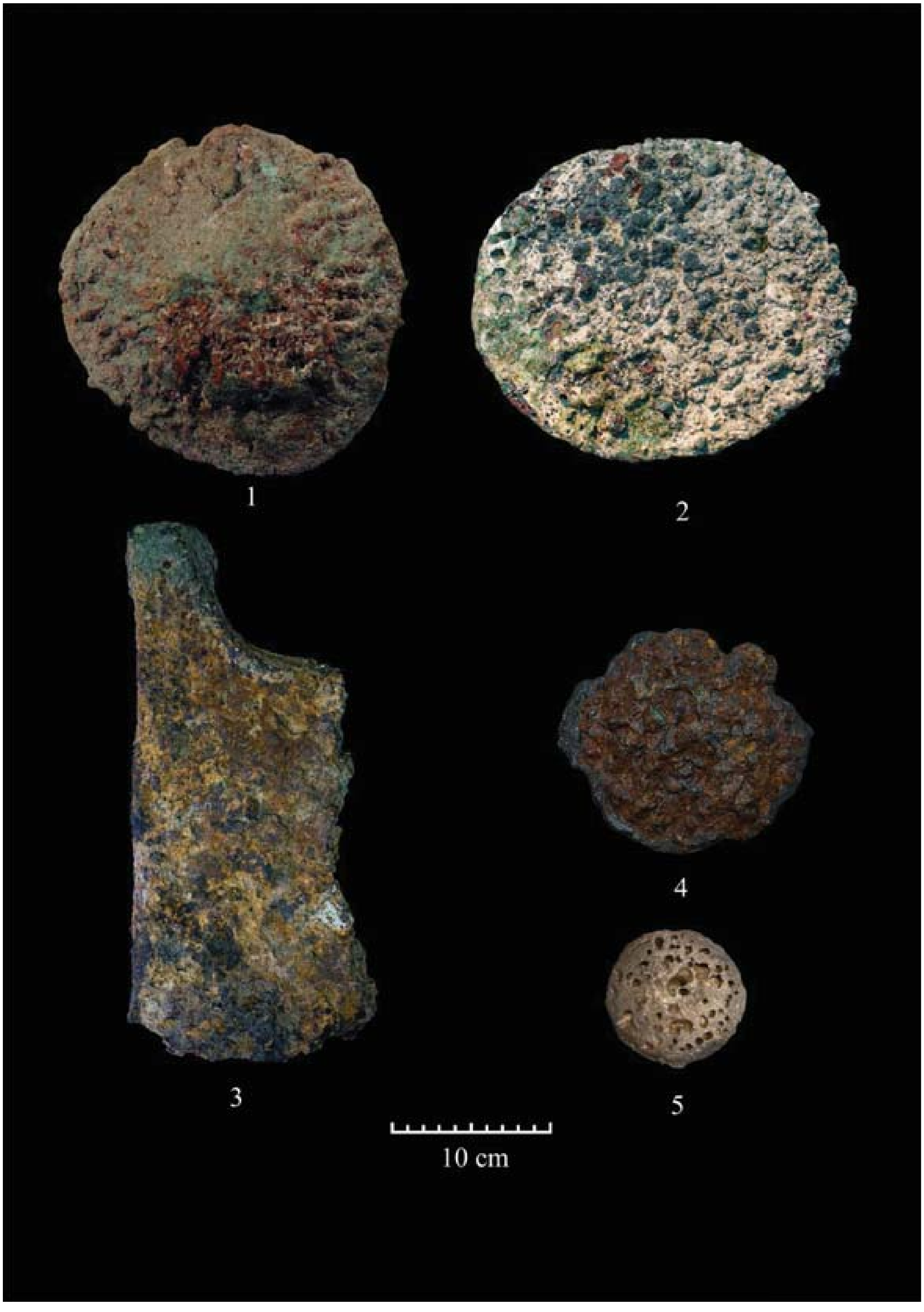


Figure 3.10: Ingot types from Bogazköy-Hattuša. (1) Bo 11/590, copper planoconvex MBA; (2) Boehmer 1972: Nr. 190, copper planoconvex LBA; (3) Bo 79/206, copper oxhide LBA; (4) Bo 83/819, copper planoconvex LBA; (5) Bo 87/69, silver planoconvex LBA.

Table 3.4: Context and composition (in wt.%) of planoconvex and oxhide copper and silver ingots from Hattusa. Quantitative results from EDXRF (Boehmer 1972: Nr.190, Bo 83/819, and Bo 87/69) and EDXRF (Bo 11/590 and Bo 797/206) (data from Lehner and Schachner in press: table 1).

Catalogue Number	Ingot type	Context	Cu	Sn	As	Pb	Zn	Sb	Ni	Co	Se	Fe	Te	Bi	Ag ppm	Au ppm
Bo 11/590	Planoconvex (5 kg)	MBA; Lower City residential building	100	0.006	0.036	0.016	0.008	0.018	0.082	0.001	0.007	0.040	0.001	0.001	290	-
Boehmer 1972: Nr.190	Planoconvex (4.4 kg)	Ind.; Büyükkale Ia in the fill behind the Phrygian East Gate	99	0.011	0.086	0.030	*bdl*	0.007	0.522	0.004	*bdl*	0.021	*bdl*	0.001	230	-
Bo 79/206	¼ Oxhide (~7 kg)	LBA; Upper City House 4 near to Temple VII	98	0.085	0.327	0.024	0.051	0.165	0.037	0.061	0.029	0.717	0.001	0.006	35	6.2
Bo 83/819	Planoconvex (1087 g)	LBA; Upper City Temple VII	96	0.014	0.046	0.018	*bdl*	0.031	0.111	0.058	0.066	3.22	0.011	*bdl*	20	-
Bo 87/49	Planoconvex (387 g)	Ind.; Upper City	5.41	0.40	*bdl*	0.45	0.36	0.05	0.10	*bdl*	-	*bdl*	-	0.06	86%	7.55%

1) Schachner 2013: 89-91; 2) Boehmer 1972: cat. inv. Nr. 190; 3) Müller-Karpe 2005, values for Ag and Au from Stos-Gale et al. 1997; 4-5) Herbordt (in press)

- = not determined, bdl = below detection limit.

3.4 Copper and bronze industries during the rise of Iron Age polities in central Anatolia

The political and economic processes that led to the rise of the Hittite territorial state in central Anatolia are evident in the production and exchange of metal commodities and finished goods. During the Bronze Age, archaeological and textual evidence demonstrates that communities developed elaborate hierarchies of production, exchange, and consumption based primarily on mechanisms of commercialism and state control leading to increases in centralization during the height of the Hittite Empire. From these data, it is therefore possible to interpret how strategic metal production sequences and commodity chains effectively integrated urban and hinterland social environments through both the organization of labor and the elaborate exchange of unfinished and finished goods. Unfortunately, little to no data of metal production exists dated directly to the end of the Hittite Empire during the 13th century BC, so it is not possible currently to determine empirically how the craft economy responded during periods of regional political and economic reorganization.

During the Mid to Late Iron Age (ca. 900-330 BC), there is an unprecedented virtuosity of metal craftsmanship associated with the rise of large scale polities, especially in tin bronze metallurgy, as is evident through the remains of remarkably well-crafted finished goods (Muscarella 1988). These include intricately finished and stylized bronze sheet metal, which often decorated architecture and clothing and also was used in the production of fine vessels. Cast objects further demonstrate the masterful familiarity with the various properties of bronze, including ornate fibulae and carefully cast socketed arrowheads. It is further clear that these finished goods were consumed within a cultural framework of status display and recognition. While bronze objects are noted across domestic contexts at Gordion, Kaman Kalehöyük, and Kerkenes Dağ, objects which required greatest skill are found in increasing frequency in elite contexts, including citadel and monumental burial tumuli at Gordion and the palace complex at Kerkenes Dağ.

Despite this development of bronze metallurgy in the Iron Age, there is almost no published data with direct evidence of Iron Age copper production (including extraction mining, primary or secondary production sequences) in central Anatolia, especially those related to the production of high value metal objects. No well stratified remains indicative of metal production are known from the plateau, aside from the Early Iron Age workshop at Boğazköy (Seeher 1997), Tell Tayinat (Roames 2011), Büyükkardıç in Erzincan Province (Şenyurt 2006; Şenyurt, et al. 2006), and a single bronze crucible fragment from early-mid 4th c. BC Gordion (Toteva 2007: 43) used in the secondary production of leaded tin bronze (Rademakers 2014). Yet according to art historical analyses, typologically distinct categories of finished goods typify "Phrygian" style and are thus interpreted to have been produced locally, at least in terms of the secondary production of finished goods (Muscarella 1988: 183-186, and references therein).

Given the current state of evidence, there are three main possibilities that explain the absence of production sites. First, production sequences are located within urban bounds and are similar to Bronze Age strategies, but current excavations and data have not yet uncovered material evidence. Second, all primary and secondary production sequences involved in metal industries must have been located outside of the cities but yet within the bounds of the polity. There is reason to believe that this would be the case, especially since pyrotechnological activities associated with metal production can be hazardous and unhealthy in dense urban environments. The further possibility that workshops were operating in both iron and copper/bronze metallurgy would strengthen this hypothesis, because iron workshops are typically more labor intensive than bronze workshops alone. Lastly, the various primary and secondary production sequences may have occurred outside of central Anatolia, thereby requiring polities in central Anatolia to import primary ingots of metal and finished goods. This hypothesis requires long-distance exchange and connections with manufacturing centers elsewhere in the Mediterranean and Near East. This model would be consistent with Sherratt and Sherratt (1993: 375), who argue that economic growth first centered in the capital and labor intensive manufacturing zone of the eastern Mediterranean prior to the emergence of secondary states elsewhere in the region. This hypothesis also problematizes any art historical analysis that supposes local styles among many of the objects known to central Anatolia.

3.4.1 Archaeological and archaeometallurgical evidence for copper trade and production during the Iron Age

While there is a general lack of data from central Anatolia, sparse data from directly adjacent regions do suggest that secondary production activities, at least, were supported by the dispersed urban infrastructure during the 9th-5th c. BC. Some evidence suggests that within the florescence of the Neo-Hittite states during the first half of the 1st millennium BC, the circulation of precious metal commodities were similar to those adopted by state institutions of the Late Bronze Age. Silver ingots, including three with Aramaic inscriptions, and Hacksilber pieces were found associated with the lower palace and *Hilāni* temple structures of the prominent regional center of Zincirli-*Sam'al* in southeastern Anatolia (Müller-Karpe 1994: 99-100; von Luschan and Andrae 1943: 119-121). Furthermore, a tuyère and several casting molds, one of which for jewelry, associated with the palace further demonstrate elite sponsorship of metal technologies. A single bronze bun shaped ingot, composed roughly of a 10% tin bronze, was also discovered here but it was from an uncertain context (von Luschan and Andrae 1943: 121).

Data concerning trade and production is no more clear during the Iron Age in east Anatolia and the Caucuses (Belli 1991; Seeliger, et al. 1985; Seidl 1988), where the establishment of Urartian fortress settlements during the 9th-7th centuries BC united into a state in competition with and defense against powerful Assyrian interest based in northern Mesopotamia (Smith 2003; Zimansky 1985). Examples of secondary production are evinced by primary ingots of copper and apparent bronze working tools from sites including Van-Toprakkale, Kayalıdere, and Çavuştepe (Müller-Karpe 1994: 101-102). Further examples of secondary production of copper and iron in domestic contexts, and possibly primary production, is noted from the site of Armavir (Argištixinili), where extensive excavations of Urartian households were associated with copper and iron working slags (Martirosyan 1974). This region, extending from the Upper Tigris to the Caucuses is rich in metal resources, and it is likely to produce more important data concerning the rise of metal industries and their social organization during the Iron Age (for earlier periods, see Courcier 2014).

From the few analytical studies of finished objects from across Iron Age central and eastern Anatolia, data clearly point towards two important developments in copper metallurgy. First, there is the clear dominance of leaded and unleaded tin bronze relative to pure copper and other copper alloys for the production of most Iron Age copper based objects. This observation is supported empirically by the adoption of tin bronze across many object type categories (Atasoy and Buluç 1982; Faraldi, et al. 2013; Hirao and Enomoto 1993; Hirao, et al. 1992; Hughes, et al. 1981; Ingo, et al. 2010; Twilley 1996). Trade in pure tin as a commodity, which is normally only identified by pure tin ingots, is also indirectly evinced by the production of pure tinned surfaces on bronze sheet metal, indicative from the 7th c. BC shields from Ayanis in eastern Turkey (Ingo, et al. 2010) and more recently identified on decorative bronze sheet metal from Kerkenes Dağ dating to slightly later during the 7th-6th c. BC (this dissertation, objects 02TR01U02met01, 02TR01U02met02 and 11TR24U11met01, see Figure 3.11). The interregional adoption of tin bronze is particularly interesting given the reliance of long-distance trade necessary to produce it. It is increasingly likely that local occurrences of tin were probably not sufficient to supply bronze workshops of this size; therefore we must expect tin to be imported inter-regionally in large sums (for weight amounts of tin from 6th c. BC texts from Uruk, see Oppenheim 1967: 240-242). While it is not possible at this time to determine empirically whence the tin came, it seems increasingly likely that Iberian tin is a candidate, which would have been circulated by Phoenician traders across the Mediterranean, in addition to central Asian sources transported over traditional routes. What is less clear is if the production of tin bronze using non-local tin experienced disruptions in tin supply during regional shifts in polities, specifically during the 12th-10th centuries of the Early Iron Age. Data from Chapter 5 will examine this in some detail, thanks to the clearly stratified and continuous deposits at Boğazköy dating from Late Bronze Age through the Late Iron Age.

Second, and perhaps related to the dominance of tin bronze, is a precipitous decline in the production and consumption arsenical copper beginning sometime around the 10th century BC. Copper alloy objects with greater than 1.0% arsenic are increasingly rare for the Iron Age, evinced from selective analyses from this study, Kaman Kalehöyük, Phrygian tumuli in Ankara, and the analysis Urartian bronzes, all referenced above. This observation also holds for most of the Neo-Assyrian bronzes from Nimrud analyzed by Curtis (2013). This is likely the cause of several possible factors or a combination thereof, including but not limited to a decline in the use of iron arsenide speiss, decreases in the use of common polymetallic arsenical minerals like

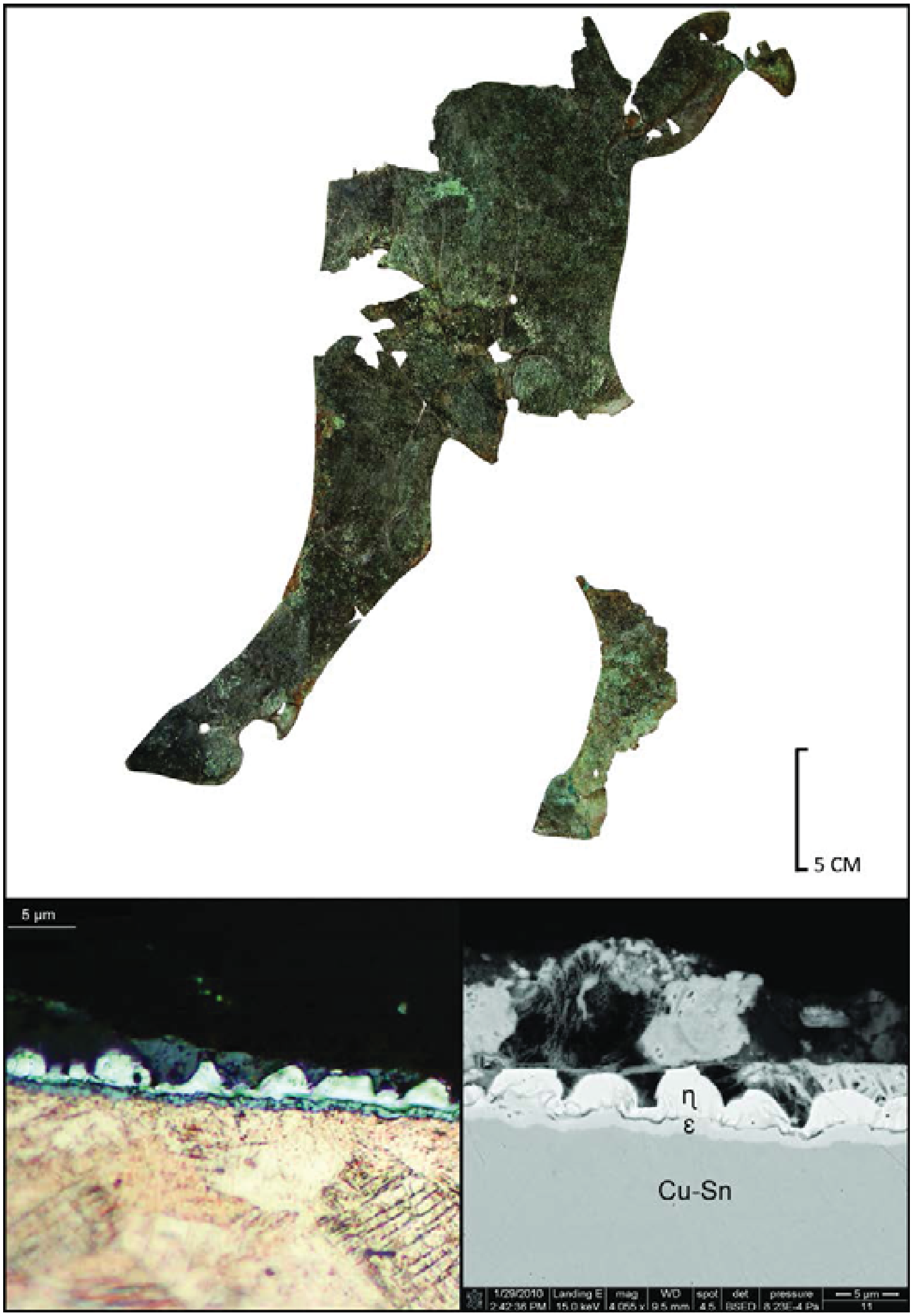


Figure 3.11: Top: one of two tin bronze sheet metal ibex recovered from excavations at the monumental entrance to the Palace complex at Kerkenes Dağ (02TR01U02met02). Bottom left: optical micrograph of a polished and etched (in alcoholic ferric chloride, Scott 1991: 72) section of a sample showing diagnostic eta and epsilon intermetallic phases of copper-tin indicative of surface tinning. Bottom right: backscatter electron micrograph detailing a similar region of the same sample highlighting the phases (see Meeks 1986).

arsenopyrite or enargite, more efficient refining technologies, increased frequency of remelting episodes, and the adoption of primary production technologies that allowed the selective vaporization of arsenic into air, perhaps through roasting ores in open space.

3.5 Conclusion: the organization of copper metallurgy and how trade tracks onto the development of polities

In this chapter I used data primarily from Bronze Age and Iron Age regional centers to examine the organization of metal production and trade. Data from the Bronze Age is richer, allowing the following interpretations. First, Early Bronze Age strategies of metal production and organization were adopted and enhanced during subsequent periods of increasing social complexity. Following Yener (2000), these strategies include adaptive and fairly regionalized primary and secondary production; the prolific use of polymetallic ores common to Anatolia but uncommon to other regions in the Near East; and finally the development of geographically segmented divisions of labor into what Yener called "mutli-tiered organization of production." Towards the end of the 3rd millennium BC and by the beginning of the 2nd millennium BC, evidence points towards the development of incipient industrialism and markets. The regional landscape of copper production and trade appears to be highly structured according to an industrial ecology, where dispersed natural resources extend networks of trade into regional centers, and where the pull of cooperation and economies of scale enforce the emergence of highly clustered economic activities.

Second, this evidence for increased modes of secondary production is apparent in urban contexts during the MBA, where workshop clusters appear across domestic and palace/temple elite contexts. Texts from Kültepe further inform the nature of metal trade, demonstrating a particular foci of production along the northern periphery of central Anatolia, including those proximate to the polity of *Durhumit*. Archaeometallurgical evidence from Kültepe add further nuance to the texts, showing that there is a clear gap in the textual data, where copper is also derived from ore sources to the south in the central Taurides. Evidence points towards a somewhat decentralized copper and bronze production economy, and a centralized production of high-value objects made of silver, iron, and gold.

Third, the imperialistic efforts of the Hittites transformed the nature of metal commodity and finished goods flow by requiring an expanded system of tribute and tax into the core. This effectively brought metals, both raw materials and objects, into the inventories of the palace and temples, first and foremost at the empire capital of Hattuša. Textual data demonstrate important differences between the flow of materials and objects coming in as tribute and taxes (mostly copper and tin) and those being stored in palaces and redistributed (mostly silver and gold). Archaeological data reveal how during the later phases of the LBA, metal workshops across Boğazköy-Hattuša were variously associated with both elite domestic and palace/temple contexts, demonstrating differential sponsorship in production activities.

Lastly, the reemergence of polities during Iron Age shows a paucity of data relating to metal production and trade. It was suggested above that this is most likely due to the fact that production activities have either not yet been discovered in urban contexts or they are simply not there, reflecting a novel organization of regional production not yet observed in central Anatolia. Trade in pure metal, however, must have occurred given the near complete adoption of tin bronze and decline in arsenical copper, as evidenced from peripheral regions. I will evaluate this problem as it relates specifically to Bronze Age production and trade strategies in the following chapters.

CHAPTER 4: ARCHAEOLOGICAL CONTEXT AND CHRONOLOGY OF THE SAMPLES

4.1 Introduction

This chapter presents the background information pertaining to the stratigraphic, chronological, and contextual information of the samples analyzed in this dissertation. A total of 1147 copper base samples were used in this study, 1074 from the multi-period site of Boğazköy and 73 samples from the single period Iron Age city of Kerkenes Dağ. A total of 381 samples dating primarily to the Late Bronze Age and Middle to Late Iron Age assemblages were analyzed by EDXRF and the remainder samples were prepared and analyzed by pXRF in the field (see Chapter 5). Most of the samples come from non-funerary contexts, with the exception of several fibulae discovered during excavations of Iron Age 7th-8th century BC pithos and urn burials in the Lower City (Büyükkale phase IIa). The chronological and contextual information is summed up in Table 4.1, and these will be more fully discussed below. Unless noted, inventory numbers, descriptions, and contextual details concerning the find spots of the objects where available are presented briefly in Appendix A.

4.2 Boğazköy

The impressive remains of the archaeological site of Boğazköy (directly adjacent to the modern village of Boğazkale in Çorum Province) are situated at the narrows of the southwestern end of the Budaközü Valley (Figure 4.1). This location consists of several large outcroppings of rock, a deep perennially watered canyon, and several flat laying plateaus watered by natural springs. By the mid 1800s, European travelers visited the location and variously published reports on the remains of the Great Temple (Temple 1) and the extramural sanctuary of Yazılıkaya with its impressive reliefs of gods and kings in stone (Alaura 2006; Schachner 2011a: 21-32; Şentürk, et al. 2001). In 1893-94 Ernst Chantre directed the first major excavations at Temple 1, the elite citadel at Büyükkale, and Yazılıkaya (Chantre 1898). In addition to further elucidating the Bronze Age architecture, his discoveries included a small repertoire of cuneiform tablets that, with the later discovery of palace archives by Winkler and Makridi in 1906, helped in the decipherment and description of the Hittite language by Hrozny. These data later helped to identify the remains of Boğazköy as Hattuša – capital of the Hittites.

Winkler and Makridi's excavations of Büyükkale and small sondages elsewhere at the site, which lasted from 1906-07 and 1911-12, were bolstered by the efforts of Puchstein and Kohl beginning in 1907. Puchstein effectively helped manage a comprehensive survey of the city and select excavations of fortifications and temples in the Upper City (Puchstein 1912). After a nearly two decades from 1931-39 and 1952-77, Kurt Bittel directed excavations focused primarily on work at Büyükkale which finished in 1966. Extensive excavation projects moved to the Lower City, Temple 1, and further detailed work at Yazılıkaya. Since 1952, work at Boğazköy has been uninterrupted. This work, which operated under the auspices of the Deutsche Orient-Gesellschaft and the Deutsches Archäologisches Institut, generated some of the first stratigraphic control concerning the development of the city and ushered in a new era of empirical material studies concerning Hittite archaeology.

From 1978 to 1993, Peter Neve, an architectural historian, resumed detailed research of Temple 1 and domestic architecture in the Lower City. Afterwards, he began excavations at the so-called Südburg fortress, Nişantaşı, and an elaborate investigation of the entire Upper City temple precinct and monumental city walls and gates. His work demonstrated a broad new understanding of the development and distribution of cult architecture in the Upper City (Neve 1996).

Jürgen Seeher directed the project from 1994 to 2005. His experience and previous focus as a prehistorian helped influence a novel program of intensive archaeological investigations focused on the absolute chronology and economic life of the city from the point of view of archaeological remains. His excavations at Büyükkaya, a prominent high place in the north of the city, revealed for the first time in central Anatolia a continuous and well-documented stratigraphy tracking changes from the Late Bronze Age with intact Early Iron Age and Middle to Late Iron Age deposits. This work, which began first with Neve in 1993 the year before his retirement, has demonstrated how the Hittite capital gradually declined, was reused, and then experienced a reemergence as a prominent polity during the Mid to Late Iron Age. His later work focused on select excavations of monumental grain silos, water reservoirs, and urban infrastructure in the Sarıkale Valley.

In 2006 Andreas Schachner continued work in the Sarıkale Valley and then in 2009, he began a large new program in the Lower City to understand both the development of the city from its Bronze Age beginnings into the capital of the Hittite Empire. This renewed work has also shed light on the large cut rock Kesikkaya and its associated Hittite monumental architecture, terraced Iron Age structures, and Galatian architecture. Other excavations by Schachner at Yenicekale, the middle plateau between Yenicekale and Sarıkale, and the city wall have variously revealed fundamental data to the design and dating of both monumental and domestic architecture in the northwestern slope of the Upper City.

Table 4.1: Total number of copper alloy samples from Boğazköy and Kerkenes Dağ that were analyzed for chemical composition in this study.

			Time Period				
	Region	*Subregion*	*EBA*	*MBA*	*LBA*	*EIA*	*MIA / LIA*
Boğazköy	**Büyükkale**	-			3		2
	Büyükkaya	-	8		115	35	52
	Lower City	City Wall			3		4
		Kesikkaya, Northwest		16	195		3
		Kesikkaya, Posternmauer			9		
		Kesikkaya, South			30		10
		Northern Quarter		3	13		9
		Temple 1 Magazines			6		
	Northwest Slope	Granary			29		11
		Middle Plateau			1		
		Northwest Slope		2	1		
		Yenicekale					1
	Upper City	East Reservoirs			8		2
		King's Gate			1		
		Lion's Gate			1		
		Nişantepe			1		1
		South Reservoirs			9		
		Südburg			1		6
		Temple Quarter			71		
		Upper City					3
		Yerkapı			1		1
	Upper City West	Middle Plateau			28		
		Sarıkale Valley			362		8
		Yenicekale			5		1
Total			***8***	***21***	***892***	***35***	***114***
Kerkenes Dağ	**Cappadocian Gate**	-					32
	Megaron	-					1
	Palace	-					28
	South West	-					1
	Street	-					4
	Urban Block 8	-					7
Total							***73***

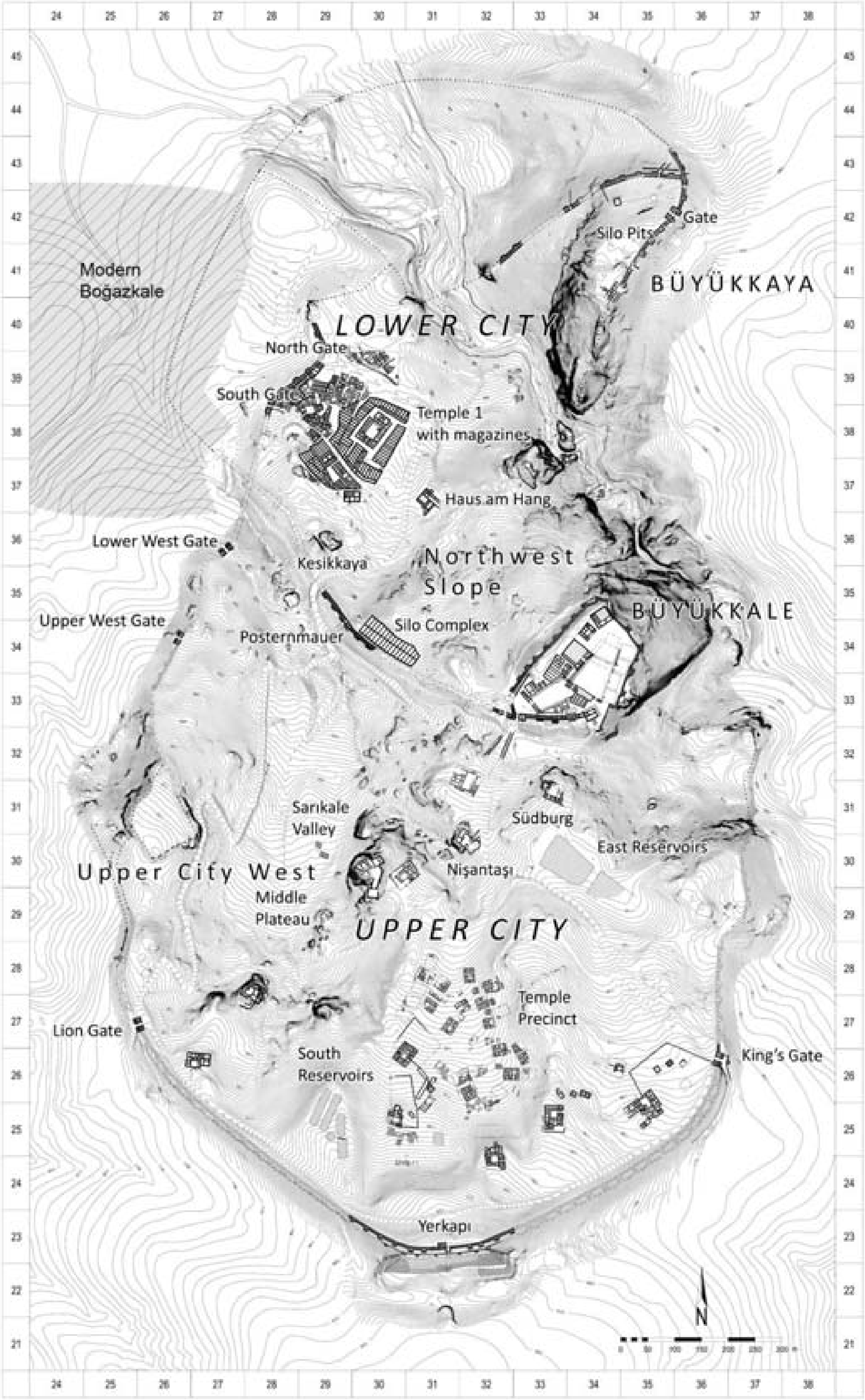


Figure 4.1: Map of Boğazköy with emphasis on the Late Bronze Age. Note most recent excavations at the Lower City are not shown here (courtesy of the Boğazköy Expedition).

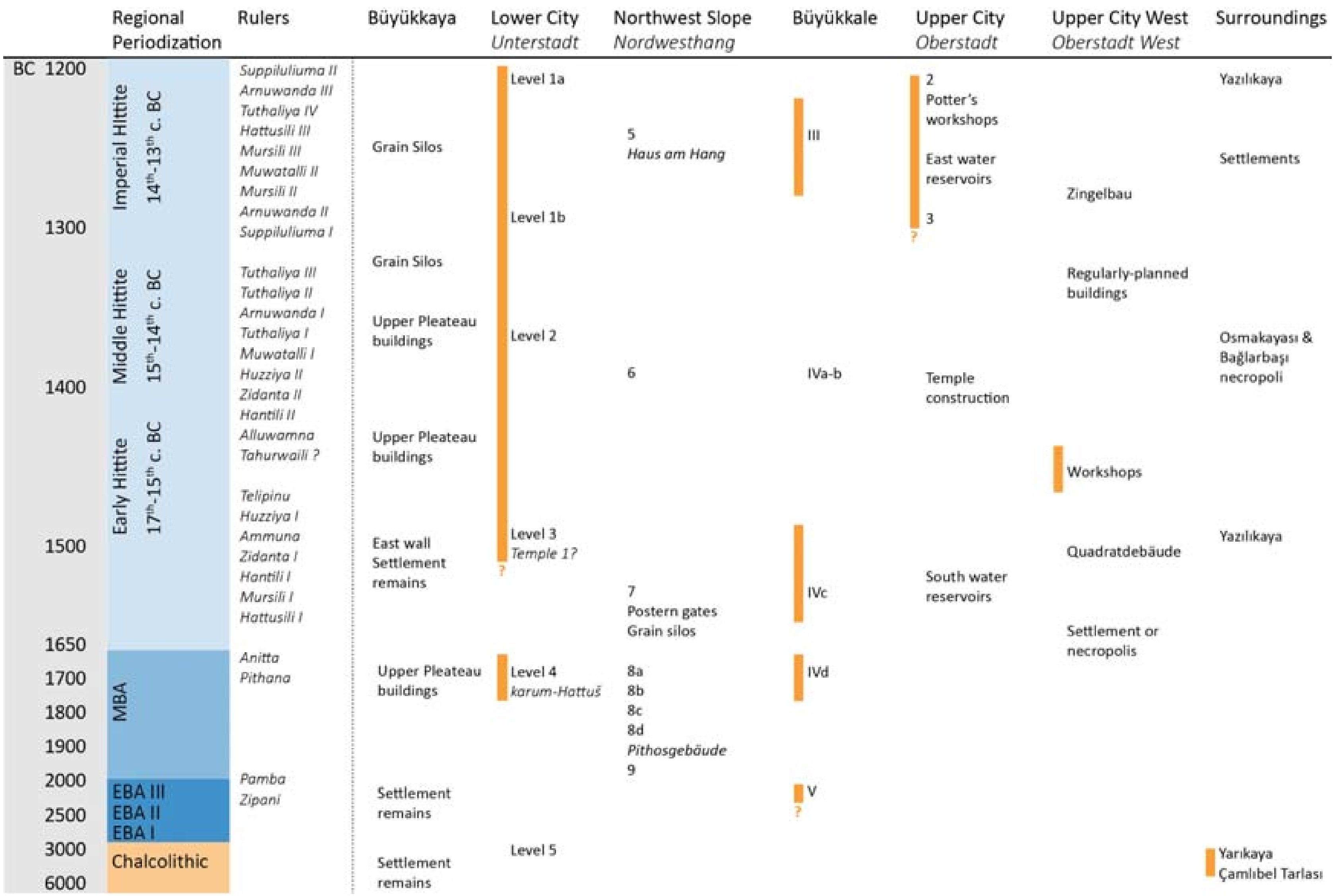


Figure 4.2: Chronological development, stratigraphic periods, and key features from locations at Boğazköy-Hattuša from the Chalcolithic until the end of the Late Bronze Age. Bars represent periods of positively identified metal production (adapted from Schachner 2011: 14-15).

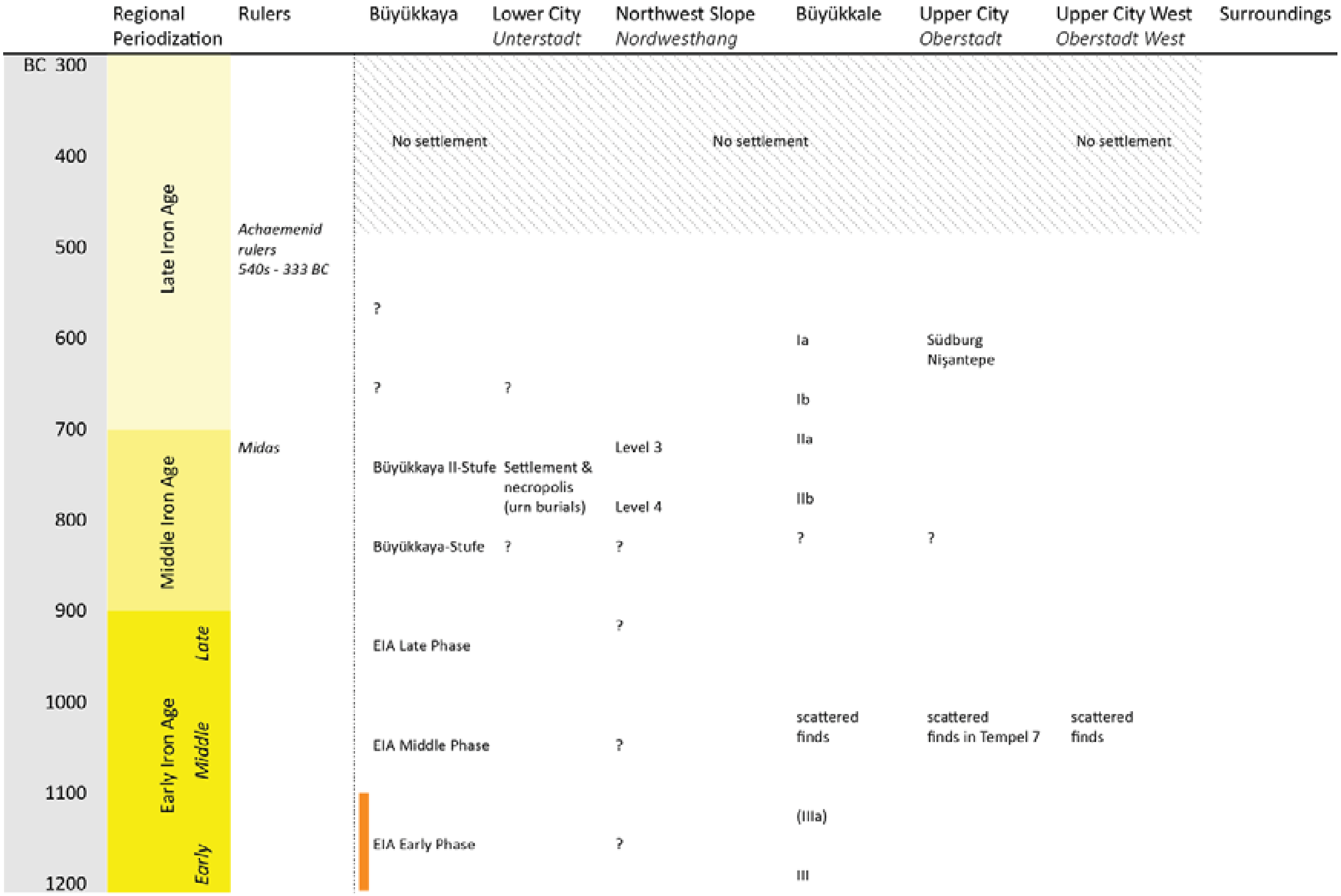


Figure 4.3: Chronological development, stratigraphic periods, and key features from locations at Boğazköy-Hattuša during the Iron Age. Bars represent periods of positively identified metal production (adapted from Schachner 2011: 16-17).

Given the multifaceted nature of the site with a highly variable topographic terrain and extensive excavations over the years in different localities of the site, the chronological framework is quite complex (Mielke 2006: 14-18). This complexity has further problematized historical inference based on the rich textual record (Klinger 2006; Seeher 2008). Thanks to the application of modern absolute dating techniques, the issues of intrasite synchronization are being resolved (Schoop and Seeher 2006; Seeher 2006a). Figures 4.2 and 4.3 represent the relative and absolute chronology that is used in this dissertation, incorporating the most recent synthesis of the site by Schachner (2011a).

4.2.1 Büyükkaya

Büyükkaya is the name of a prominent rocky ridge in the northeastern area of the walled city. It measures roughly 550 x 200m, and its southwestern rock face of the ridge plunges around 100 m down to the Lower City. Two arms of the Hittite city wall bound the northern corner of this region, which can be further broken down into three distinct areas, including the upper, middle, and lower plateaus. After initial investigations by Bittel in 1952 and 1954, renewed and focused investigations were undertaken by Neve in 1993 and then Seeher from 1994 to 1998. This region of the Boğazköy is important in particular because of its intact multi-period period remains which date from the Early Chalcolithic (6th millennium BC) and then after a gap continuously from the end of the EBA III through to the Middle Iron Age, including one of the only well-dated Early Iron Age sequences in central Anatolia (Genz 2004; Schoop and Seeher 2006). Material remains dating to the EBA and EIA both demonstrate that metal production was a central activity in this region. Analyses of copper alloy objects include eight from the late EB III, 115 from the LBA, 35 from the EIA, and 52 from the Middle Iron Age.

Significant Late Bronze Age developments in this region included the monumental construction of city walls throughout the Lower City dated to the 16th century BC. Associated finds to a large multi-roomed building complex on the Upper Plateau date the building to the Büyükkale IVa-b phases (early Empire period) (Seeher 1999: 328). The northern city wall and earthen silos with stone lined floors are associated with somewhat later radiocarbon dates placing these structures into the Empire period 14th-12th centuries BC (Schoop and Seeher 2006: 58).

Early Iron Age strata are located on the Middle Plateau of Büyükkaya, where excavations revealed a series of contexts stratigraphically above stone-lined Hittite silo pits (Genz 2004; Seeher 1998). The oldest phase of this settlement consists of a series of small pits and post-holes. The middle phase consists of several wide rectangular and shallow pits measuring up to 8 x 5 m associated with numerous post-holes. The remains of wooden revetments or supports suggest that these pits functioned as semi-subterranean structures, possibly functioning as pigsties (Seeher 2010: 223). In the last phase, a small rectangular metal workshop with stone foundations and an oven structure was found in association with crucible tuyère fragments, slag, and metal tools. Radiocarbon analyses dated these phases between ca. 1200-1000 BC (Schoop and Seeher 2006: 58-60; Seeher 2000: 374). All samples come from these occupational phases except for a socketed chisel (ETD 96/31) which was recovered from a mixed context in the lower plateau of Büyükkaya with later Phrygian type and local Early Iron Age pottery. Comprehensive resettling of all the plateaus is noted during the 9th century BC and by the 8th century the upper plateau was fortified (Seeher 1999: 327-328).

4.2.2 Büyükkale

Büyükkale is located in the center of the city on a large raised plateau ca. 250 x 140m in size that is surrounded on all sides by steep slopes and exposed rocky cliffs that fall into the

Lower City and Northwestern Slope. The relative chronology of deposits here consist of five major phases dating from the EBA III with near continuous occupation through till the Mid to Late Iron Age. The monumental building project of a palace during the Imperial Hittite period ca. 14th-12th centuries BC (Büyükkale III) overlaid most of the previous remains, including known domestic architecture during the MBA (Büyükkale IVd) and Early Hittite (Büyükkale IVc) phases. The Imperial Hittite palace located here included several distinct structures, including a reception hall, courtyards, residence for palace officials, and several rooms dedicated to the palace archives. Following the abandonment of the palace during the 12th century BC, a large fortified Phrygian building was constructed over the Hittite palace during the 9th-8th centuries BC of the Middle Iron Age (Neve 1982).

A total of six diagnostic objects from Büyükkale were available for analysis, all of which are previously published (Boehmer 1972). Three objects dating to the Late Bronze Age include a cast shaft-hole axe (Bo 477/d) from Room B of the level IIIb palace; a stylized belt with gold wire (Bo 284/e) from Room A; and a planoconvex ingot (Boehmer 1972, Nr. 190) found in a poor context of the burnt debris behind the back gate of the Phrygian eastern tower dated to level 1a. Two further objects clearly dating to the 9th-8th century BC include a bilobate arrowhead (Bo 443/i/3) from debris over Building D and one fibula (Bo 307/n) found in the east canal in Phrygian debris.

4.2.3 Lower City and Northwestern Slope

The Lower City, or alternatively called the *Altstadt* or Old City, of Boğazköy consists of several distinct areas bounded by the postern wall and Büyükkaya to the south, the city wall to the north and west, and to the east the topography dips into the Budaközü before reaching the west-facing cliffs of Büyükkaya. This region is characteristically flat, allowing for the urban infrastructure to develop less restricted as elsewhere at the site. While this region is dominated by the so-called Hittite period Great Temple (Temple 1), the Lower City has a deeper settlement history extending to at least the late 3rd millennium BC and Middle Bronze Age. There is good reason to infer that the remains of this earlier city functioned prominently within the framework of the Middle Bronze Age trading network described in Chapter 3. Evidence from a contemporary Old Assyrian text (Kt 89/k 387b) from Kültepe refers to the city of *Hattuš* as one with a king, a palace, and a hinterland over which he ruled (Barjamovic 2011: 287).

The earlier urban phase in the Lower City are evinced in the northern quarters excavated in 1938-1957 by Bittel and the new work directed by Schachner since 2009 in the region northwest of Kesikkaya and adjacent to the 16th century BC Early Hittite postern wall. A small sample of metal objects coming from these earlier contexts were collected for analysis, including three from Bittel's excavations in the northern quarter and another 16 derived from secure domestic contexts northwest of Kesikkaya. The majority of these objects include eye needles, pins, and discarded weapons; however, a single planoconvex ingot (Bo 11/590), discovered in a room with a pyrotechnological installation, presents conclusive evidence for secondary production during this period of the city (Schachner 2012: 89, 91, fig. 11; Lehner and Schachner in press). A further two samples come from MBA contexts along the northwestern slope up to the Büyükkale, including a spearpoint from the so-called *Pithosgebäude* (Bo 311/s). A large curved and flat knife (Bo 645/t) from these general contexts, possibly dating to the Büyükkale IVd period was also analyzed.

By the end of the 16th century BC and coinciding with developments across the city, the densely settled Lower City transformed as the rest of the city developed under Imperial Hittite rule (Schachner 2011a: 71-82). With the construction of the postern walls, Temple 1, rows of storage magazines, large multi-roomed elite residence, and large paved streets, the Lower City was transformed into a space of monumentality. Associated with the residential quarters of this area north of Temple 1, Müller-Karpe cogently describes a range of secondary metallurgical activities (1994: 80-82). It is clear from these analyses that by the Imperial Hittite period ca. 14th-12th century BC, and perhaps earlier, many metal production activities operated independently of state institutions yet were still sponsored by elite households. Recent work focused on the large and cut spire of rock called Kesikkaya, has further revealed how large monumental architecture, dating perhaps to the early phases of Imperial Period, was integrated with the natural landscape (Schachner 2014: 104). In addition to material from these phases, metal remains associated with an early Imperial Hittite period *Hallenhaus* structure (Schachner 2010: 167-168) and other fragmentary buildings demonstrate a wide variety of tool and ornament consumption. From these contexts, 195 samples come from the Hittite houses and related deposits, six samples come from contexts within the Temple 1 magazines, and a further 39 come from contexts associated monumental architecture and exposures of the city walls.

Further analyses come from objects derived from contexts associated with the large scale granaries, which were excavated by Seeher in 1999 and 2000. These monumental granaries are located directly on the northern side of the postern walls and downslope to the west of Büyükkale. Several radiocarbon dates place the construction of the granaries into the 16th century BC (Seeher 2006b: 74), which coincide with the construction of the postern walls and is contemporary with the construction of the southern water reservoirs of the upper city (Schachner 2009a; Schoop and Seeher 2006: 59-60). A total sample of 29 objects was selected from these contexts, including mostly pins, needles, tools, and projectiles. A single flat, curved blade knife from earlier excavations in this area (Bo 645/t), dating to BK phase IVc or IVb, was also sampled for analysis.

The Iron Age in the Lower City and Northwestern Slope primarily dates to the Middle and Late Iron Age. Three regions in particular had securely dated materials. First, Middle Iron Age remains from above the Temple 1 magazines, include examples of cult architecture and a large necropolis with a wide variety of internment types (Neve 1973: 142, fig.141; 1975: 95). Seven examples of fibulae, a socketed lance, and finely hammered sheet were analyzed from these contexts. Second, recent excavations south of Kesikkaya have unearthed a large terraced Iron Age building (Schachner 2014: 99-103), from which nine objects were analyzed, including fragments of wire, tools, and a single bilobate socketed arrowhead. Scattered Iron Age objects associated with debris next to the city wall during restauration in 2012 and 2013 were also analyzed. Two objects from excavations northwest of Kesikkaya, including a double headed pin and a fragment of sheet metal, were also analyzed. Finally, 11 objects from Late Iron Age structures above and near to the LBA granaries deposits were examined for analysis (Genz 2006, 2007). These include examples of wire, needles, sheet metal, and a fibula.

4.2.4 Upper City

Whereas the urban development of the Lower City and Büyükkale extends into the Early Bronze Age, the earliest securely dated structures in the Upper City date to the mid to late 16th century BC, including the so-called *Südteiche* or South Reservoirs (Schoop and Seeher 2006: 60-62; Seeher 2006d, 2008). This important fact reshapes our understanding of the development of the Upper City and its monuments, which were previously thought to have been constructed only during the Imperial Hittite period during the time of Ḫattušili III or Tudḫaliya IV early in the 13th century BC. Now, along with the monumental constructions of the Lower City, including the construction of the silos and postern walls, the Upper City represents an important extension of state power to a couple centuries earlier during the beginning of the Hittite imperial strategies (Schachner 2009a).

Compared again with the Lower City, the layout of the Upper City is quite different (Neve 1996). The flat plateau of this southernmost extent of the city supported the construction of at least 30 temples, the majority of which are located in the so-called central Temple Quarter (Neve 1999). The largest temples (Temples 2, 3, 5, 30, and 31) are located outside of the Temple Quarter in conspicuous areas of the Upper City. The southern city walls, together with the massive Yerkapı construction and distinct gateways, project further monumentality at the city (Neve 2001). Other monumental buildings were characteristically constructed on prominent rises of rock, including the buildings at Sarıkale, Yenicekale, and Nişantaş, yet the functions of these buildings remain somewhat unknown. A couple of large buildings just south of the postern wall and west of Temple 31 and the Südburg, including the so-called *Westbau*, functioned as a palace archive as indicated by the preservation of over 1000 sealed bullae in various rooms (Herbordt, et al. 2011; Neve 1996: 52-58). Mielke (2011a: 171) has argued that the *Nordbau* was used as official stables due to its proximity to the palace at Büyükkale. Late Hittite phases of the Temple Quarter have provided some evidence of shifting use of the temples in addition to reuse of the space for workshop activities, including pottery production and possibly also metal production (Müller-Karpe 1988; 1994: 82-84).

Ninety-two objects were analyzed from the Upper City. These include 71 objects from the temple quarter including also several objects from the Temple 7 inventory on Sarıkale. These objects are comprised of many diagnostic types, including sickles, various axes, stemmed arrowheads, tools, armor plates, and pins. Two separate copper ingots were also analyzed from these contexts, including a planoconvenx ingot (Bo 83/819) from Temple 7 and a quarter oxhide ingot from a house cellar context in between Temples 4 and 6 (Neve 1979: 301) dated to the 14th century BC. These objects will be published by Herbordt (in prep), where she analyzes their contextual significance within the temples, especially as they relate to the economic functioning of these institutions and their inventories.

With the assistance of Andreas Schachner in 2013, we were also able to analyze a small sample of one of the copper alloy dowels which were used to fasten the cyclopean masonry located at the northwestern side of the King’s Gate (MA- 136337). A single lamellar headed pin discovered during clearance of the Yerkapı (Bo 82/19) was also included in this analysis. Additionally, the surface measurement of the well-known inscribed sword of Tudḫaliya II which was found by chance near the Lion Gate in 1991 during road clearance (Neve 1993: 648-652; Ünal, et al. 1992). Several small tools, needles, pins, and indeterminate sheet metal from the East and South Reservoirs were also analyzed.

The Early Iron Age and the early phases of the Middle Iron Age in this region of Boğazköy have produced only scattered finds at the Sarıkale. However by the late 7th century BC, evidence for Phrygian settlement around the Nişantaş/Südburg area south of Büyükkale demonstrates significant investment in fortification not unlike Kerkenes Dağ. A total of six objects were analyzed from the Nişantaş/Südburg area, including a two-part composite ornament (Bo 89/29), a pair of tweezers (Bo 89/31), two fibulae (Bo 88/37 and Çorum Müzesi Inv.1-2430-91), and two toggle pins (Bo 89/128 and Bo 89/99).

4.2.5 Upper City West

The Upper City West comprises a low, northwards down-sloping valley which spatially connects the Lower City and the Upper City. Investigations led by Seeher began here in 2001 until 2005 and were resumed by Schachner in 2006 until 2008. Among many important details, research in this region has provided first an empirical understanding of the chronological development of the Upper City north of the postern wall. Second, investigations have shed some light on domestic architecture during the Imperial Hittite phases of the city in addition to large regularly planned buildings of unknown function. Two areas of focus were established first in the Sarıkale Valley and then later on the middle plateau between Yenicekale and Sarıkale further to the south. Excavations in the Sarıkale Valley have revealed at least six major phases of development. The oldest phase dates to the end of the 16th century BC and consists of two regularly planned structures (so-called *Quadratgebäude*) roughly 19 x 19m and 17.8 x 16.2m in dimensions (Seeher 2006c: 171-179). In 2008, another building probably dating to this phase (Gebäude 7) was found, in which were found two diagnostic metal objects of known types, including a copper alloy knife (Bo 08/217) and a lugged axe (Bo 08/227) (Schachner 2009b: 28).

The following phase is defined by a heavily eroded building overlaying *Quadratgebäude* 2. This phase is followed by another phase, which is characterized by intact secondary metal production installations, including a large earthen bowl shaped furnace and a melting crucible dating to the late 15th to 14th century BC (Seeher 2004: 70; 2006c: 175-176). The next phase is referred to as the *Badezimmer-Horizont* which is characterized by heavily fragmented structures, one of which had the remains of a terracotta bathtub installation (Seeher 2004: 67-69)\. Excavated from the same area were a tuyère fragment and a rod-ingot mold, together with other raw materials and tools (Seeher 2005: 70). The following phases are characterized by more fragmentary structures with pottery dating to the 14th-13th centuries BC, and finally the so-called *Zingelbaukomplex*, which consists of a large building measuring approximately 31.5 x 25m (Seeher 2003: 7). A total of 362 objects were sampled and analyzed from these contexts. The vast majority of these objects consist of fragmentary wire, needles, pins, and indeterminate sheet metal; however this large sample size, clearly dating from the 16th-14th centuries BC, represents the largest set of metal analyses from the site. A further 28 samples come from the so-called GAL-MEŠEDI elite residence located on the middle plateau, which dates to the early 14th or early 13th centuries BC (Lehner in press-a; Schachner 2008, 2009b, 2015, in press-a). From the excavations at the small monumental complex at Yenicekale, I analyzed a further 5 objects dating to the Imperial Hittite period and another from the Middle Iron Age (Schachner in press-b).

4.3 Kerkenes Dağ

Located approximated 50km to the southeast of Boğazköy, the low granitic mountain of Kerkenes Dağ was the chosen location for the new foundation of an Iron Age capital in the mid to late 7th century BC. Based primarily on circumstantial evidence, this city is most likely to be identified with ancient Pteria, mentioned by Herodotus (Przeworski 1929; Summers 1997: 86; 2006a: 166-167). Archaeological investigations of the material culture present at the city demonstrate that it was culturally Phrygian, at least from evidence derived from elite contexts. This is most convincingly argued on the basis of fragmentary texts and graffiti written in the Old Phrygian language (Brixhe and Summers 2007); evidence of cult practice from images, graffiti and semi-iconic idols well known across Phrygian central Anatolia (Summers 2006a: 181); and the distinct architectural traditions that include free-standing two-roomed buildings with pitched, thatch-covered roofs (Langis-Barsetti 2013; Summers and Summers 2006). Within perhaps no more than three generations of time, the city was destroyed and abandoned during the mid-6th century BC, perhaps due to prolonged conflict between Croesus, the king of Lydia, and the westward expanding powers of Persia ruled then by Cyrus the Great in the 540s BC.

Without any evidence for earlier occupation on the mountain, Kerkenes is thus a new city with elite foundations that echo Phrygian rule. The city may be what Summers and Summers (2013: 138) call an “ideal” city, because evidence of overarching design and control of the city planning can be found in many contexts across several scales across the site. The urban layout, composed of radially aligned compounds and streets, demonstrates clear evidence of centralized planning. Encompassing 271 hectares of urban space, the 7.5kms of city wall, composed entirely of hewn uncut granite blocks, extensive glaçis fortifications, and periodic towers, are passable only through one of seven monumental gateways. Within the city, a large urban compound with a heavily fortified monumental entranceway is interpreted to be a palace, while a diversity of separate urban compounds extend into nearly all open space in the city. Other buildings across the site, including several monumental two-roomed buildings or halls, appear to have non-domestic functions, perhaps correlating with conspicuous cultic institutions (Summers 2007; Summers, et al. 2004). Outside of the city walls and located on prominent ridges, several immense tumuli serve as burial monuments most probably of the rulers of the city.

The first archaeological investigations of the site were conducted by Erich Schmidt in 1928, who was then part of the Oriental Institute excavations at Alişar Höyük, directed by Hans Henning von der Osten. Schmidt’s test trenches across the city, in addition to the cartographic surveys by F. Blackburn in 1927, helped provide crucial evidence for the initial dating of the site, which they placed into the pre-Hellenistic Iron Age (Schmidt 1929; Summers and Summers

1998). The site did not receive further serious attention until 1993, when Geoffrey and Françoise Summers began a long-term project at the site under the auspices of the British Institute of Archaeology in Ankara. One of the initial and on-going foci of research at the site has been the intensive surveying on the site, including extensive subsurface remote sensing, have effectively mapped out much of the urban block layout of the site (Branting 2004; Branting and Summers 2002; Branting, et al. 2007). Selective excavations began in 1996 and 1998 with several new test trenches. Beginning in 1999 and into 2000, clearance of the so-called Palace Complex fortification and Cappadocian Gate began, and in 2002-2005 larger scale excavations of these structures revealed their impressive preservation and the first conclusive details of cultural affinity associated with the city and its development. Further clearance and excavations of the Cappadocian Gate resumed in 2007 and finished in 2011. Investigations in the central and northern city were initiated in 2003 with the excavation of a megaron styled building and in 2010 with the excavation of a monumental two-roomed structure. Finally, the excavation of so-called Urban Block 8 in the northern end of the city, which was first investigated in 1996, continues to uncover domestic contexts to complement our understanding of the city which has been understood in terms of elite contexts until recently.

Samples of copper and copper alloy objects were collected predominantly from the Palace Complex and Cappadocian Gate, where there was a greater diversity of finds. Because of the depositional history at the site, in addition to the fact that there is very little overburdern from later periods, all samples are chronologically contemporaneous and are assumed to be bounded in date by the 7th-6th century BC date of the city.

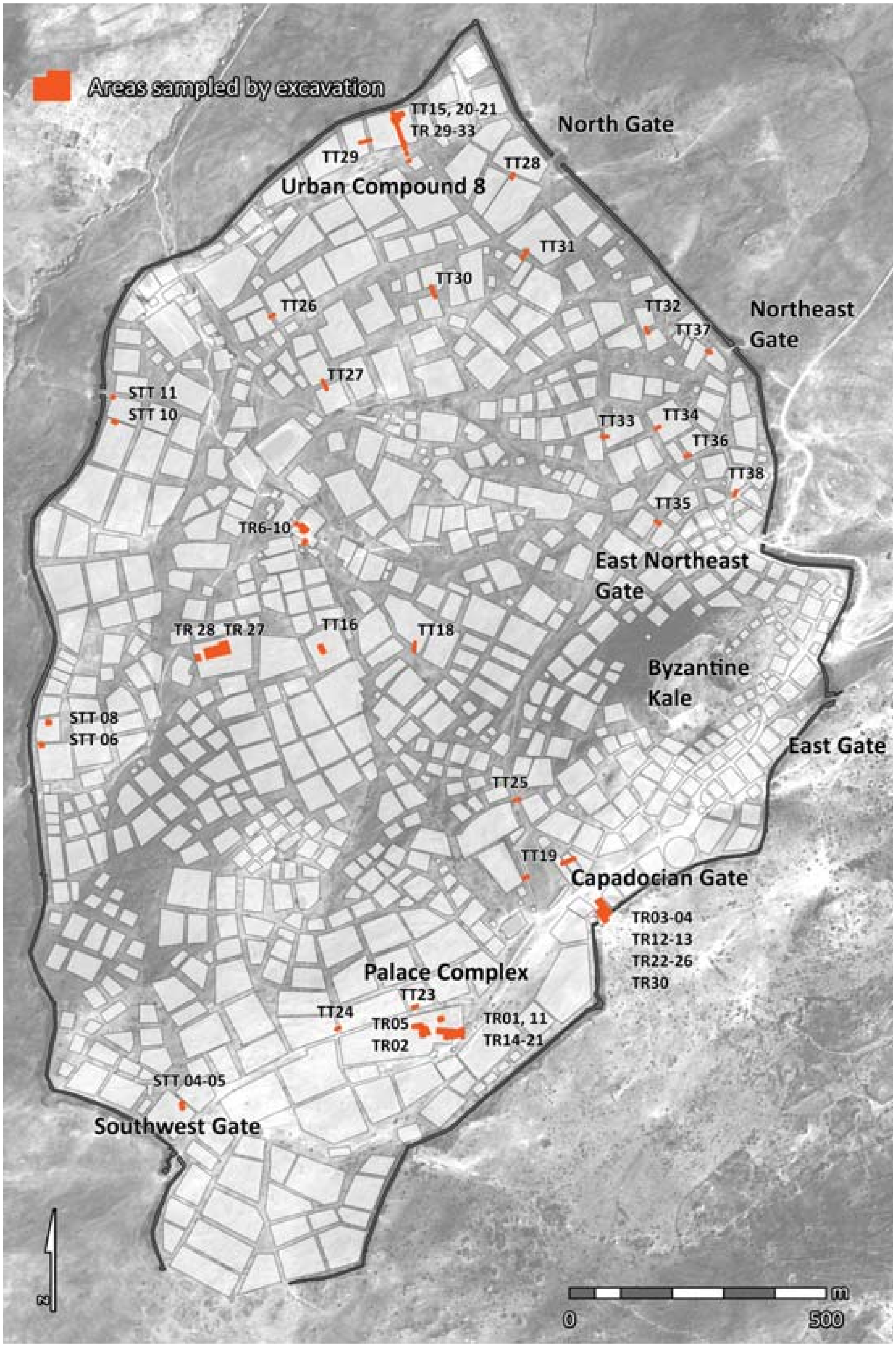


Figure 4.4: Iron Age city plan of Kerkenes Dag noting areas sampled by excavation up to 2014. Data from the project archive and Branting (2004).

4.3.1 Palace Complex

The Palace Complex is located on a high rise in the southern city along a major transport corridor linking the Southwest Gate, the Cappadocian Gate and further extensions into the lower elevations of the city to the north. The complex occupies the single largest walled urban compound in the city and is the only compound that his fortified with a glacis. Clearance and excavations at the Palace Complex extending from 1999 to 2005 were focused on the articulation and relation of the glaçis fortifications, the so-called Monumental Entrance into the compound, and two large two-roomed structures immediately afterwards. This work has been summarized in Summers and Summers (2008), who describe three phases of development (see also Figure 4.4). First, two compounds were separately laid out, including Structure A which was initially fortified with a glaçis fortification similar in construction to the city walls. It is unclear what the function of this early building was. In the following phase, Structure A was joined with the urban compound immediately to its west with a stone pavement leading up to the so-called Audience Hall and the Ashlar Building. The final phase of construction comprised the addition of the Monumental Entranceway, which also included the addition of semi-iconic stele and a monument crafted from stone with Phrygian dedicatory inscriptions (Brixhe and Summers 2007; Draycott and Summers 2008). Taken together, this complex is exemplary as a material extension of state power in an appropriate context, presumably also the residence of the ruler over the city and state.

In association with the stone monuments and architectural embellishments of the Palace Complex monumental entranceway were many objects of metal (151 total objects, nearly half of the total excavated from the site), predominantly iron, that appear to function primarily as architectural support and decoration. Several meters of well-preserved iron bands together with

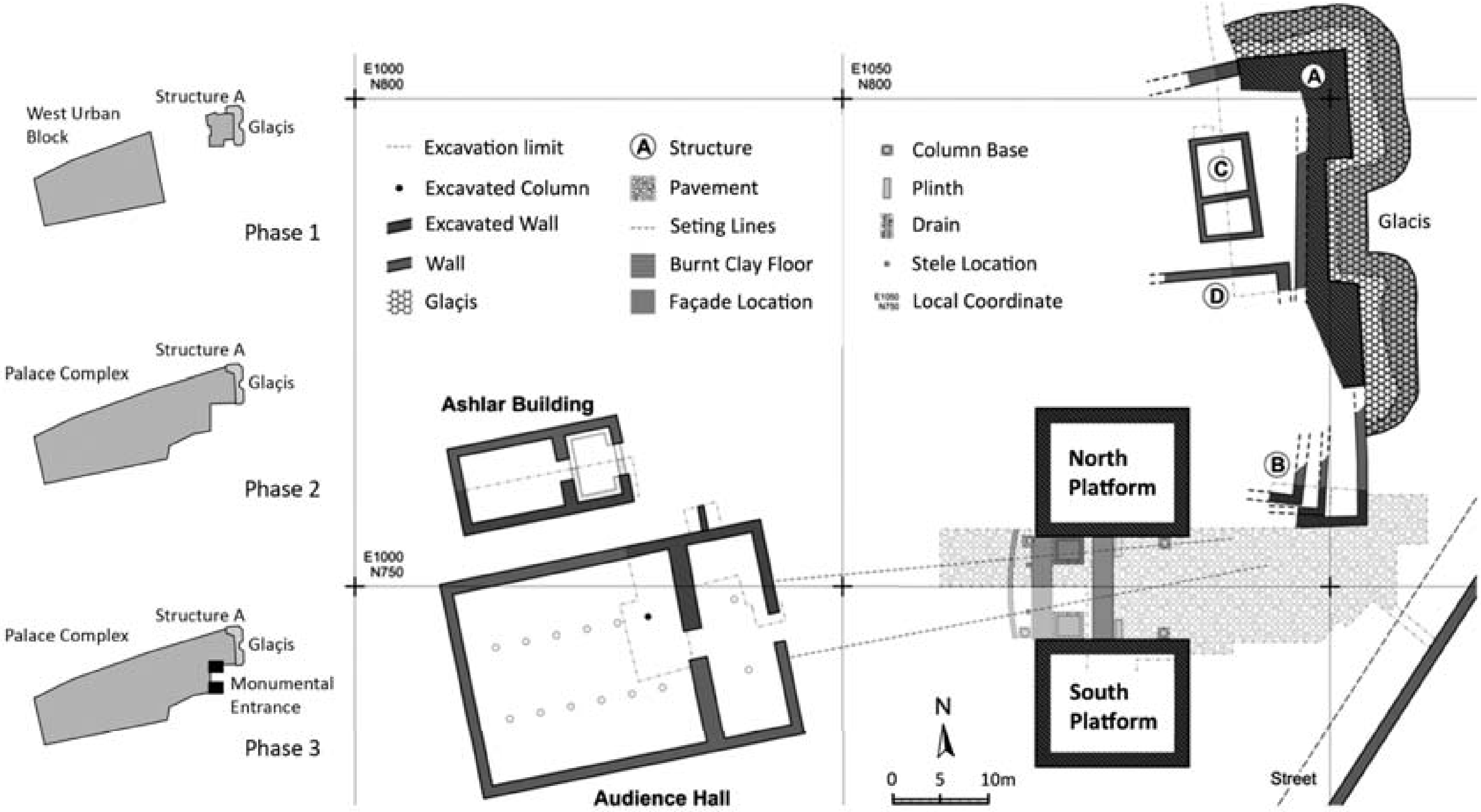


Figure 4.5: Schematic of developmental phases of the Palace Complex and its plan according to clearance and excavations from 1999 to 2005 (adapted from Summers and Summers 2008: figs. 22, 27).

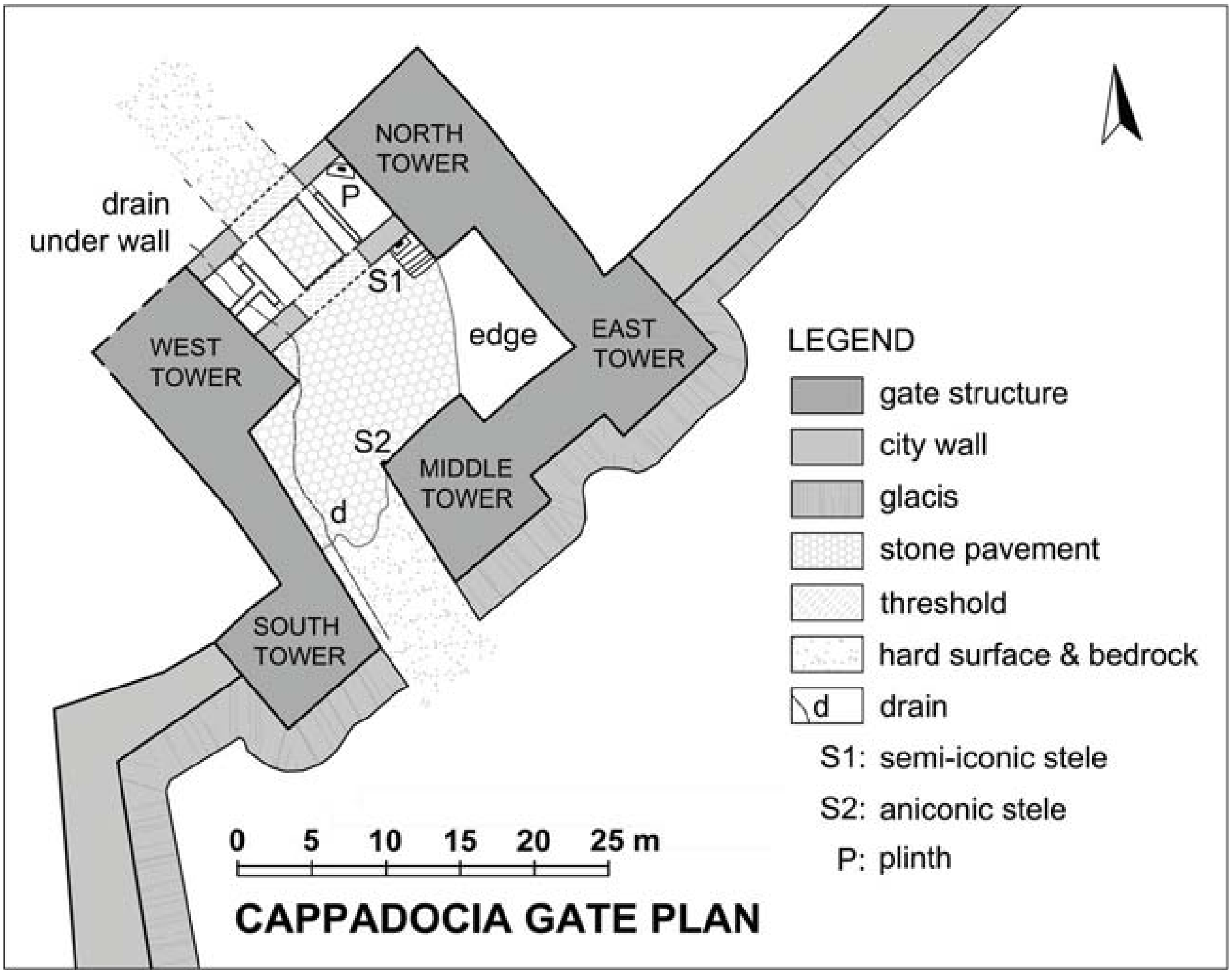


Figure 4.6: Cappadocia Gate Plan (Kerkenes Dağ Project archives).

15+ cm round-headed iron spikes likely held together large wooden doors situated between the north and south platform. Objects of different copper alloys, lead, silver and gold were also found lying on the pavement surface or in collapsed debris. Among the copper and copper alloy objects, samples include a single sample of a nail from the Ashlar Building, two pins from Structure D, and 26 diverse objects consisting mostly of decorative sheet metal, nails, and wire fragments from the Monumental Entranceway. Several of the smaller fragile objects were also discovered in between pavement stones. The most striking examples of copper metallurgy come from the sheet metal examples, including two finely hammered and crafted twin facing ibex

(02TR01U02met01 and 02TR01U02met02), which probably decorated the wooden planks of the entrance doorway. These objects further demonstrate the use of tin washing to create a silver-colored coating, which has direct technological parallels from Urartian shields discovered at Ayanis (Ingo, et al. 2010).

4.3.2 Cappadocian Gate

This gateway complex is located in the southeastern side of the city walls and is one of five such monumental entranceways into the city on the eastern side (Figure 4.6). The structure is composed of five towers, three in the front and two in the back, which flank an offset central passageway leading into the city (Summers in press). Clearance and excavations beginning in 1999, with particular intensive focus in 2010-2011, revealed that this structure probably had multiple functions in addition to defense and the control of transportation. Elements of cult evinced by presence of an aniconic stele and stepped monument inside of the passage chamber suggest that the gate complex was invested with visual aspects of ideology. This similar pattern is also present at the Monumental Entrance of the Palace complex, where semi-iconic crenulations flanked at least one side of the passageway. Collapsed walls and intense burning demonstrate that the structure was intentionally destroyed in a single event. Two individuals were found crushed below the collapsed and burnt debris (Summers n.d.).

A range of metal objects were discovered in these contexts, including as in the Palace a great deal of architectural iron in the form of finely forged bands and spikes which held the wooden planks of the doorway together. A single example of a delicately crafted gold and electrum attachment piece with granulation was discovered below the collapsed rubble suggesting that it was lost shortly before the structure was destroyed. Copper alloys in the form of finely hammered sheet metal, pins, nails, needles, and lobate arrowheads were also discovered in these contexts. A total of 32 these copper alloy objects were sampled for analysis.

4.3.3 Urban Quarters and Streets

Select excavations elsewhere in the city, including those of Schmidt in 1927, have shed some further light on the organization of the city and the various activities that took place outside of the contexts of the Palace Complex and Cappadocian Gate. This work has primarily sought to simultaneously ground truth the extensive subsurface remote sensing data and to examine select identifiable urban contexts, including aspects of urban organization and household dynamics.

First, excavations led by Branting focused on street deposits across the city. Preserved deposits, mostly preserved alongside the outside of buildings, contained diagnostic compacted microstrata that formed during the use-life of the city. I sampled two objects from TT25, including a fibula and wire fragment, a double headed pin from TT27, and fibula fragment from TT31. Second in 2003, excavations in the lower central city examined so-called megaron structures and adjacent buildings within a single urban compound (Summers et al. 2004). This work primarily confirmed and added to the interpretation of the remote sensing data. While the activities associated with these buildings are unclear, excavations confirmed that the city burning extended into the lower city. No indications of domestic activity were preserved within these structures. Fragments of a small trinket mold (K03.157) suggest that metallurgical activities may have possibly occurred within the compound however no pyrotechnological debris was noted here. Few metal remains were recovered during these excavations aside from a rosette headed tack and a single trilobite arrowhead (03TR06UI2met0l), which was sampled for analysis. Later excavations at the nearby large two-roomed structure (referred to as a “Temple”), yielded no preserved deposits however an adjacent building at the backside of the structure had several intact contexts, indicating that this small building may have been used for storage (unpublished, but see Branting et al. in Summers and Summers 2011: 5-7).

Third, ongoing excavations in the northern residential quarter of the city, which was first sampled by excavation in 1996, have begun to reveal the entire urban compound (Urban Compound 8). Remote sensing data most recently published by Langis-Barsetti (2013) demonstrate that this compound contains a diversity of structure types, including a large two-roomed hall (Summers 2007: 259). This compound experienced significant burning before it was abandoned. In one storage room, excavations recovered the remains of what was probably a piece of intricate furniture decorated with carved ivory. A diverse assemblage of metal objects, including iron, silver, gold, and copper alloys, attest to the breadth of access individuals had at this urban compound. A total of seven objects from these contexts were sampled for analysis, including pin fragments (98TT21U01met02, 96TT15U13met05, and 11TR29U14met02), sheet metal (11TR29U34met02 and 11TR29U34met03), a large piece of forged copper (97TT15U00met01), and a single bilobate arrowhead (11TR29U32met01).

4.4 Conclusion

In this dissertation a sample of over 1000 objects were analyzed from Boğazköy and Kerkenes Dağ, two of the largest regional centers in Central Anatolia. The results of the compositional analyses are presented and discussed in Chapter 5. Artifact samples cut across a wide chronological, contextual, and typological matrix. Despite the complexity of the site, Boğazköy has one of the best empirically and stratigraphically defined settlement history in central Anatolia, including structures and deposits across several diverse social contexts. This important fact allowed the sampling of objects ranging across these social contexts, from domestic/residential structures and activity areas to those directly associated with the palace and temple. By far the bulk of the samples were taken from Late Bronze Age and Mid to Late Iron Age contexts. This is mostly due to the fact that the majority materials from Boğazköy date to these periods, and materials securely dated to the Early Bronze Age and Middle Bronze Age are exceeding rare. These data constitute the first well-defined and description of copper metallurgy inferred from finished objects dating to these periods in central Anatolia.

A further set of objects from the site of Kerkenes Dağ were sampled and analyzed. Most of these samples come from contexts within the Palace Complex and Cappadocian Gate, but several others come from domestic contexts in the north of the city. The most striking characteristic of these samples is that they all date within the life of the city ca. late 7th century – 540s BC. The chronological resolution is so fine from this site that these objects effectively comprise a tight range of time within the Late Iron Age.

This allows the effective comparison with Boğazköy in two distinct ways. First, from a cultural-historical point of view, it is now possible to describe any patterns of metal production and consumption from these periods over time. Second, a cross-cultural comparison between sites and contexts allow the testing of hypotheses, first outlined in Chapter 1, regarding the evolution of top tier regional centers and the fundamental relationship between trade and social organization.

CHAPTER 5: COMPOSITIONAL ANALYSIS OF COPPER ALLOYS

5.1 Introduction

In this chapter, the results of bulk chemical analyses of 1141 archaeological metal objects from Boğazköy and Kerkenes Dağ are presented and discussed. These data highlight how these two regional centers strategically accessed a wide variety of copper metal resources and technologies. These patterns reflect socioeconomic processes that effectively characterize how individuals and institutions organized production, exchange, and consumption over time. The bulk of the data, as described in the previous chapter, principally derives from contexts associated with the approximate height of political and economic activity as capitals of archaic states, and by extension, the climax of Bronze Age and Iron Age urbanism in central Anatolia. At Boğazköy further data is included here from earlier and later contexts to develop a chronologically bracketed understanding of metal industries at the site. These data examine how metal technologies developed in the context of expansionist states.

The compositional data were quantified using x-ray fluorescence spectrometry (XRF), including both a bench-top energy dispersive XRF (EDXRF) and an in-field portable XRF analyzer (pXRF). EDXRF analyses were conducted at the Curt-Engelhorn-Zentrum Archäometrie (CEZA) in Mannheim, Germany during the 2012-2013 academic year, and pXRF analyses were conducted on site in the field in Turkey during the summer of 2013. Compositional data from both methods are presented in Appendix B and C, respectively.

Details of the analytical techniques used in this dissertation, including sample preparation, instrumental parameters, accuracy, precision and sensitivity are presented below. I include also a brief discussion on data treatment and presentation, following which the EDXRF and pXRF data are presented and a rationale for the comparability between analytical methods is determined. The descriptive statistics of the compositional data are then discussed in a univariate manner element by element. Subsequently, I examine the relationships between elements and archaeological assemblages through bivariate and multivariate statistical analyses.

5.2 Analytical methods

Samples of archaeological metal were collected in the field from 2008-2013 with the main purpose of bulk compositional analysis. In practice, excavated metal objects are first mechanically cleaned down to the stable corrosion layers by conservators, photographed, and drawn. Compositional analyses are completed later using three non-destructive instrumental methods and these can be ranked according to their invasiveness to the sample (See Table 5.1). Where possible, additional sample material was taken in order to allow observation by optical microscopy. In general, samples consisted of small cuttings (ca. 1-5mm) or drillings of objects. Most objects were inevitably impacted by environmental degradation and were visibly affected by corrosion. Careful effort was taken to abrade mechanically all corrosion from preserved metal in the sample to avoid contamination in the analysis. Subsequent to abrasion, samples were then roughly polished using dry sandpaper grades 600 and 1200.

5.2.1 Analytical parameters and instrumentation

Most samples are first analyzed using a portable x-ray florescence analyzer (pXRF). The main benefit of this analyzer is that it is portable so that analysis can be conducted directly in the field or in the museum. This method is often the only possible method to date to conduct compositional analysis, especially fragile and highly valuable museum display objects. While quantitative analysis of copper alloys is theoretically possible, several limitations are important to consider here (see also Heginbotham, Bezur et al. 2010; Liritzis and Zacharias 2011). First, without careful invasive sample preparation, pXRF essentially analyzes the surface of the object, which is often altered by the corrosion of the original cast or forged shape. Selective corrosion of elements like iron and tin may therefore produce misleading deviations from the original metal composition. Other effects which determine the surface chemistry of metal objects, such as inverse segregation of alloy phases, plating/coating, or even conservation treatments, can produce very misleading results derived from surface analysis. To mitigate the effects of these limitations, small minimally perceivable areas of corrosion were removed mechanically where possible prior to analysis. These objects were then immediately retreated and conserved for storage. On an average working day in the field, about 30 to 40 objects could be photographed, prepared, analyzed, and finally conserved for storage.

Select prepared samples were analyzed for composition by EDXRF using methods outlined by Lutz and Pernicka (1996). In general, samples are further prepared to carefully remove all visible corrosion where possible. Often this also resulted in reducing clippings into several smaller pieces to help ensure a more accurate reading of the average composition. This method has a distinct advantage over pXRF in that it analyzes bulk composition and is therefore more reflective of the original composition of the metal. Detection limits and accuracy are generally much improved using this method; however limitations include invasive sampling and longer analysis times. For select samples scanning electron microscopy equipped with an EDX analyzer was employed in order to determine phase compositions and microstructures.

In addition to the sample macroscopic effects described above, other matrix effects associated with xray fluorescence techniques above can include significant instrumental error into the analysis. While many of these effects, including the absorption or enhancement of x-rays into the matrix, can be quickly modeled and corrected in the software quantification procedures, significant instrumental errors may result from irresolvable spectra of overlapping xray emissions. This is particularly important for archaeological copper alloys because of a number of important elements which can be potentially hidden from analysis. Typically, sensitivity decreases for some elements where photon emissions of similar energies are not resolvable by the XRF detector. This is particularly true of lead (Pb), because this element has several complex emission spectra that can overlap with a range of other important elements common to archaeological copper. For example, the As Kα, which overlaps with the Pb Lα line, can be totally obscured if the Pb concentration is too high. This can also be true for the zinc Kα line which overlap with the Cu Kβ line. Therefore with the presence of relatively elevated concentrations of overlapping elements, the sensitivity will be reduced and the minimum detection limit increases.

The summary statistics for measurements of standard reference materials using both pXRF and EDXRF are presented in Tables 5.2, 5.3, and 5.4. In order to determine the analytical precision and accuracy of both these methods, data which further informs instrumental comparability, several measurements of industrial and in-house standards were analyzed. Nominal values of the standards are compared against an average of several measurements (accuracy) and their relative standard deviation (precision). The minimal detection limit for each method is also calculated using Equation 5.1 below. This calculation is another measure of precision which determines probabilistically the lowest concentration that is reliably measureable in a given material matrix. Concentrations below this for either of the methods are considered here as semi-quantitative indicators. Results from these analyses demonstrate that the EDXRF methods used in this study are generally superior to the pXRF methods. EDXRF is more sensitive to lower concentrations and more accurate across a wide range of concentrations by an order of magnitude.

Table 5.1: Analytical parameters of instrumentation to measure elemental composition used in this study.

Method	Purpose	Analytical Parameters
pXRF Thermo NITON XL3t	In field non-destructive / semi-quantitative compositional analysis of the artifact surface to characterize the type of metal alloy.	General Metal mode, 2 averaged analysis points, 100 s analysis time.
EDXRF Thermo QUANTX	Quantitative bulk analysis of elemental composition	See Lutz and Pernicka (1996).
SEM-EDS Zeiss EVO MA 25 scanning electron microscope with a Bruker QUANTAX silicon drift EDX detector	Characterization of materials, backscatter electron imaging to examine heterogeneity and composition. Semi-quantitative compositional analysis of solid metal phases and inclusions observed within the sample using spot/area analysis.	Backscatter electron (BSE) imaging: accelerating voltage 30 kV, average dead-time 35-40%, and working distance 6.8 – 7.4 mm (all semi-quantitative measurements taken at 7.0 mm and 1500x magnification). Elemental concentrations are ZAF standardless corrected and normalized to 100 wt%.

Equation 1: Minimum detection limit (MDL) using the Student t's method.

$$MDL = T(n-1, 1-\alpha = 0.99) \times \sqrt{\sum_{i=1}^{1=n} \frac{(X_i - \overline{X})^2}{n-1}}$$

Table 5.2: Summary of mean values, standard deviation, relative standard deviation (%RSD), and minimum detection limit (MDL) for 13 elements and calculated from one standard reference material CTIF B12 (tin bronze) using pXRF. Results derive from 10 measurements taken intermittently throughout the duration of this study.

	CTIF B12				
Element	*Nominal*	*Observed Average*	*Standard Deviation*	*%RSD*	*MDL*
Cu wt.%	85.65	86	0.021	0.02	0.09
Mn wt.%	0.235	0.24	0.004	1.87	0.02
Fe wt.%	0.162	0.19	0.004	2.20	0.02
Co wt.%	-	-	-	-	-
Ni wt.%	2.63	2.66	0.009	0.33	0.04
Zn wt.%	0.60	0.51	0.008	1.54	0.04
As wt.%	0.111	0.05	0.004	7.62	0.02
Ag wt.%	-	-	-	-	-
Sn wt.%	9.57	10.3	0.02	0.17	0.08
Sb wt.%	0.117	0.12	0.003	2.34	0.01
Au wt.%	-	-	-	-	-
Pb wt.%	0.201	0.26	0.004	1.41	0.02
Bi wt.%	-	-	-	-	-

Table 5.3: Compositional analysis of known copper alloy nominal standards which occupy a broad compositional range. In general, analytical accuracy noticeably decreases at concentrations less than 0.10 wt. % which is within the error range necessary to determine the major and many minor constituents. Industrial and in-house standards were analyzed at the Curt-Engelhorn-Zentrum Archäometrie

Standard		Cu	Sn	As	Pb	Sb	Ni	Co	Fe	Zn	Bi	Ag
MET1	**pXRF**	73	4.23	4.48	3.39	1.97	2.65	2.90	2.29	3.52	-	1.85
	Std	73.3	3.85	4.89	3.34	1.84	2.71	2.8	2.47	3.53	0.0001	2.08
	%error	*0.8*	*9.8*	*8.4*	*1.4*	*6.8*	*2.3*	*3.6*	*7.4*	*0.4*		*11.0*
MET2	**pXRF**	78	6.45	2.82	4.27	3.88	0.95	0.87	0.95	1.15		1.01
	Std	77.1	6.61	3.00	4.32	3.9	1.00	0.74	0.85	1.05	0.0001	1.16
	%error	*0.7*	*2.4*	*6.0*	*1.3*	*0.6*	*5.2*	*17.3*	*11.8*	*9.9*		*13.3*
MET3	**pXRF**	96	0.47	0.33	0.54	0.44	0.47	0.50	0.45	0.51		0.28
	Std	95.7	0.47	0.37	0.58	0.47	0.45	0.46	0.47	0.47	0.0001	0.3
	%error	*0.3*	*0.2*	*11.6*	*7.1*	*6.4*	*3.8*	*9.1*	*4.0*	*8.5*		*7.0*
BAM-376	**pXRF**	100	0.04	0.01	0.04		0.02	0.03	0.02	0.13	0.02	0.01
	Std		0.02473	0.0199	0.0236	0.0202	0.0209	0.02079	0.02346	0.02173	0.02	0.0163
	%error		*41.5*	*34.7*	*48.3*		*28.2*	*20.3*	*27.5*	*516.7*	*15.0*	*20.2*
ERM-EB-374	**pXRF**	92	7.77	-	-	-	-	-	-	0.09	-	-
	Std	92.22	7.6		0.00083		0.00327		0.004	0.00404		0.00121
	%error	*0.1*	*2.2*							*2004.0*		
BAM-367	**pXRF**	89	0.02	-	0.04	-	9.23	0.07	1.40	-	-	0.01
	Std	87.88	0.0105		0.0298		9.72	0.0498	1.443	0.0715		
	%error	*1.5*	*109.5*		*37.6*		*5.0*	*46.6*	*3.3*			
BAM-211	**pXRF**	87	10.61	0.07	0.96	0.05	0.08	-	0.07	0.66	-	0.04
	Std	87.71	10.6	0.0213	0.74	0.033	0.122		0.11	0.56	0.002	0.059
	%error	*0.3*	*0.1*	*223.9*	*29.3*	*36.4*	*34.4*		*32.7*	*17.9*		*32.2*
BAM-375	**pXRF**	58	0.17	0.08	3.63	-	0.10	0.02	0.20	37.76	0.02	0.02
	Std	58.32	0.209	0.0231	2.9	0.0122	0.105	0.01964	0.207	38.02	0.00686	0.0166
	%error	*0.6*	*16.7*	*237.7*	*25.1*		*3.1*	*6.9*	*2.9*	*0.7*	*249.9*	*3.6*
BAM-227	**pXRF**	84	6.09	0.17	5.23	0.13	0.26	-	0.13	3.47	0.02	0.02
	Std	85.57	6.01	0.081	4.12	0.16	0.284		0.129	3.46	0.0088	
	%error	*1.3*	*1.4*	*112.3*	*26.9*	*20.6*	*10.2*		*0.8*	*0.2*	*93.2*	
BAM-228	**pXRF**	85	10.02	-	1.49	0.09	0.09	-	0.01	3.36	0.01	-
	Std	85.34	9.76	0.024	1.24	0.078	0.109		0.036	3.32	0.0086	
	%error	*0.5*	*2.6*	*100.0*	*20.1*	*14.1*	*18.3*		*72.2*	*1.3*	*27.9*	
NBS-398	**pXRF**	100	-	-	-	-	-	-	-	0.04	-	-
	Std		0.00048	0.0025	0.00099	0.00075	0.0007	0.00028	0.00114	0.0024	0.0002	0.00201
	%error									1525.0		
NBS-399	**pXRF**	100	-	-	-	-	0.05	-	-	0.09	-	0.014
	Std		0.009	0.0047	0.0114	0.003	0.0506	0.00005	0.002		0.00105	0.0117
	%error						*11.1*					*19.658*
NBS-400	**pXRF**	100	-	0.01	0.03	-	0.07	-	-	0.05	-	0.03
	Std		0.02	0.014	0.0128	0.0102	0.0603	0.00006	0.0041	0.0114	0.00245	0.0181
	%error			*7.1*	*142.2*		*7.8*			*364.9*		*65.7*

Table 5.4: Summary of mean values, standard deviation, relative standard deviation (%RSD), and minimum detection limit (MDL) for 15 elements and calculated from two standard reference materials BAM376 (pure copper) and BAM211 (copper tin bronze) using EDXRF. Calculated from 30 measurements taken during each measurement cycle throughout the duration of this study.

	BAM376					BAM211				
Element	*Nominal*	*Observed Average*	*Standard Deviation*	*%RSD*	*MDL*	*Nominal*	*Observed Average*	*Standard Deviation*	*%RSD*	*MDL*
Cu wt.%	-	100	0.006	0.0	0.024	87.71	88	0.108	0.1	0.413
Mn wt.%	0.02059	0.02	0.002	-	0.006	0.0019	bdl	-	-	-
Fe wt.%	0.02346	0.023	0.002	8.6	0.008	0.11	0.117	0.002	2.0	0.009
Co wt.%	0.02079	0.02	0.002	8.1	0.006	-	0.001	0.001	141.2	0.003
Ni wt.%	0.0209	0.027	0.003	9.7	0.010	0.122	0.133	0.003	2.1	0.010
Zn wt.%	0.02173	0.007	0.004	57.4	0.015	0.56	0.439	0.050	11.3	0.189
As wt.%	0.01999	0.019	0.002	11.9	0.009	0.0213	0.009	0.003	37.2	0.012
Se wt.%	0.021	0.024	0.001	3.2	0.003	0.00114	0.003	0.001	35.8	0.003
Ag wt.%	0.0163	0.015	0.000	2.7	0.002	0.059	0.049	0.001	1.9	0.004
Sn wt.%	0.02473	0.026	0.001	4.8	0.005	10.6	10.09	0.096	0.9	0.366
Sb wt.%	0.0202	0.017	0.001	6.1	0.004	0.033	0.026	0.002	5.7	0.006
Te wt.%	0.0215	0.02	0.001	5.8	0.005	-	0.001	0.001	91.7	0.002
Au wt.%	-	0.002	0.001	89.2	0.005	-	0.025	0.006	21.9	0.021
Pb wt.%	0.0236	0.021	0.002	7.9	0.006	0.74	0.675	0.012	1.8	0.047
Bi wt.%	0.02	0.018	0.001	7.0	0.005	0.002	0.005	0.001	26.7	0.006

5.2.2 Comparing methods and reproducibility

It is useful to compare analyses of similar samples across instruments to determine the degree of comparability between them. For this study, 34 select objects of archaeological metal were analyzed using both methods. Results highlight two important considerations and can be observed in bivariate scatter plots for each element in Figures 5.1-5.3. Linear regressions were computed to test the coherence of the data, where a goodness of fit statistic (R^2) was computed to observe any trends in instrumental accuracy and patterns of over- or under-estimation of the calculated concentration values. First, the previously ascertained differences in sensitivity are reflected in the results, where objects low in concentration of measured elements do not correlate significantly, however higher concentrations improve in correlation. Second, this is complicated however by the effects of surface chemistry and corrosion. Elevated concentrations of iron (Fe) often indicate the presence of corrosion or other contaminants of the bulk chemistry. Furthermore, tin selectively corrodes out of bronze and is deposited on the object's surface in a complex assortment of corrosion minerals. Even small amounts of corrosion left over after sample preparation could theoretically greatly affect the calculation of elemental concentration which would thus be potentially quite misleading. The selective corrosion of tin and deposition of iron as contaminants is a likely explanation for the large differences in these elements between pXRF and EDXRF methods. Arsenic, lead, nickel, and cobalt all have highly significant agreement between the two methods ($R^2 > 0.95$), while the remaining elements have significant or insignificant correlations. Zinc has a highly insignificant correlation ($R^2 < 0.01$), and this is probably explained by its low concentration relative to higher concentrations of copper. These results demonstrate that extreme caution is necessary when combining results from different methods without considering how quantifications behave across standard reference materials and samples. Nevertheless, these results do demonstrate that qualitative or semi-quantitative comparisons between methods are reproducible and permit the testing of the central hypotheses in this study.

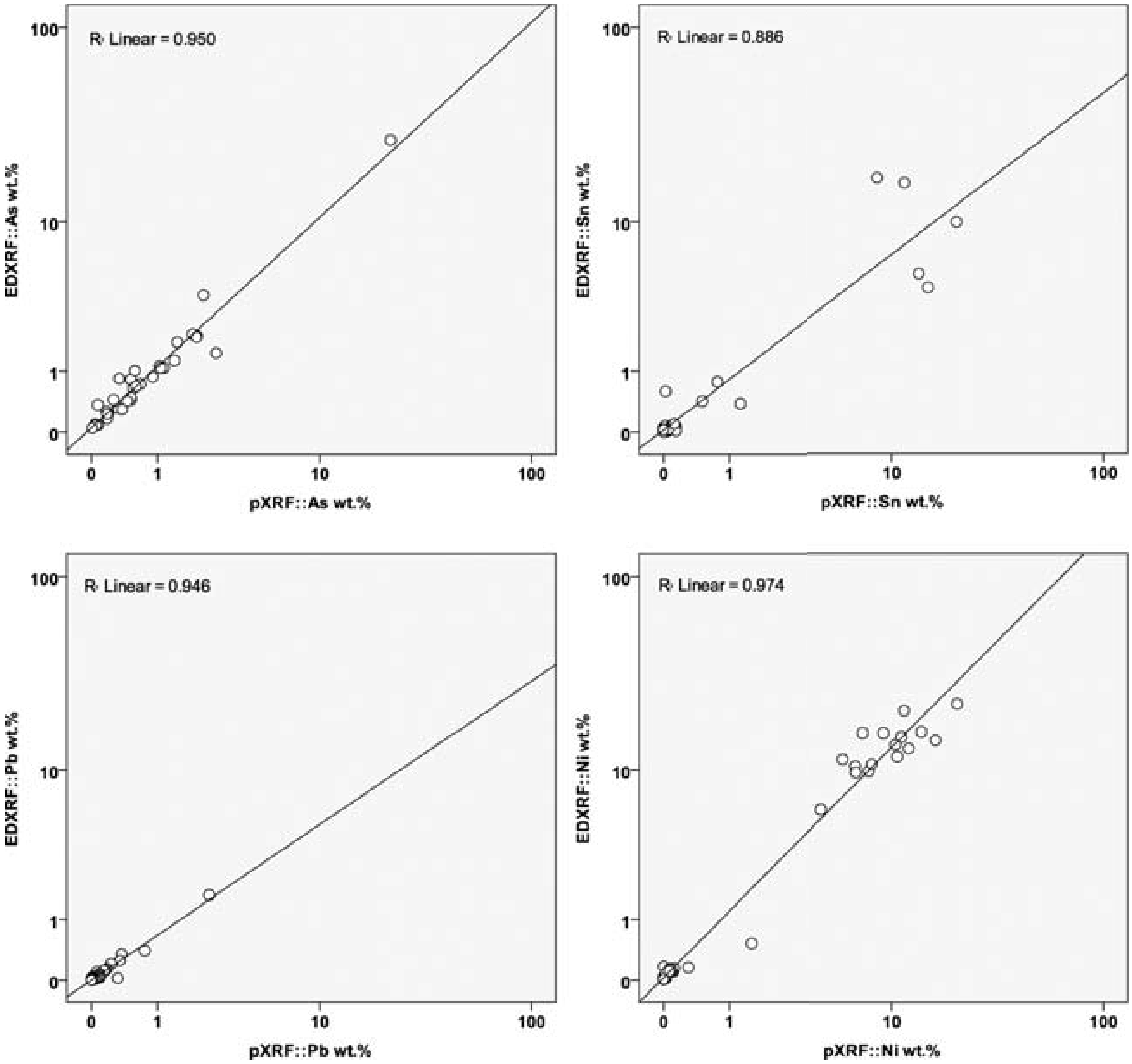


Figure 5.1: Comparison of EDXRF and pXRF methods across elements arsenic (As), tin (Sn), lead (Pb), and nickel (Ni).

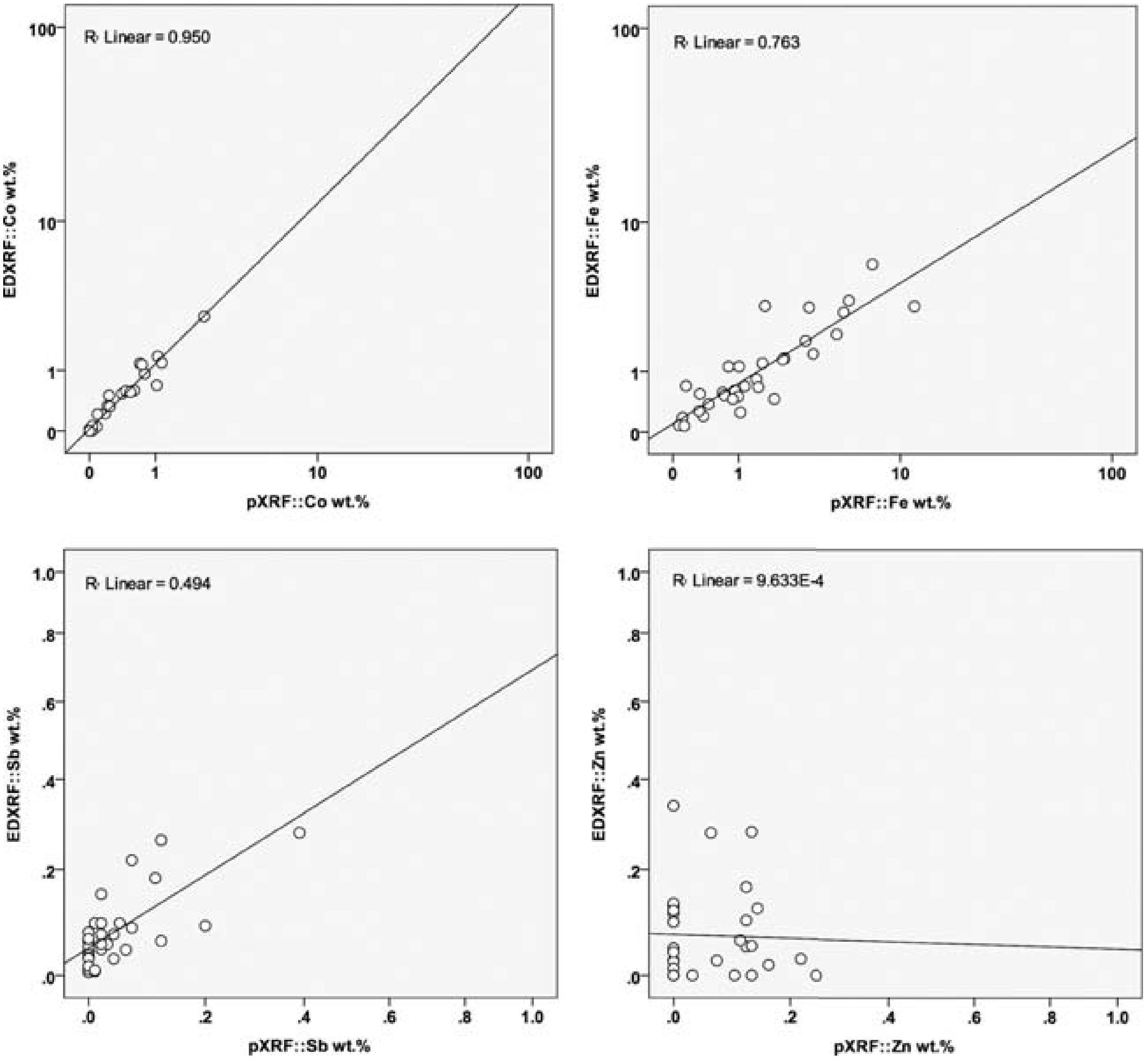


Figure 5.2: Comparison of EDXRF and pXRF methods across elements cobalt (Co), iron (Fe), antimony (Sb), and zinc (Zn).

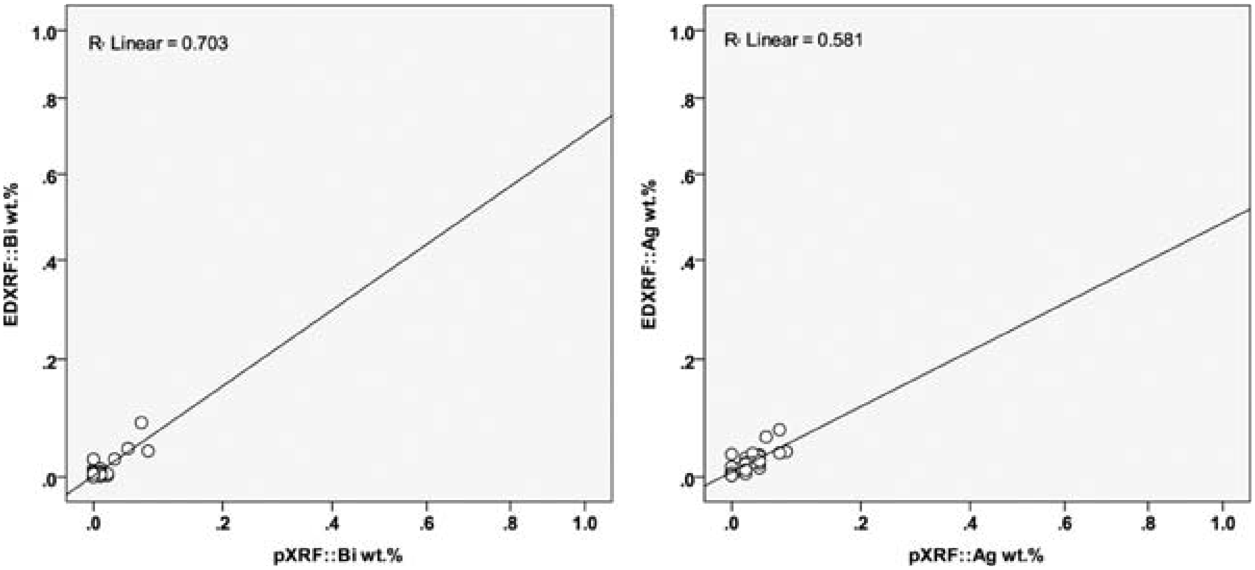


Figure 5.3: Comparison of EDXRF and pXRF methods across elements bismuth (Bi) and silver (Ag).

5.3 Distribution of major and minor elements

The results of the all compositional analyses using pXRF and EDXRF can be found in Appendix B and C. The discussion below employs simple statistical summaries of the elemental concentration data. Aside from copper, all the analyzed major and minor elements are described individually here by giving the mean average, median, absolute range, and the 5th-95th percentile range. Furthermore, the statistical summaries for each period and site are presented in two broad subset categories: a summary for tin bronze (i.e. all objects containing more than 1% tin) and a summary for copper (i.e. all objects containing less than 1% tin). A single sample of silvered copper (Cu-Ag) from Kerkenes Dağ will not be discussed as part of the statistical description. For all elements, concentration distributions are presented graphically as frequency histograms in log scale to aid the interpretation.

These subset groups closely resemble functional groups of copper alloy types, however this analysis does not make an a priori assumption about the intentionality of these alloy types. These types reflect empirically defined groups observed in the total assemblage, and as such they are treated here as quantitative types rather than known culturally or historically determined categories of metal or technology. The cut-off of 1% for most elements follows similar analytical programs, except for zinc which I consider at 5% or more due to the high variability in zinc content of ores and smelting conditions (see also Thornton 2007). Additionally, these subset groups defined here most likely represent intentional mixing during some stage in the production sequence. This is possible to assume because these elements often do not co-occur in common copper ore types at such high concentrations, especially in the case of tin and zinc. These elements often only enter the metal system through the intentional addition of different ore types in a mixed/co-smelting technique, through a cementation process of adding different ore minerals into molten copper, or in the later remelting of different metal types together in a crucible. This issue is discussed further in the discussion section of this chapter.

5.3.1 Arsenic

Arsenic content is an important marker for ore choice, reduction technologies, and alloying traditions; however, it is often impossible to discriminate among these processes because significant concentrations of arsenic can be attained in any and each of these principle steps or decisions during the production sequence (Lechtman 1991, 1996; Lechtman and Klein 1999). For this reason there is considerable debate regarding the functionality of arsenic in archaeological metal (Thornton 2010), which is further kindled by the lack of strong empirical evidence left in the archaeological record of arsenical copper production (Rehren, et al. 2012; Thornton, et al. 2009).

A summary of the EDXRF and pXRF arsenic measurements from this study are given in Table 5.5 and histograms in Figure 5.4. There is significant variation between assemblages with the commonly observed drop-off of its concentration over time. At Boğazköy during the EBA average arsenic content is ca. 1.8% with a high deviation from the mean given even the smaller sample size. Arsenic content ranges between 0.04 – 3.98% demonstrating that copper production incorporating arsenical ores varied during this time period, likely also reflecting reuse. This likely reflects the intentional alloying of copper with arsenic to improve the performance characteristics of pure copper. The equivalent pattern is observed for the MBA and LBA assemblages with a noted trend for the decrease in arsenic content. During the LBA, several outlier samples with an arsenic content > 5.0%, including pins, needles, and edged-tools, all attest to the presence of an arsenical copper production tradition, but these examples amount to less than one percent of the total analyzed assemblage for the LBA. One remarkable disc-shaped cast pendant (ETD 98/21), with iconographic solar motifs of stylized concentric circles has an arsenic content of 26.9% (Figure 5.9). Compared against the known corpus of copper technologies in all of Anatolia, this object is unique, with the possible technological parallels from late EBA burial goods of cast arsenical copper from Horoztepe (Smith 1973) and other objects of exceptionally high arsenic content from the Caucasus (Meliksetian, et al. 2011). This distinctly silvery alloy is typical of arsenical coppers with high arsenic content, and it is almost impossible that this alloy could have been produced accidentally. Preliminary microscopic investigations reveal that this object was likely cast and cooled rapidly allowing for only limited segregation of arsenic to the cooler surfaces. This observation rules out the possibility that the object's arsenic content is primarily superficial, the result of arsenic sweating, inverse segregation, or a coating from direct contact with arsenic-enriched hot vapor. High arsenical copper is also shown by the well-known EBA cast bronze bull from Horoztepe mentioned above, however in this case superficially-enriched arsenic appears to be the result of inverse segregation rather than vapor coating (see Smith 1973 for a discussion of the microstructure). More likely is the addition of arsenical minerals to a smelt or molten copper to produce high arsenical copper. Minerals such as the brightly colored arsenic sulphides realgar (As_4S_4) and orpiment (As_4S_3), which are known in north-central Anatolia (Özbal, et al. 2008), could have been directly added to molten copper, allowing the reduction and diffusion of arsenic.

Table 5.5: Arsenic (As) content of copper alloys at Boğazköy and Kerkenes Dağ.

	Copper			Tin Bronze		
Arsenic %	**Mean**	**Median**	**Range**	**Mean**	**Median**	**Range**
Boğazköy (EBA)	1.87	1.32	< 0.04 - 3.98			
Boğazköy (MBA)	1.18	1.06	< 0.10 - 3.17			
Boğazköy (LBA)	1.36	1.02	< 0.11 - 3.81	0.98	0.79	< 0.15 - 2.50
Boğazköy (EIA)	0.81	0.54	< 0.12 - 1.74	0.65	0.58	< 0.24 - 1.26
Boğazköy (MIA/LIA)	0.7	0.58	< 0.04 - 1.53	0.36	0.28	< 0.01 - 1.04
Kerkenes Dağ (MIA/LIA)	0.06			0.18	0.11	< 0.01 - 0.68

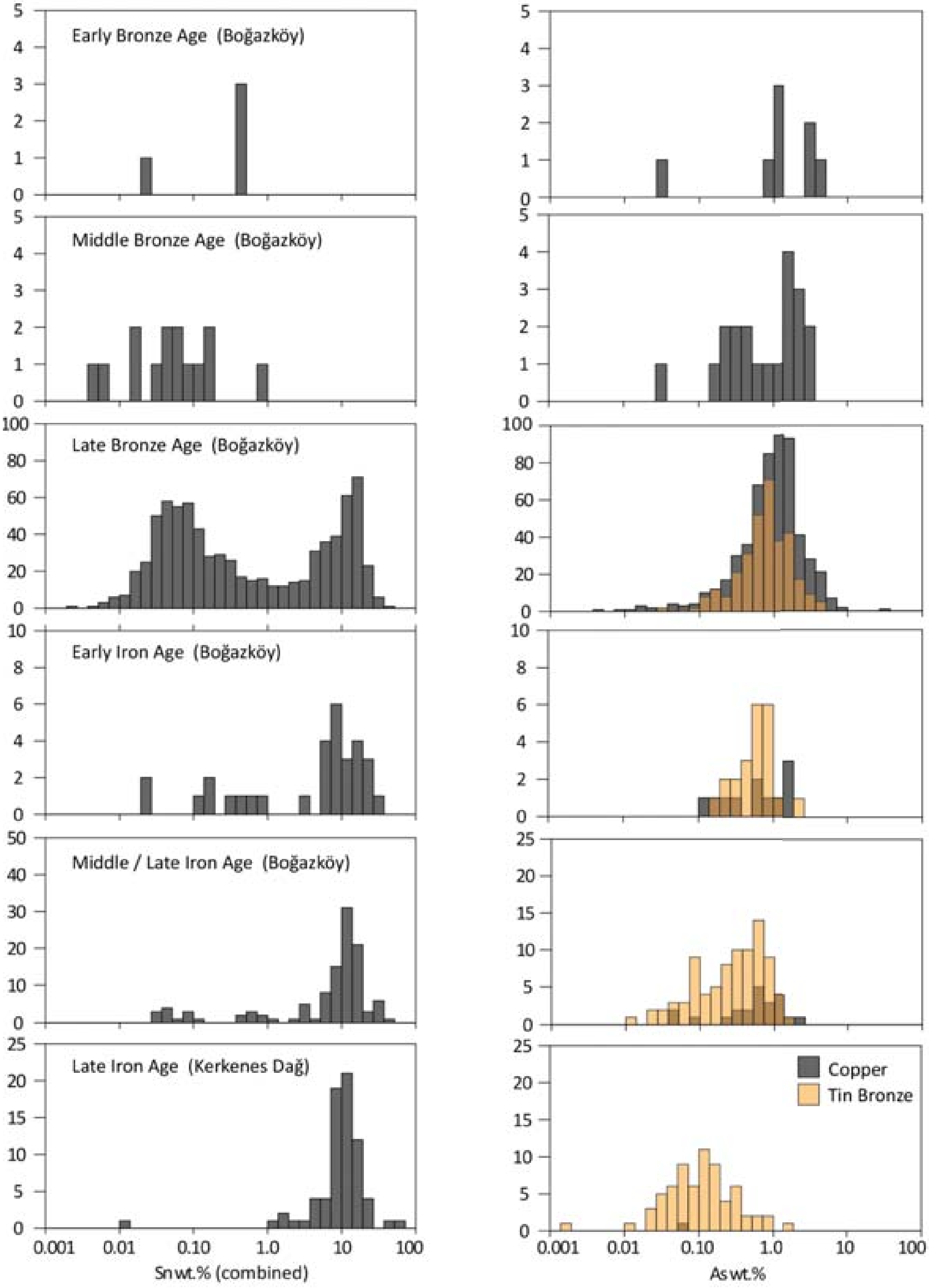


Figure 5.4: Diachronic frequency histograms of tin (Sn) and arsenic (As) from Boğazköy and Kerkenes Dağ. Note that distribution of tin is not differentiated between copper and tin bronze.

Figure 5.5: Cast pendant (ETD 98/21) from Boğazköy. This broken pendant is produced with an exceptionally high arsenic content (26.9% As) and low traces of other elements. This alloy is distinctly silvery in color.

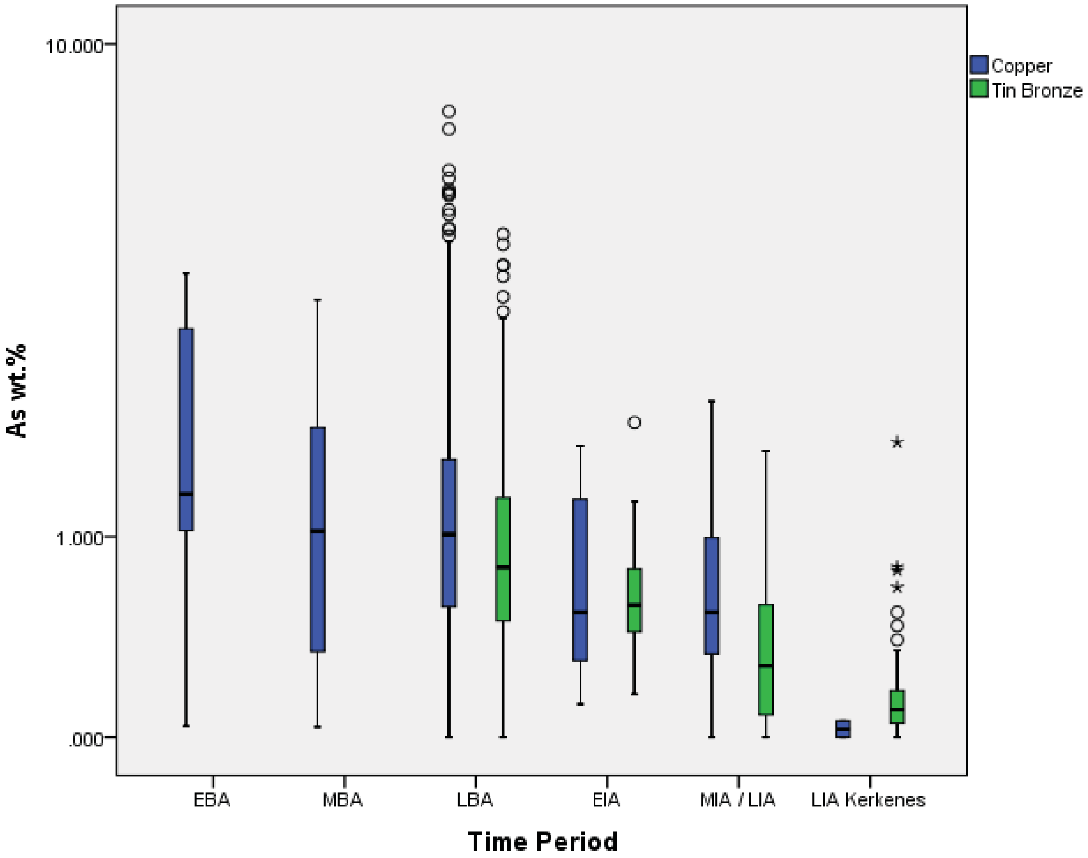


Figure 5.6: Boxplot of arsenic (As) content through time for all objects from the EBA to the LIA at Boğazköy and Kerkenes Dağ. Bars and whiskers show quartile ranges, circles and asterisks symbolize outliers.

There is also a small difference in the average arsenic content between copper and tin bronze, where tin bronzes typically have less arsenic than copper unalloyed with tin. Figure 5.10 demonstrates the marginal deficiency of arsenic among the tin bronzes through time at Boğazköy. During the LBA and the EIA, the presence of ternary Cu-As-Sn alloys is likely explained by recycling practices (Lehner 2014b). This is consistent with the possibility that these alloy types, in aggregate, were treated differentially, which is demonstrates an awareness of the effects of arsenic in copper, even in low concentrations around 1.0% As. The difference in arsenic content between copper and tin bronze becomes greater during the Middle Iron Age, where copper alloyed with tin generally has less arsenic, and those alloys with high zinc (>5.0%) are remarkably deficient in arsenic.

During the Iron Age, arsenic content generally falls into a range 0.1-1.6%, with an average and median within the range of 0.5-0.8%. This pattern contrasts with previous Bronze Age production strategies, which is likely explained by increased efficiencies in copper smelting and a decline in the use of common arsenical minerals like arsenopyrite (FeAsS), arsenic sulphides realgar (As_4S_4) and orpiment (As_2S_3), and even more rare minerals like enargite (Cu_3AsS_4)), all of which are known to occur in polymetallic copper sulphide deposits across Anatolia. Analyses of copper from 7th-6th c. BC contexts at Kerkenes Dağ demonstrate an even further constrained presence of arsenic, with an average content around 0.1-0.2%. Few analyses of archaeological copper from Anatolia dating to this time period have been analyzed to date, so a comparative understanding of parallel industries is not possible at this time. Analyses of Urartian and Late Assyrian metalwork, however, indicate a broadly similar technology in terms of low arsenic content (Curtis 2013; Hughes, et al. 1981).

5.3.2 Tin

Table 5.6: Tin (Sn) content of copper alloys at Boğazköy and Kerkenes Dağ.

Tin %	Copper Mean	Median	Range	Tin Bronze Mean	Median	Range
Boğazköy (EBA)	0.16	0.01	< 0.01 - 0.44			
Boğazköy (MBA)	0.08	0.03	< 0.01 - 0.50			
Boğazköy (LBA)	0.11	0.05	< 0.01 - 0.51	10.5	9.9	1.21 - 22.3
Boğazköy (EIA)	0.24	0.16	< 0.01 - 0.96	12.8	9.9	5.69 - 26.5
Boğazköy (MIA/LIA)	0.25	0.07	< 0.01 - 0.77	12.9	11.6	3.07 - 28.8
Kerkenes Dağ (MIA/LIA)	0.01	0.01	< 0.01 - 0.01	12.3	10.4	1.94 - 23.9

Scholars have recognized for several decades that copper with significant levels of tin, much higher than would have been present in locally-produced Anatolian copper, was present in the region since at least the early third millennium BC (see Chapter 2). In fact, because tin and copper never cooccur in any major copper deposits of Anatolia, we can reasonably assume that copper-tin (Cu-Sn) alloys were produced by the intentional addition of tin to copper to create tin bronze. This provides for an important marker of long-distance exchange and intentionality among technological choices, however the precise economic structures and technological traditions associated with early bronze production are hotly debated because scholars still do not fully understand the origin of tin as a material nor the technological steps by which it was alloyed with copper (Pare 2000; Radivojević and Rehren 2015; Radivojević, et al. 2013).

Tin concentrations measured from all assemblages are summarized in Table 5.6 and illustrated in Figure 5.4. No tin bronzes were observed for the earliest time periods represented at Boğazköy, with tin content remaining unchanged and ranging from < 0.01-0.44% during the EBA and <0.01-0.50% during the MBA. These results contrast strongly with previous work done regarding the Early and Middle Bronze Ages. Until now and for the lack of better data, we assumed that the spread of tin consumption was highly regular among polities across Anatolia. The data from this study, however, points towards a highly irregular consumption pattern of tin across the region, demonstrating how the tin trade did not pervade into all regions, or it is at least not well represented empirically in the contexts at Boğazköy. The lack of tin bronze (the definition of tin bronze in this study copper with more than 1% tin) during these formative periods suggests that tin consumption and its trade did not enter into this small polity until the transformation of the site into the administrative and ritual center of the Hittite Empire during the beginning of the LBA.

During the LBA, the median and mean tin content are both within the well-known 1:10 tin-copper ratio observed across the Near East during the third and second millennia BC. Tin ranges from 1.21-22.3% which demonstrates that tin content was not always selected for a 1:10 alloy. Low tin objects, especially those within 1.0-5.0% range, is largely consistent with the recycling of different imported copper alloys, involving the mixing of tin-bronze objects with local copper. In total, 326 of the 889 LBA objects analyzed in this study contain more than 1% tin, and are thus classified as tin bronzes. This represents about 37% of the entire assemblage, where roughly 33% of the assemblage is arsenical copper and 24% are of pure copper.

The replacement of arsenical copper and pure copper can also be observed in terms of the ratio of tin bronze alloys to other categories of copper alloys. During the EIA there is a noticeable increase in the use of tin to alloy with copper, when bronze accounts for roughly 67% of the assemblage (22 of 33 objects). In general, tin displays a well-known bimodal distribution in the assemblage. This reflects intentionality in alloying. A noticeable mode occurs around 0.4 wt. %, which is a rather enriched presence of tin suggesting that traces of tin entered the metal in a workshop where tin was processed periodically. A second mode exists around the well documented 1:10 ratio. The 1:10 ratio in producing intentional tin bronzes exists cross-culturally, however variations in the concentration of tin demonstrates that this ratio was more of a rule of thumb for a range of concentrations. Among tin bronzes there is a large range from 5.7-26.5% tin, and while this range is likely exaggerated due to surface effects in the analysis, this large range still attests to a significant deviation from the mean ratio of 1:10. At the lower end of the second mode, around 1.0-4.0%, there is little change in the working properties of the alloy (including color, hardness, tensile strength, etc.), which suggests that alloys in this range are produced by mixing metals through a process of recycling.

Together with a large assemblage of production debris, two samples of very well preserved bronze casting waste (ETD 97/236 and ETD 97/239) associated with a casting workshop located at Büyükkaya (Seeher 1998): fig. 11) demonstrates the production of tin bronze during the later phase of the EIA. A large concentration of iron (1-2.5 wt.%) was trapped in the copper metal, most likely in oxide form, which suggests that either the casting debris comes from a fairly impure copper or iron was enriched on the surface as corrosion within intragranular cracks of the metal. Both samples were fairly enriched in tin with concentrations over 15% and up to 19.2% however they vary in the amount of lead and silver. This suggests that several episodes of remelting and casting are represented in the assemblage. A relatively high concentration of silver 1.37% found in sample ETD 97/236 suggests further that this metal was derived from the remelting of scavenged metal that were plated in silver – a practice well known to earlier periods in Anatolia and several examples exist in Boğazköy.

During the Middle and Late Iron Age occupation at Boğazköy, represented by 117 objects predominantly from occupational contexts at Büyükkaya, Kesikkaya, and the Sarıkaya Valley, the ratio of tin bronze increases relative to copper and arsenical copper. Among the

MIA/LIA assemblages at Boğazköy, 79% are classified as tin bronze, accounting for more than twice the ratio of tin bronze during the Late Bronze Age. At Kerkenes Dağ, from 74 copper alloy objects nearly all are alloyed with tin, with roughly 89% of the assemblage total comprising tin bronze and 8% of the assemblage comprising tinned low zinc brasses (Cu-Sn-Zn). Only one object from Kerkenes Dağ is classified as pure copper – a small dome-headed tack from the Palace Complex (05TR21U09met03).

5.3.3 Lead

Lead may enter copper alloys through either its intentional addition or unintentionally through the smelting of copper ores together with lead minerals which are commonly present with polymetallic ores in Anatolia. Furthermore, the reducibility of lead is quite high relative to copper, in addition to its lower melting temperature, permits the entrapment of lead metal into smelted copper up to several percent before one might remove visible lead minerals. The advantages of lead in a copper alloy would likely have been noticed by smiths for its diagnostic properties in lowering the melting temperature of the alloy, improving the castability, and ductility, among a range of other performance characteristics. These advantages led many early smiths to intentionally add lead metal into alloys, especially when casting objects into complex molds. Because these two trajectories explain the presence of lead, and are not necessarily mutually exclusive, it is often impossible to determine convincingly which trajectory was in operation. Exceptions include when excessive amounts of lead are measured, often in the range of greater than 8-10% lead.

The lead (Pb) concentrations observed in objects analyzed for this study are summarized in Table 5.7 and Figure 5.5. Median lead concentrations are between 0.11-0.17% for the Early and Middle Bronze Age with little variation between the two periods. During the Late Bronze Age, the median value for lead remains in the 0.12-0.19 range across alloy groups, however a much higher variation in lead concentration is observable across the assemblage. 19 copper alloy objects from the LBA assemblages have more than 2.0% lead, with one object observed with a 22% lead concentration. This object is a small cast figurine of a horned bull with a bottom socket (Bo 89/41) which was discovered in the northwestern section of the Südburg. This concentration almost certainly is derived from the intentional addition of lead into the low tin bronze alloy.

A similar pattern is observed during the Iron Age, where a small proportion of tin bronzes have appreciable concentrations of lead. During the Early Iron Age at Boğazköy, only two objects have greater than 2.0% lead, including a single cast stemmed and spurred arrowhead of distinct design (Bo 97/25) with around 26% lead. Objects dating to later phases of the Iron Age at Boğazköy demonstrate a great use of leaded tin bronzes. Around 15% of the total assemblage appears to be leaded, including mostly, although not exclusively, cast objects like bilobate/trilobite arrowheads and fibulae. Interestingly, not all arrowheads and fibulae are leaded tin bronzes, which demonstrates wide variation in alloy choice across broad categories of common metal object types. At Kerkenes Dağ, leaded tin bronzes are also common among cast objects like fibulae and arrowheads, providing excellent primary evidence that leading tin bronzes was a commonly practiced technology and widespread in central Anatolia during the Iron Age.

Table 5.7: Lead (Pb) content of copper alloys at Boğazköy and Kerkenes Dağ.

		Copper			Tin Bronze	
Lead %	**Mean**	**Median**	**Range**	**Mean**	**Median**	**Range**
Boğazköy (EBA)	0.34	0.17	< 0.01 - 1.50			
Boğazköy (MBA)	0.21	0.11	< 0.01 - 0.76			
Boğazköy (LBA)	0.30	0.12	< 0.01 - 1.29	0.44	0.19	< 0.01 - 1.29
Boğazköy (EIA)	0.18	0.18	< 0.02 - 0.47	1.71	0.22	< 0.05 - 6.14
Boğazköy (MIA/LIA)	0.34	0.09	< 0.02 - 1.13	1.38	0.36	< 0.01 - 5.48
Kerkenes Dağ (MIA/LIA)	0.07	0.07	< 0.07 - 0.07	1.48	0.26	< 0.02 - 9.07

5.3.4 Iron

Iron content in the objects measured in this study can be relatively high, where concentrations can reach in access of 4.0% iron in some objects. These high values, which in one sample from Kerkenes Dağ reaches as high as 19.3% iron (11TR24U21met02), are likely the result of iron-rich contamination at the surface and in intra-granular corrosion. However results in the 1.0-4.0% range are entirely possible, indicative of a smelting technology operating at reasonably high temperatures and increased reducing environments (Cooke and Aschenbrenner 1975: 264; Craddock and Meeks 1987). Iron content can also indicate proximity to the original smelt in the production chain, where each remelting event could lead to decreases in iron which would oxidize rapidly. Therefore, it becomes difficult to determine with bulk analyses like XRF whether elevated concentrations of iron are the result of contamination, bimetallic microstructure, or small amounts of iron alloyed with copper. In these cases, often the only method to determine the actual concentration of iron in copper is with EPMA analysis coupled with microscopy.

A large miscibility gap in the iron-copper thermodynamic system prevents the two metals from forming an alloy. At around 835˚C a solid phase of 98.1% iron will be in equilibrium with a

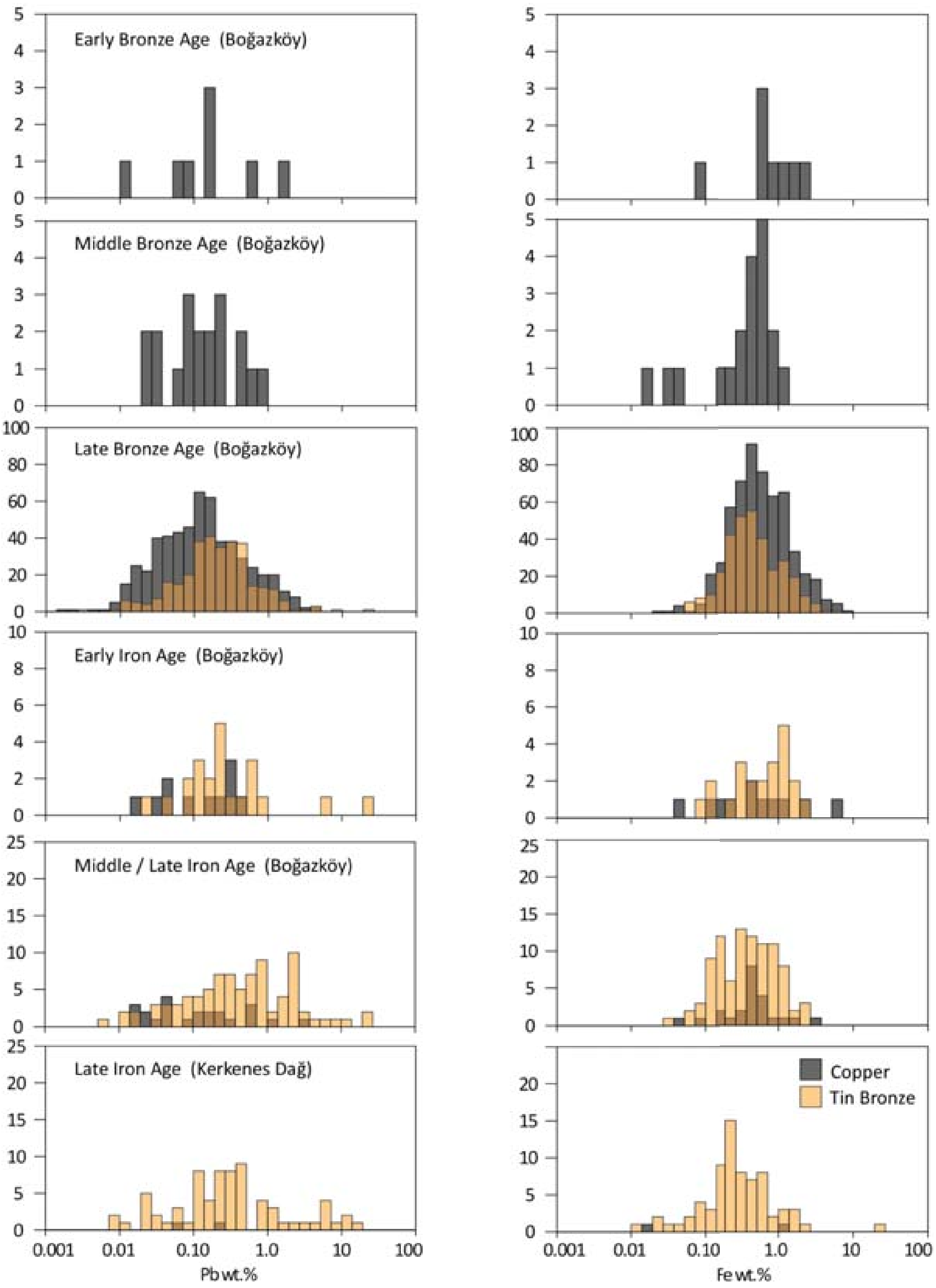


Figure 5.7: Diachronic frequency histograms of lead (Pb) and iron (Fe) from from Boğazköy and Kerkenes Dağ.

liquid phase of copper containing 98.7 copper, whereupon cooling the resultant material would be a highly segregated, brittle bimetallic and not an alloy (Cooke and Aschenbrenner 1975: 259). Further adding to the complexity of this system, experiments have shown that once other alloying agents like arsenic, tin, nickel, and cobalt are added to the iron-copper system, the solubility limit of iron increases. Cooke and Aschenbrenner also note that there should be no major difference in the performance characteristics of a few percent of iron in copper (1975: 266), however further quantitative research of this sort should be undertaken to test their experimental results.

Iron content in the objects analyzed in this study are summarized in Table 5.8 and presented graphically in Figure 5.5. During the earliest periods, iron content ranges from 0.02-2.08% with a single mode around 0.60%. A couple of pins from Büyükkaya (Bo 96/38 and ETD 97/196) have iron concentrations around 2.08 and 1.45% respectively and a single flat knife from the Lower City (Bo 348/h) with a value of 1.38%, all of which demonstrate the range in which iron content is reflected across a range of finished object types. A single planoconvex ingot from a residential context in the Lower City is remarkably deficient in iron (Bo 11/590, 0.04% iron), suggesting that this ingot may have been refined before arriving to Boğazköy.

During the Late Bronze Age, the larger sample size permits a more refined understanding of the distribution of iron concentration across the assemblage. A single mode exists around 0.60% iron and is well distributed in a range of 0.13-2.76%, with objects as high as 8.39% iron. There is an appreciable difference between copper/arsenical copper and tin bronze in iron content. In aggregate, iron content is lower in tin bronze alloys suggesting that purer copper was chosen to alloy with tin before the production of finished objects, or the alloying process itself drew iron out of the molten copper. That iron content is generally higher among arsenical copper alloys also suggests that iron minerals were associated with arsenical copper production specifically, an observation that is consistent with iron arsenide production at Early Bronze Age Arisman in Iron (Rehren, et al. 2012). Two locally produced pure planoconvex copper ingots from Late Bronze Age Boğazköy (Bo 83/819 and Boehmer 1972: Nr. 190) attest to some of these patterns. These demonstrate a significant range in iron content, ranging from 3.2 to 0.07% iron, yet remarkably deficient in arsenic (0.05 to 0.09% As respectively).

The remarkable presence of cupronickel at Boğazköy, defined as alloys with greater than 1% Ni, also demonstrate significant quantities of iron. This is likely explained by the increased miscibility of iron in nickel and cobalt than with copper alone. This interesting observation, which has only been observed previously in a few samples from Kaman Kalehöyük (Hirao and Enomoto 1997), suggests that iron minerals played a significant role in the reduction of nickel rich copper ores or mixed ore smelts.

During the Iron Age, nascent concentrations of iron appear to increase briefly during the Early Iron Age and then drop again during subsequent periods. A single lamellar disc headed pin (Bo 97/35) from Büyükkaya has a concentration of 5.6% iron but also significant concentrations of arsenic (1.1%) and nickel (2.6%). Tin bronze casting waste (ETD 97/239 and ETD 97/236) is also enriched in iron (2.5% and 1.05%, respectively), which demonstrates the accidental presence of iron in the production of cast tin bronze objects. In aggregate the average iron concentration decreases during the Middle and Late Iron Ages with a mode value at 0.48%, however several objects have concentrations between 2-3.0% iron. At Kerkenes Dağ, the average iron content is even lower, with only two examples above 2.0% iron, including two indeterminate tools (11TR29U34met02 and 11TR24U21met02). The modal value for this assemblage is around 0.25%.

Table 5.8: Iron (Fe) content of copper alloys at Boğazköy and Kerkenes Dağ.

Iron %	Copper Mean	 Median	 Range	Tin Bronze Mean	 Median	 Range
Boğazköy (EBA)	0.91	0.68	< 0.09 - 2.08			
Boğazköy (MBA)	0.49	0.41	< 0.02 - 1.15			
Boğazköy (LBA)	0.85	0.53	< 0.13 - 2.76	0.65	0.43	< 0.11 - 1.86
Boğazköy (EIA)	1.06	0.46	< 0.04 - 5.63	0.81	0.76	< 0.10 - 1.57
Boğazköy (MIA/LIA)	0.61	0.46	< 0.09 - 1.86	0.54	0.39	< 0.09 - 1.56
Kerkenes Dağ (MIA/LIA)	0.02			0.63	0.24	< 0.03 - 1.24

5.3.5 Nickel and Cobalt

Nickel and cobalt, together with iron, often co-occur among ore deposits in Anatolia, and because of their similar physical properties they often behave similarly (Davis 2000). For this reason, very significant correlations between nickel and cobalt are often observed among archaeological copper alloys, especially when concentrations exceed 1000 ppm in either element. Additionally, nickel and cobalt are excellent indicators of the kinds of ores used in the primary reduction of the copper metal, as has been demonstrated for Bronze Age copper alloys derived from nickel-containing falhores across central Europe (Krause 2003) and nickel-rich copper sulphides in the highlands of the Near East (Hauptmann 2007: 297; Tadmor, et al. 1995) and the Arabian Peninsula (see Weeks 2004: and references therein).

Concentration summaries of nickel are found below in Tables 5.9 and 5.10 respectively, and they are displayed in histograms in Figure 5.6. Nickel ranges from less than the detection limit at <0.01 to 0.04% during the Early Bronze Age, but during the Middle Bronze Age a small mode in the 0.2-0.3% range occurs, indicative in the utilization of a new ore source. This observation also holds for recent analyses of copper alloys at the regional center of EBA and MBA Kültepe-*Kaniš* in central Anatolia (Lehner, et al. 2015). This is consistent with an

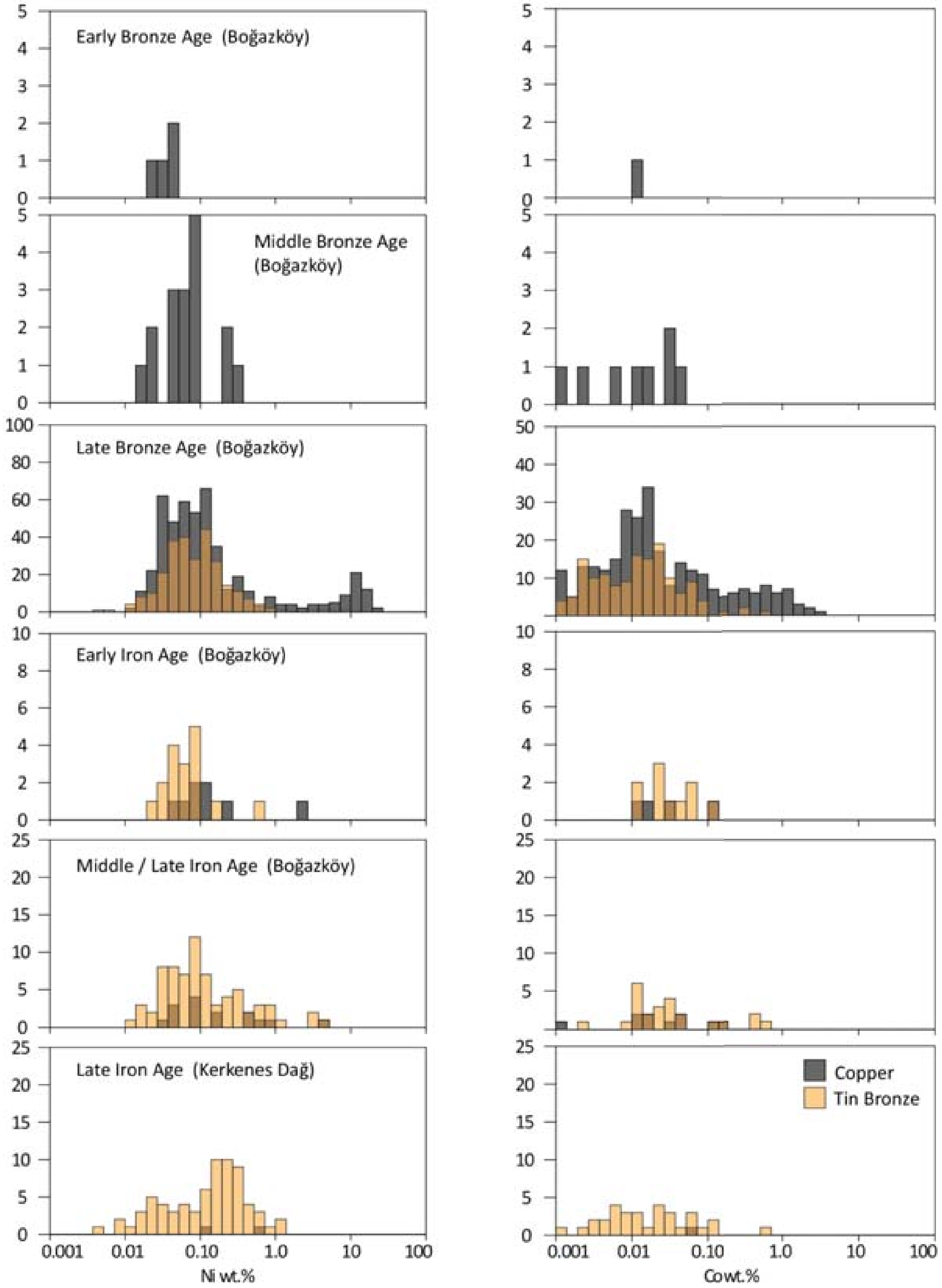


Figure 5.8: Diachronic frequency histograms of nickel (Ni) and cobalt (Co) from from Boğazköy and Kerkenes Dağ.

increase in the geographic scope and use of increasingly diverse ore choices as the polity size increased.

In addition to this distinct modality, the concentration of nickel and cobalt during the Late Bronze Age at Boğazköy demonstrates two more modalities, both of which can be further characterized as kinds of cupronickel alloy. Cupronickel, which will be discussed further below, is an alloy of nickel with copper and has distinct performance characteristics that distinguish it from arsenical copper. For the purposes of this study, low nickel cupronickel has a nickel content of 1.0-10% and high nickel cupronickel has a content of >10% nickel. These categories are well represented in the Late Bronze Age assemblage at Boğazköy.

The second modality, or low nickel cupronickel, is represented by a diverse array of 34 finished objects found without pattern across contexts at Boğazköy. Aside from two examples, low nickel cupronickel is not alloyed with tin, and is more commonly alloyed with arsenic in excess of 1% As, and it displays a reddish color. This alloy type is well known across the Old World (Slotta 2001) and can be observed as early as the Late Chalcolithic from the metal hoard at Nahal Mishmar (Tadmor et al. 1995, see also Hauptman et al. 2004). It is generally considered that nickel entered the copper here through the unintentional smelting of nickel-rich copper sulphide ores which are common to the ophiolitic deposits spanning from Cyprus, the eastern Taurides, and the southern Arabian Peninsula. A stamp seal excavated (Bo 05/13) from the Late Bronze Age workshop context in the Sarıkale Valley at Boğazköy (Herbordt in Seeher 2006c: 176, 186), which is composed of three distinct alloy types together in one composite object, indicates how specialist metal craftworkers had access to multiple copper alloy types and utilized them selectively (Figure 5.12). This modality of cupronickel is also observed, although much less so, during the Middle and Late Iron Age objects at Boğazköy, which is indicative of either recycling or continued use of nickel-rich ores in the region.

High nickel cupronickel represents the third modality of nickel concentration and is comprised exclusively by 35 objects dating to the Late Bronze Age Anatolian cupronickel dating to the Late Bronze Age was likely produced from a mixed ore smelting process with sulphides like arsenopyrites and chalcopyrites together with minerals rich in nickel and colbalt such as pentlandite or siegenite. Copper-nickel-cobalt sulphide ore sources are rare in Turkey, however exceptions include but are not limited to the Pancarlı copper-nickel source near to Bitlis (Çağatay 1987) and the nickel-iron sulphide deposits near to Divriği, Sivas (Harada, et al. 1971). Because the solubility limits of cobalt and iron increase with nickel, nickel copper alloys tend to exhibit high correlations with these traces. One striking example is a large typical rolled head pin (Bo 09/972) with a composition of 22.4 wt.% Ni, 2.7 wt.% Co, 5.8 wt.% Fe, and the remainder is copper with traces of tin (Figure 5.13). Backscatter analysis using SEM-EDS detected a compositional gradient of these four elements with high nickel phases upwards of 33.7 wt.% Ni, 5.3 wt.% Co, and 11.3 wt.% Fe.

However, two major variables determine the composition of nickel, cobalt, and iron in copper alloys. First, copper nickel sulphide ores will have varying initial compositions of cobalt and iron. Second, these elements have varying oxidation stabilities in relation to temperature, which means that their composition depends partly on the smelting environment. Figure 5.13 compares cobalt and nickel across time periods and sites to demonstrate how these two variables may affect the observed compositions. In these data, there are at least two positive trends, best visible in the Late Bronze Age assemblage. These data are inconclusive by themselves in determining which of the two above variables are more important. However the data are consistent with at least two major copper nickel sources, two smelting technologies, or both.

Cupronickel at Boğazköy appears to be limited to ornaments composed of finely hammered sheet pendants, pins, and seals. The chain links of the tin bronze tablet with the inscribed treaty between Tudḫaliya IV and Kurunta of Tarhuntassa were also made from cupronickel with around 6.49-7.17 wt.% Ni and impurities of cobalt and iron (Zimmermann, et al. 2010). Low nickel cupronickel (ca. 1.0-8.0 wt.% Ni) is well-known to the Near East, with early examples from the Nahal Mishmar hoard and elsewhere in Syro-Mesopotamia and the upper Euphrates (Hauptmann, et al. 2002b; Hauptmann and Pernicka 2004; Tadmor, et al. 1995). High nickel cupronickel is better known in the archaeological literature as occurring with Bactrian coinage ca. 170 B.C. (Cheng and Schwitter 1957; Howard-White 1963; Schwitter and Cheng 1962) which are suggested to derive from nickel-rich ore bodies in East Asia (Chen, et al. 2009). The Bactrian alloys differ because they are often also alloyed with zinc or lead. High nickel cupronickel may be considered exceptional because nickel changes the color of copper rapidly to a silvery color with increasing concentrations, and it alters the working properties of copper, too. At higher concentrations of nickel, copper-nickel alloys become more ductile however they work-harden quickly upon cold hammering. These characteristics would have surely been noticed by metal smiths.

There is no reason to suggest that the technologies behind the production of Bactrian coinage and those represented at Hattuša are genetically linked, however its precocious development in Anatolia, apparently, is certainly intriguing. A few examples have been also noted at Kaman-Kalehöyük (Hirao and Enomoto 1997) and in an unprovenanced example of a bracelet with an inlayed and stylized electrum repoussé presentation scene from Çorum province with around 16.5 wt.% Ni and 2 wt.% Co (Lehner in press-b). Another unprovenanced example of a figurine in 'Hittite' style is known to the Levant with around 17 wt.% Ni and 2.1 wt.% Co (Northover 1998).

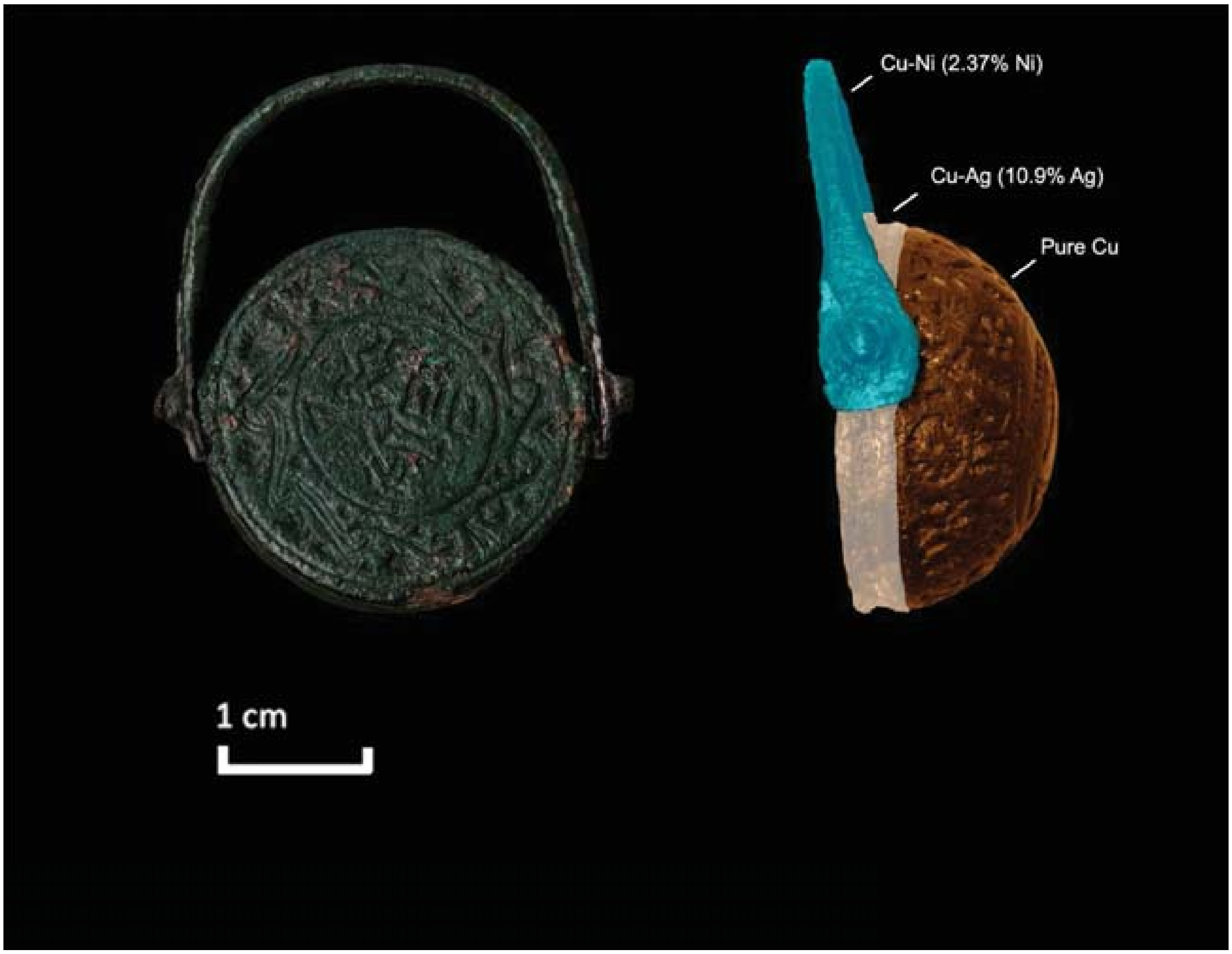
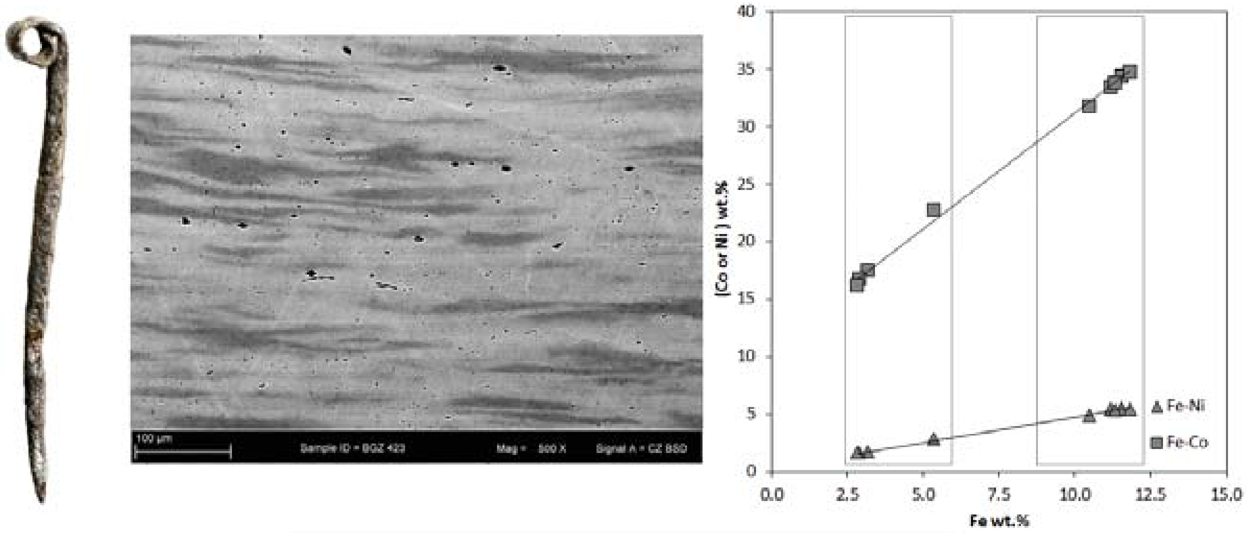


Figure 5.9: Stamp seal (Bo 05/13) composed of three separate copper alloys, including an attached band of low nickel cupronickel.



	Cu wt.%	Fe wt.%	Co wt.%	Ni wt.%
Dark phase	49.6	11.3	5.3	33.7
Light phase	78.5	2.9	1.6	16.7

Figure 5.10: In depth analysis of rolled head pin (Bo 09/972) from the Sarıkale Valley of Boğazköy. Point analyses across light and dark phases in the backscatter electron image (center) indicates a very strong coherence among related elements nickel, cobalt, and iron, reflecting the original casting segregation.

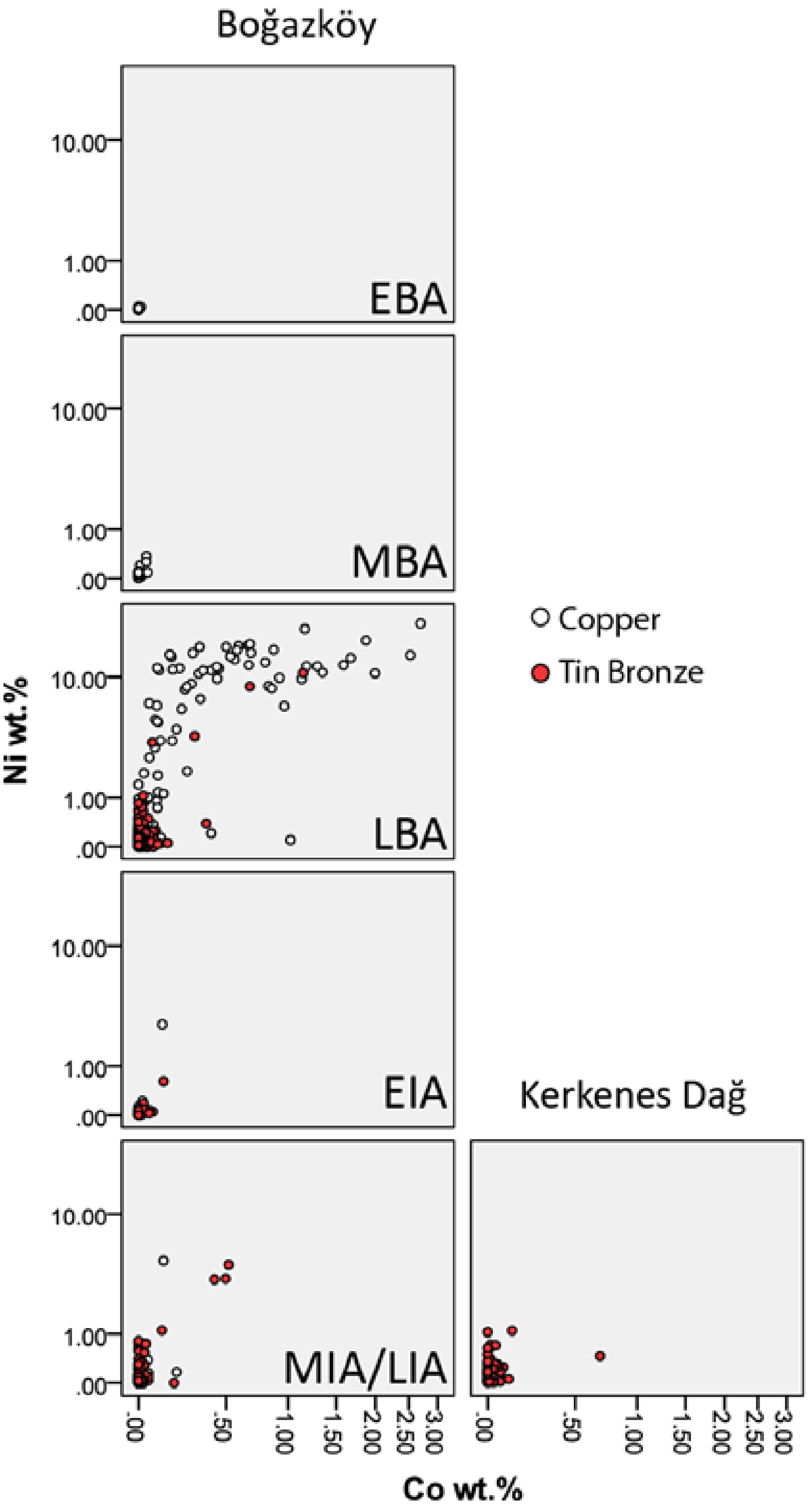


Figure 5.11: Concentrations of nickel (Ni) and cobalt (Co) compared across time periods and sites in this study.

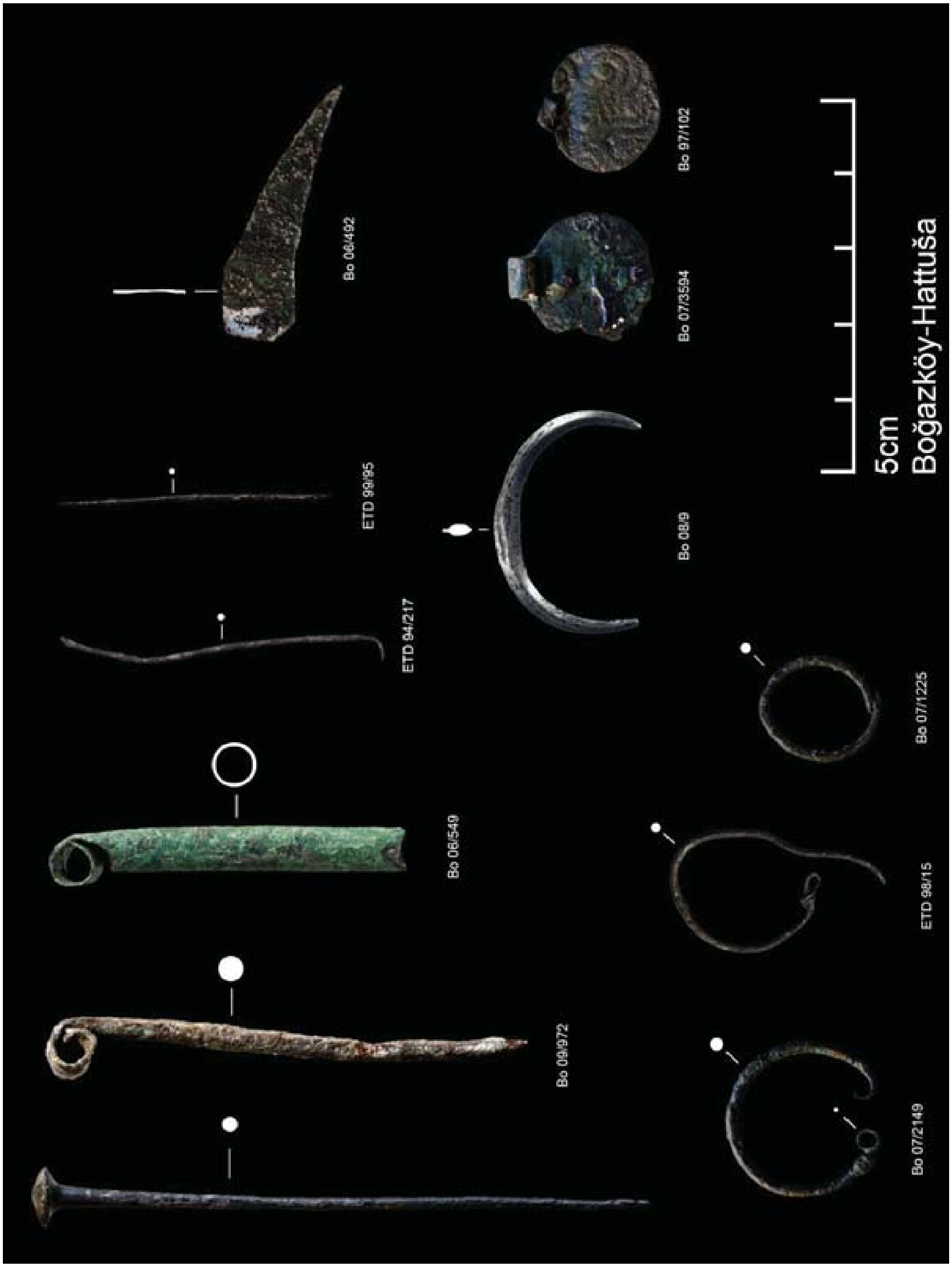


Figure 5.12: Select examples of finished objects produced of high nickel cupronickel (>10.0 wt.% Ni) from Boğazköy dating to the Late Bronze Age.

Table 5.9: Nickel (Ni) content of copper alloys at Boğazköy and Kerkenes Dağ.

	Copper			Tin Bronze		
Nickel %	**Mean**	**Median**	**Range**	**Mean**	**Median**	**Range**
Boğazköy (EBA)	0.02	0.01	< 0.01 - 0.04			
Boğazköy (MBA)	0.08	0.07	< 0.01 - 0.31			
Boğazköy (LBA)	1.18	0.07	< 0.01 - 11.2	0.18	0.06	< 0.01 - 0.40
Boğazköy (EIA)	0.30	0.08	< 0.01 - 2.61	0.08	0.05	< 0.01 - 0.17
Boğazköy (MIA/LIA)	0.33	0.05	< 0.01 - 0.75	0.25	0.06	< 0.01 - 0.82
Kerkenes Dağ (MIA/LIA)	0.12			0.22	0.17	< 0.01 - 0.71

Table 5.10: Cobalt (Co) content of copper alloys at Boğazköy and Kerkenes Dağ.

	Copper			Tin Bronze		
Cobalt %	**Mean**	**Median**	**Range**	**Mean**	**Median**	**Range**
Boğazköy (EBA)	0.00	< 0.01	< 0.01 - 0.01			
Boğazköy (MBA)	0.01	< 0.01	< 0.01 - 0.04			
Boğazköy (LBA)	0.07	< 0.01	< 0.01 - 0.45	0.02	< 0.01	< 0.01 - 0.06
Boğazköy (EIA)	0.02	< 0.01	< 0.01 - 0.12	0.02	< 0.01	< 0.01 - 0.07
Boğazköy (MIA/LIA)	0.02	< 0.01	< 0.01 - 0.12	0.02	< 0.01	< 0.01 - 0.12
Kerkenes Dağ (MIA/LIA)	0.06			0.02	< 0.01	< 0.01 - 0.08

5.3.6 Antimony, Silver, and Zinc

The concentrations of antimony (Sb), silver (Ag), and zinc (Zn) are summarized below in Tables 5.11, 5.12, and 5.13, respectively. Histograms of the respective elements are also given in Figures 5.7-5.8. These elements are generally considered trace elements in Bronze Age and Iron Age copper alloys, and they are often indicative of the types of ores used in the primary production of raw copper. In particular, antimony and silver are sensitive to ore attribution studies because these metals tend to maintain their relative ratios from ore to metal, however ore smelting technologies may alter these ratios depending on temperature and reducing conditions. There are no general trends noticed from these trace elements that are considered meaningful in this study across all time periods for antimony and silver, aside from the possibility that there may exist a bimodal distribution for silver during the Early and Middle Bronze Ages.

At Kerkenes Dağ, there is an important rise in the content of zinc alloyed with copper among select objects. This is particularly remarkable because zinc vaporizes rapidly and is generally lost to the air in most open smelting and melting environments. Zinc in excess of 5% is noted for several samples from Kerkenes Dağ, which suggests that zinc may have been intentionally controlled for using a cementation process. In this process, zinc ores may be directly added to molten copper into a covered crucible, which prevents zinc vapor from escaping, effectively entrapping the metal into an alloy of brass (Thornton 2007). Craddock (1978) and Forbes (1964: 268-269) in fact posited that copper-zinc alloys were innovated first in Anatolia, as evinced by the discovery and analysis of early brass artifacts from Tumulus MM at Gordion (Steinberg 1981). Yet it is clear that copper-zinc alloys are dated much earlier into the first half of the 3rd millennium BC in the Aegean and Mesopotamia (Thornton 2007: 126). The finds are exceedingly rare which suggest that the production of early copper-zinc alloys was either quite limited in production or the result of accidental production from zinc-rich copper ores. The development of brass in the Iron Age, which is poorly understood in the pre-Roman periods, suggests that metalsmiths selected ores specifically to create alloys ultimately similar to tin bronze but altered the alloy to produce a metal that was increasingly similar to gold.

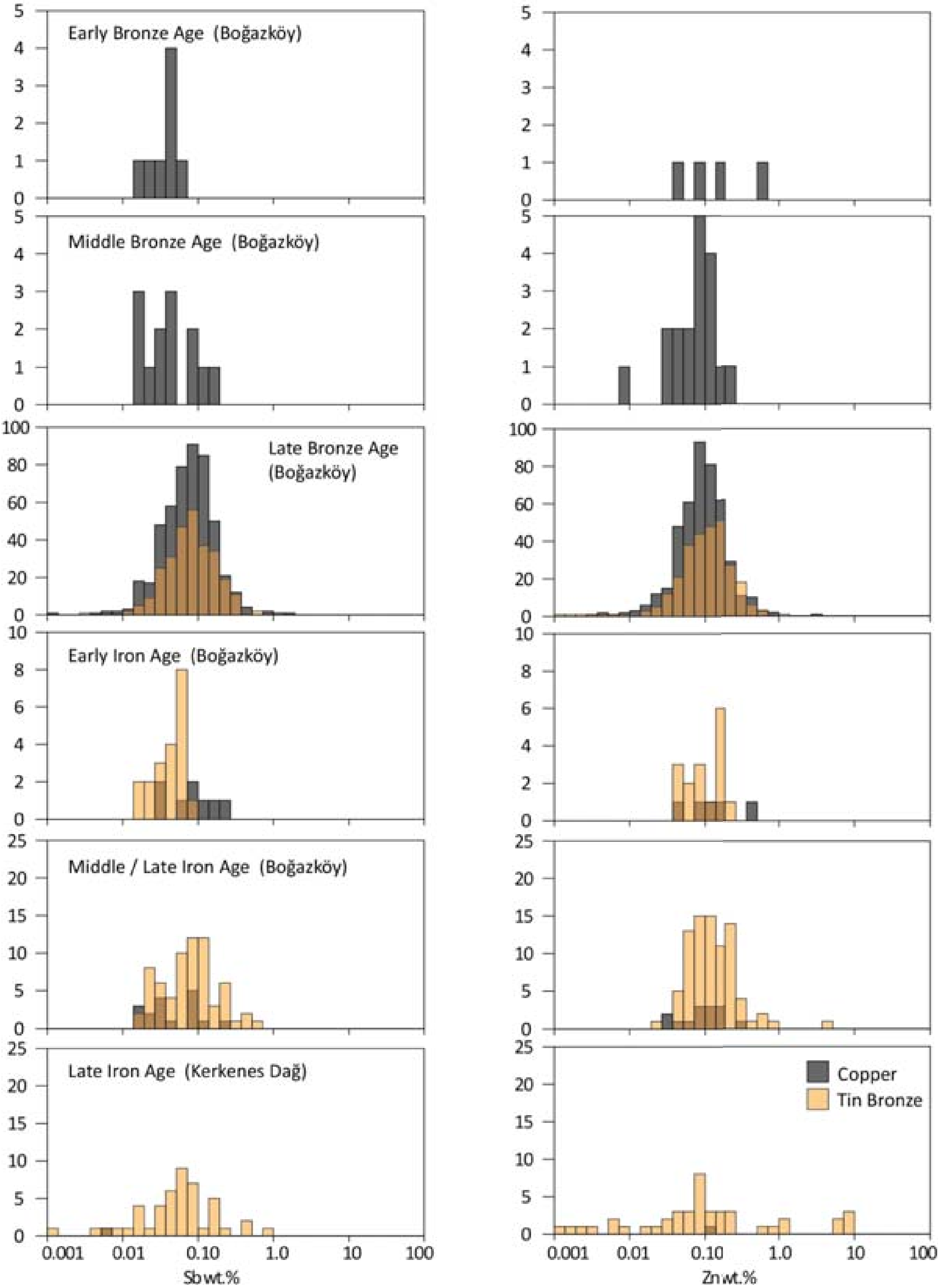


Figure 5.13: Diachronic frequency histograms of antimony (Sb) and zinc (Zn) from Boğazköy and Kerkenes Dağ.

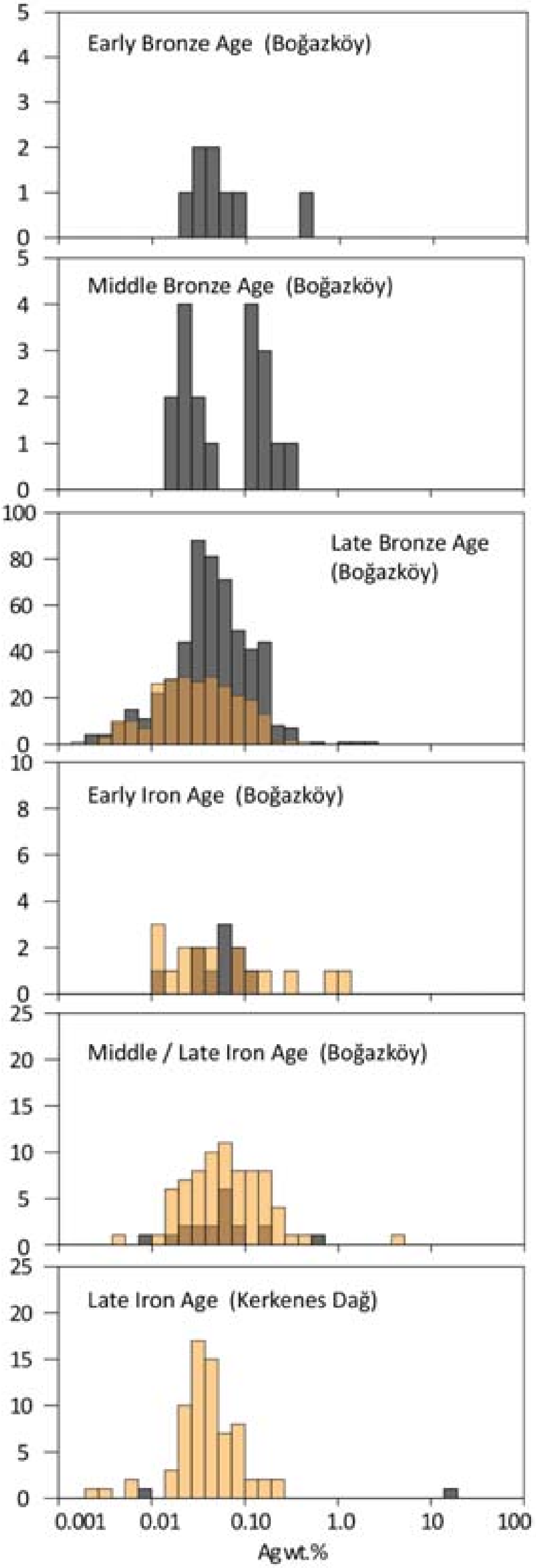


Figure 5.14: Diachronic frequency histograms of silver (Ag) from Boğazköy and Kerkenes Dağ.

Table 5.11: Antimony (Sb) content of copper alloys at Boğazköy and Kerkenes Dağ.

	Copper			Tin Bronze		
Antimony %	**Mean**	**Median**	**Range**	**Mean**	**Median**	**Range**
Boğazköy (EBA)	0.04	0.04	< 0.02 - 0.06			
Boğazköy (MBA)	0.03	0.02	< 0.01 - 0.13			
Boğazköy (LBA)	0.09	0.07	< 0.01 - 0.24	0.09	0.07	< 0.01 - 0.26
Boğazköy (EIA)	0.07	0.07	< 0.01 - 0.22	0.04	0.04	< 0.01 - 0.06
Boğazköy (MIA/LIA)	0.05	0.03	< 0.01 - 0.18	0.08	0.06	< 0.01 - 0.24
Kerkenes Dağ (MIA/LIA)	0.01			0.07	0.03	< 0.01 - 0.24

Table 5.12: Zinc (Zn) content of copper alloys at Boğazköy and Kerkenes Dağ.

	Copper			Tin Bronze		
Zinc %	**Mean**	**Median**	**Range**	**Mean**	**Median**	**Range**
Boğazköy (EBA)	0.10	0.03	< 0.10 - 0.56			
Boğazköy (MBA)	0.08	0.08	< 0.10 - 0.18			
Boğazköy (LBA)	0.10	0.08	< 0.10 - 0.26	0.12	0.10	< 0.10 - 0.33
Boğazköy (EIA)	0.07	< 0.01	< 0.10 - 0.38	0.09	0.07	< 0.10 - 0.18
Boğazköy (MIA/LIA)	0.07	0.06	< 0.10 - 0.18	0.19	0.10	< 0.10 - 0.38
Kerkenes Dağ (MIA/LIA)	0.12			0.09	< 0.10	< 0.10 - 0.56

Table 5.13: Silver (Ag) content of copper alloys at Boğazköy and Kerkenes Dağ.

	Copper			Tin Bronze		
Silver %	**Mean**	**Median**	**Range**	**Mean**	**Median**	**Range**
Boğazköy (EBA)	.09	.04	< 0.10 - 0.56			
Boğazköy (MBA)	.09	.04	< 0.10 - 0.18			
Boğazköy (LBA)	.06	.04	< 0.10 - 0.26	0.12	0.10	< 0.10 - 0.33
Boğazköy (EIA)	.05	.05	< 0.10 - 0.38	0.09	0.07	< 0.10 - 0.18
Boğazköy (MIA/LIA)	.07	.05	< 0.10 - 0.18	0.19	0.10	< 0.10 - 0.38
Kerkenes Dağ (MIA/LIA)	.01			0.09	0.00	< 0.10 - 0.56

5.4 Discussion and Conclusion

Figure 5.15 displays the progression of alloy types observed from nearly 1200 objects from Boğazköy and Kerkenes Dağ, demonstrating a progression of several alloy types over time with the greatest diversity occurring during the Late Bronze Age. Relatively pure copper and arsenical copper alloys are most common during the Early and Middle Bronze Age. Surprisingly few objects during the Middle Bronze Age are copper tin bronzes. This may be an effect of sample size and deserves to be investigated further.

The diversity of alloy types dramatically increases during the Late Bronze Age. This comes as somewhat intuitive because we know that the Hattuša as a polity radically increases in size and political and economic influence. Metallurgical technologies and traditions during this time period also develop more standard alloy types as trade in pure metal ingots proliferated, as evinced by the Uluburun shipwreck materials (Hauptmann, et al. 2002a; Yalçın, et al. 2005). Tin bronzes become noticeably more common during this time period, and ternary Cu-As-Sn alloys also appear which is suggestive of recycling but is also consistent with intentional alloying. Leaded alloys also appear during this time period. As previously observed, high nickel copper alloys appear during this time and their use appears to be limited to the Late Bronze Age, however a couple examples of copper-tin bronzes with nickel appear during the Middle and Late Iron Age. This alloy group, which includes Cu-Ni, Cu-As-Ni, Cu-Ni-Sn, and quaternary systems, demonstrates the wide use of this material. It is not yet clear if this alloy group is limited to particular functional tool types or ornaments, but its performance characteristics would have noticeably different from other copper alloys.

Alloying traditions during the Iron Age continue the use of copper tin bronzes for the production of both cast and forged shapes. The use of arsenical copper dramatically decreases during throughout the Iron Age, which likely reflects overarching changes in both local trade networks and primary reduction technologies. Leaded bronzes appear first during the Late Bronze Age; however this technology only proliferates successfully during the Iron Age with the introduction of more sophisticated casting technologies. The adoption of bronzes with significant zinc contents (ca. 1.0-10 wt.% Zn) is evinced from several samples at Kerkenes Dağ, which demonstrates the rise of a new alloy type. The innovation and adoption of this alloy, otherwise known as brass, proliferates in use only during the Roman period several centuries later. The isolation of zinc for alloying with copper in the production of brass involves a drastically different production sequence than bronze production, and it is generally considered to begin large-scale proliferation during the Roman Period (Craddock 1995; Thornton 2007). Low zinc brasses (ca. 1.0-10 wt.% Zn) are discernable in earlier periods and are likely the result of mixed smelting where zinc is introduced via a cementation process.

To observe the effects of sample size on diversity, Figure 5.16 plots the number of alloy types against the number of samples analyzed for the cultural time period in question. A clear logarithmic distribution suggests that sample size does not directly determine alloy type diversity. However the possible number of alloys is limited, which would also distribute in the same way as in sample populations with high diversity. In any case, some general conclusions can be made. These data support the intuitive theory that polity size determines the abundance and diversity of both resource types and technologies (Kline and Boyd 2010). The geographic scope of the Hittite polity would have been extensive, promoting the movement of materials and cultural knowledge over long distances in order to finance the workings of the regional center of Hattuša. Conversely, conservative alloy preference during the Early-Middle Bronze Age and the

Early Iron Age suggests diversity in complex technologies were not as available as they were during the height of the Hittite empire.

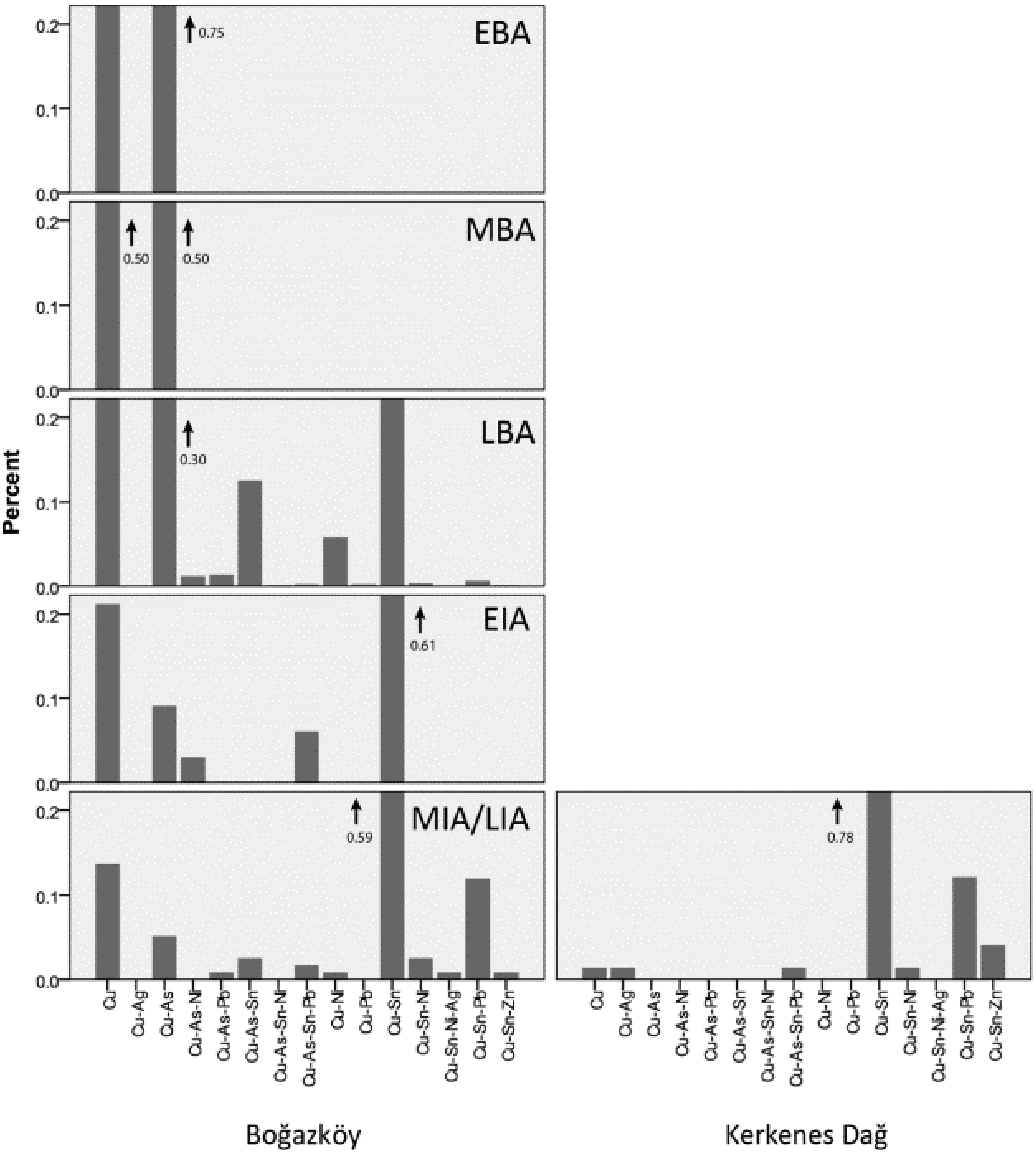


Figure 5.15: Copper alloy consumption profile at Boğazköy and Kerkenes Dağ from the Early Bronze Age to the Middle/Late Iron Age. The y-axis scale is enhanced to show the distribution of alloy types below 0.10 of the assemblage group. Those above the scale are noted with arrows and their respective ratios.

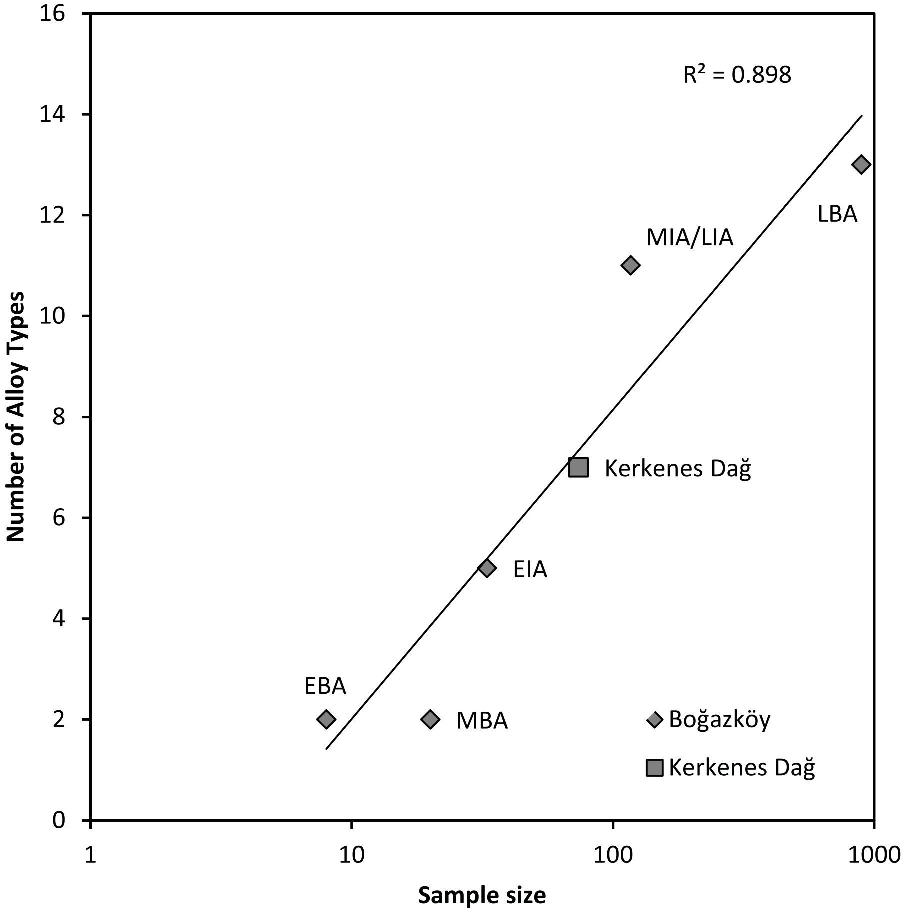


Figure 5.16: Comparison of copper alloy types versus sample size. A significant logarithmic distribution demonstrates that sample size probably affects the distribution and diversity of observed alloy types per time period.

CHAPTER 6: THE EMERGENCE OF THE METAL CRAFT ECONOMY IN THE BRONZE AND IRON AGES OF CENTRAL ANATOLIA(c.2300-400 B.C.)

6.1 Introduction

In Anatolia, the rise of metal industries during the Bronze and Iron Ages can be linked to several factors. Following Yener (Yener 2000), first industries appear to have initially adopted optimal strategies based on the manipulation of diverse local resources, including a myriad of mineral ore assemblages across Anatolia. This developed into distinct metallurgical traditions across space and time, reflecting the emergence of regionalized cultures during the 4th and early 3rd millennia BC. Lastly, the increased labor specialization and exchange associated with the rise of complex societies during the mid-3rd millennium BC gave rise to the spatial segregation of metallurgical activities and ultimately the development of a “multi-tiered hierarchy” of production. Highland production sites provisioned agricultural low lands and regional centers with primary metals for further refinement and remelting into finished products during secondary production. This further allowed elites in regional centers to effectively sponsor technological activities associated with metal production, and thereby monitor the distribution and valuation of metal commodities and finished goods in the emergence of a trade-based finance system (Bachhuber 2011).

In this concluding chapter, I further link metal industries to models of state finance. These models help explain how polities or indeed factions within polities would sponsor specialized production and trade of metal. The social organization of metal specialization and trade during the rise of the Hittite Empire, its decline, and the subsequent rise of complex Iron Age polities are exemplary of how states utilized scarce resources to finance their activities. I argue that the problems associated with state emergence, more specifically the challenges inherent to expansion and competition, determined in part how states attempted to mobilize resources in central Anatolia.

6.2 State fiscal systems and metallurgy: staple finance vs. wealth finance

To mitigate problems associated with population density pressures and resource scarcities, such as dangerous levels of within group competition, state institutions often needed to expand access to agricultural staples, commodities, finished goods, and labor. Spencer (2010) theorizes that expanding polities eventually reach a limit at which point large qualitative shifts in administrative mechanisms (bureaucracies, hierarchies, etc.) give rise to fundamentally transformative changes in how the polity or group of polities are organized. One of the principle problems expanding states face is how to sufficiently acquire and mobilize resources to adequately finance expansionistic strategies of trade and war in addition to the state institutions built around these strategies. D’Altroy and Earle argue that the key factors associated with the fiscal organization of these strategies include “the capacity of the subject groups for gross surplus production, a required state investment in political and economic security, and the potential efficiency of production, logistical, and disbursement mechanisms” (D'Altroy and Earle 1985: 188).

D’Altroy and Earle further identify two distant strategies of state finance (Table 6.1). The first strategy, *wealth finance*, “involves the manufacture and procurement of special products” that “may be amassed as direct payment from subservient populations, or they may be produced by craft specialists attached to the central authorities” (D'Altroy and Earle 1985: 188). These products are then used as media of exchange or payment for other goods and services, thus wealth in this case is used as a form of currency. The values of these products are culturally contingent, based on accepted valuation systems, and the products are often convertible into staple goods usually through some type of market transaction. Two advantages of this system is that wealth products often are less costly to store and transport, making them easier to control, and these goods further promote political alliance building through long-distance trade. Furthermore, long-distance trade in the form of tribute economies confer greater control over the means of payment, which in turn limits the capacity of peripheral polities to form an independent financial base and controls factional competition (Brumfiel 1994). The main disadvantage of wealth products, including most copper alloy products in the ancient Near East, is that they often have restricted intrinsic use values and they must be converted into staple goods for non-agriculturalists.

One important element in wealth finance is precisely where in the commodity chains involved in wealth production that controls are exercised. As described more thoroughly in Chapter 2, metal production involves a complex network of labor and resources whose activities have coalesced and dispersed variously through time. These production strategies likely reflect how they were incorporated into society as a whole. By the EB II in Anatolia ca. 2600-2300 BC, metal production activities exhibit significant degrees of labor specialization, where primary and secondary production activities were spatially discrete. Commodity chains at this point witnessed bottlenecks of control at the point of secondary production, whose activities were largely held within regional centers and in relative proximity to elite members of society.

Conversely, significant measures of the resources that a state can extract from a pre-modern economy are most likely to be related directly or indirectly to the agricultural production of staple surpluses. *Staple finance* “involves obligatory payments in kind to the state of subsistence goods such as grain, livestock, and clothing” (D'Altroy and Earle 1985: 188). These goods are then paid out by state institutions to personnel and agents of the state who require them to meet basic household needs. This system effectively centralizes everyday subsistence surplus produced as tribute in agricultural peripheries, keeps them in centralized storage in regional centers, and then remobilizes these surpluses in a redistributive system (Earle 2011). One of the largest disadvantages of staple finance systems is the costliness of transporting perishable bulk subsistence goods across long distances. For this reason, staple finance systems appear to have been most effective among smaller polities where the management of agricultural surpluses did not require long distance transport. Furthermore, intensive agricultural production strategies carry significant risk (Marston 2012) and can initiate systemic social failures and famines in bad years (Garnsey and Morris 1989; Wright, et al. 1989).

Yet despite these fundamental problems, large-scale staple finance systems are known to many chiefly societies and archaic states, especially in areas where intensive agricultural systems produced sizeable surpluses per unit labor such as in southern Mesopotamia (Algaze 2008: 41; Jursa 2010: 99; Jursa and Garcia 2015: 120) and Lower Egypt (Jursa and Garcia 2015: 156; Wenke 1989). One way large-scale staple finance systems overcame transport costs was through the decentralization of storage away from the political center. By strategically distributing centers of collection to select region centers, the transport costs associated with mobilizing surpluses can be greatly reduced and their distribution made more efficient. Ruling elite would have to relinquish some control over these resources, risking the loss of control of territories; however, power structures could be maintained in the form of landed estates attached to noble families or other governing institutions associated with the state (eg., temples).

Table 6.1: Expectations following from theoretical archaic state fiscal systems (adapted from D'Altroy and Earle 1985; Stein 1994, 1999).

Wealth finance	Staple finance
1) exotic goods as markers of status in a prestige goods economy	1) economic differentiation
2) centrally located attached specialists focusing on the production of prestige goods	2) centralized storage facilities for staples
3) pronounced differentiation of elites, especially through their emphasis on foreign connections as means of access to exotic knowledge and goods	3) evidence for rural production of surpluses
4) higher levels of inter-regional competition and warfare	4) either village-based craft production, or high proportions of local, as opposed to long-distance exchange
	5) evidence for either ritual, kinship-based, or coercive modes of surplus mobilization

6.3 Surplus finance and wealth finance during the Bronze and Iron Ages in central Anatolia

Wealth and staple finance strategies should be understood as heuristic categories. While most if not all examples of archaic complex societies never solely relied on one strategy alone, it is none the less possible to observe shifts among these strategies over time in central Anatolia. Furthermore, shifts in these strategies appear to be correlated to the sizes of the political entities, suggesting that the geographic scope of the territories and sociopolitical networks were determining factors in how archaic states in central Anatolia operated. The distribution of copper alloy types, their evolution through cultural transmission and selection, and the provenance of their raw materials attest to significant shifts in the ways the state institutions acquired and provisioned value-added goods. As discussed in the beginning of Chapter 3, the development of polities during the EB II/III and MBA (ca. late 3rd and early 2nd millennia BC), data from elite burials and architecture show how metal goods, specifically tin bronze, was incorporated into developed systems of status. Furthermore, the development of regional centers during the late 3rd millennium BC more generally is attributed to the strategies of trade and war that served to coalesce political factions into scores of polities across central Anatolia (Selover 2015). These polities were linked by strategic participation in long-distance trade networks and alliances, and within the context of greater resource acquisition, polities also competed for access and political dominance. The production of copper, silver, gold, and, to a much lesser extent, iron commodities locally available within Anatolia at this time helped drive further interaction and integration of the region.

By the beginning of the 2nd millennium BC, several sites rose to prominence in central Anatolia, including Kültepe, Acemhöyük and Karahöyük-Konya. These polities competed for access to and dominance in the trade of high value-added goods, including mostly commodities of foreign textiles and tin. Texts indicate clearly that the ruling Anatolian elite sponsored the trade of wealth surplus in a kind of market exchange. Craft workshops associated both with palaces and lower city residences provide further evidence of the multiple trajectories wealth was produced in these societies. The distribution and organization of staple surplus is poorly known during this time period; however, it is increasingly likely that agricultural and pastoral strategies were intensified to support not only increases in population densities but also the rise of emerging expansionistic strategies during the end of the MBA (Arbuckle 2012; Atici 2014).

Conflagrations and subsequent abandonment of these centers coincided with the rise of a new political entity during the 17th century BC slightly north of this region at Boğazköy, which was previously the center of a small kingdom at Hattuš. By the 16th century, this site rose to prominence as a major ceremonial and economic central place. Formed within the context of intense competition, this polity expanded to be the center of the Hittite state. As Schachner (2009a) and Glatz (2009) demonstrated, the imperial foundations of Hattuša were based on large-scale regional changes, including structural modifications in the settlement organization depopulation strategies, the development of truly monumental architecture with corporate and administrative functions, and building projects including dams, water reservoirs, and granaries.

Textual and archaeological data from the Hittite capital demonstrates that this prominent Bronze Age state utilized both wealth and staple finance strategies to maintain their bureaucracies and expansionistic activities. Significant economic differentiation both within and between polities is evident (settlement systems, architectural variation in quantity and quality, textual evidence of administrative systems). However, nearly all research on Hittite Anatolia has focused on large sites dominated by elite contexts, so we know very little about the daily life realities of commoner participation in the state (Mielke 2011b). Nearly all of the excavated remains at Boğazköy attest to state infrastructure and elite residences and therefore it is exceedingly difficult to determine empirically the wider spectrum of economic differentiation within the Hittite state as a whole. Centralized storage of subsistence goods is evident at Boğazköy with the emergence of such activities at least into the early 2nd millennium BC (Schachner 2009a; Seeher 2006b; Strupler 2013). The monumental storage of grains at the state granaries at Boğazköy, in addition to taxation lists and land tenures systems which document the centralization of staple production, attest to the role of staple finance and institutional control of rural staple surplus production. Surpluses were primarily mobilized persuasively and coercively through tribute (in the form of gifts and tax) and religious rituals and festivals, and these activities were primarily provisioned by the landed estates of the palace and temples. According to the Hittite Laws, wages for labor and services could be made in measures of grain or weights of silver, which was widely convertible into surplus goods.

Specialization and exchange in wealth surpluses, predominantly in the form of primary metal commodities and finished goods, provided an important mechanism of networked state interaction across its territory and potential political alliances. Similar to the organization of Mycenaean wealth finance systems, the production of value added metal goods operated primarily to create and maintain political networks between ruling members of the state and other regional elites whose cooperation determined in part the success of the state (Galaty and Parkinson 2007; Parkinson, et al. 2013).

Metal production throughout the Middle and Late Bronze Age occurs within the context of detached specialists who were provisioned, in part, by state institutions including the palace and temples. Metalsmiths who processed gold would have had their raw materials almost entirely provisioned by the state. Current data suggests that metal production activities occurred within the urban infrastructure of Boğazköy; however, depending somewhat on how one interprets the functional attributes of Boğazköy as a capital and how residential contexts were integrated into the city, these somewhat autonomous and proximate production activities were probably sponsored by state institutions. Bulk metals, in the form of primary commodities (ingots) and finished goods, were provisioned from subject polities as far as Cyprus and Syria, however the majority of copper metal imports appear to have been procured from Anatolian sources within

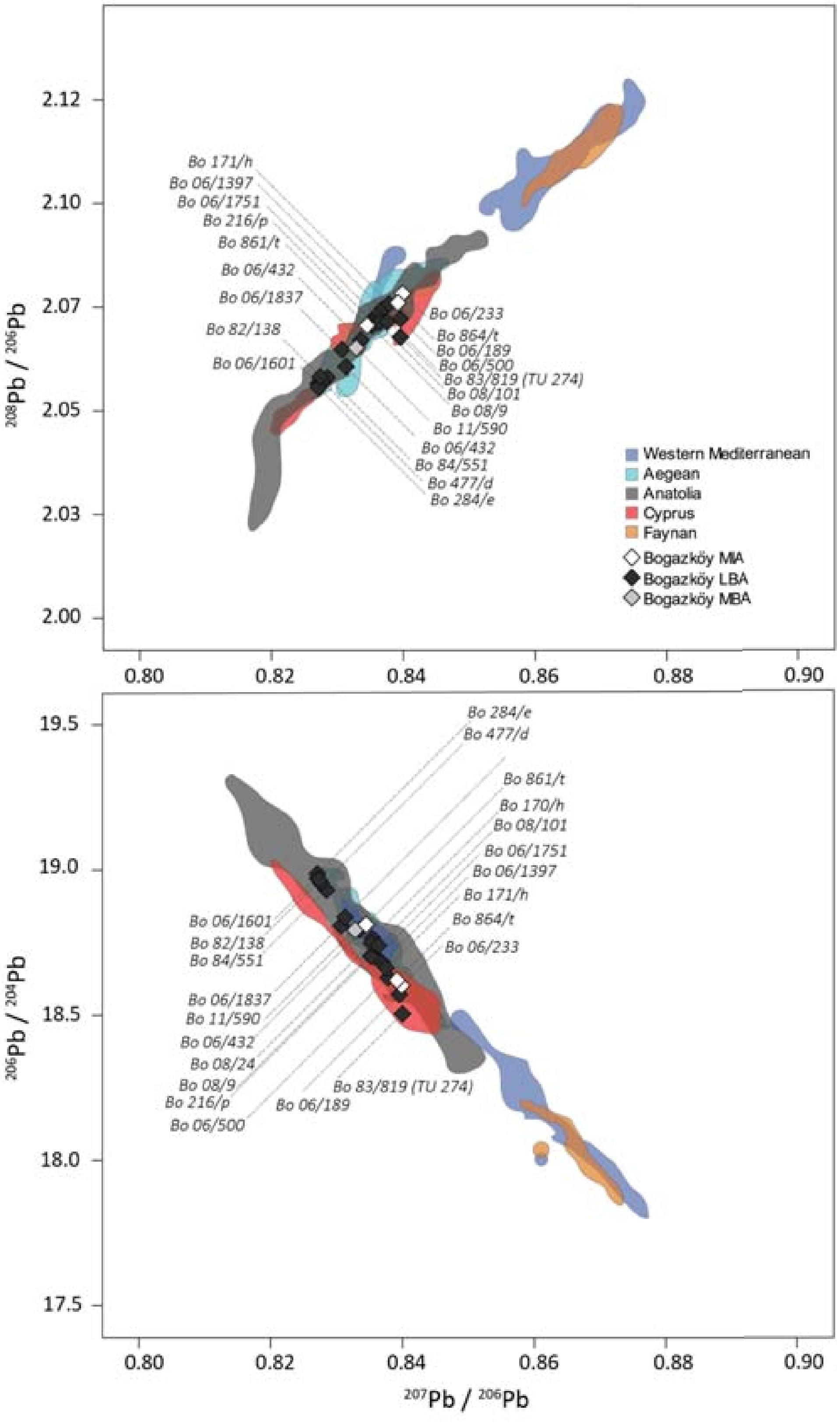


Figure 6.1: Preliminary lead isotope biplots comparing known ores to select artifacts recovered from Late Bronze Age and Iron Age contexts at Boğazköy.

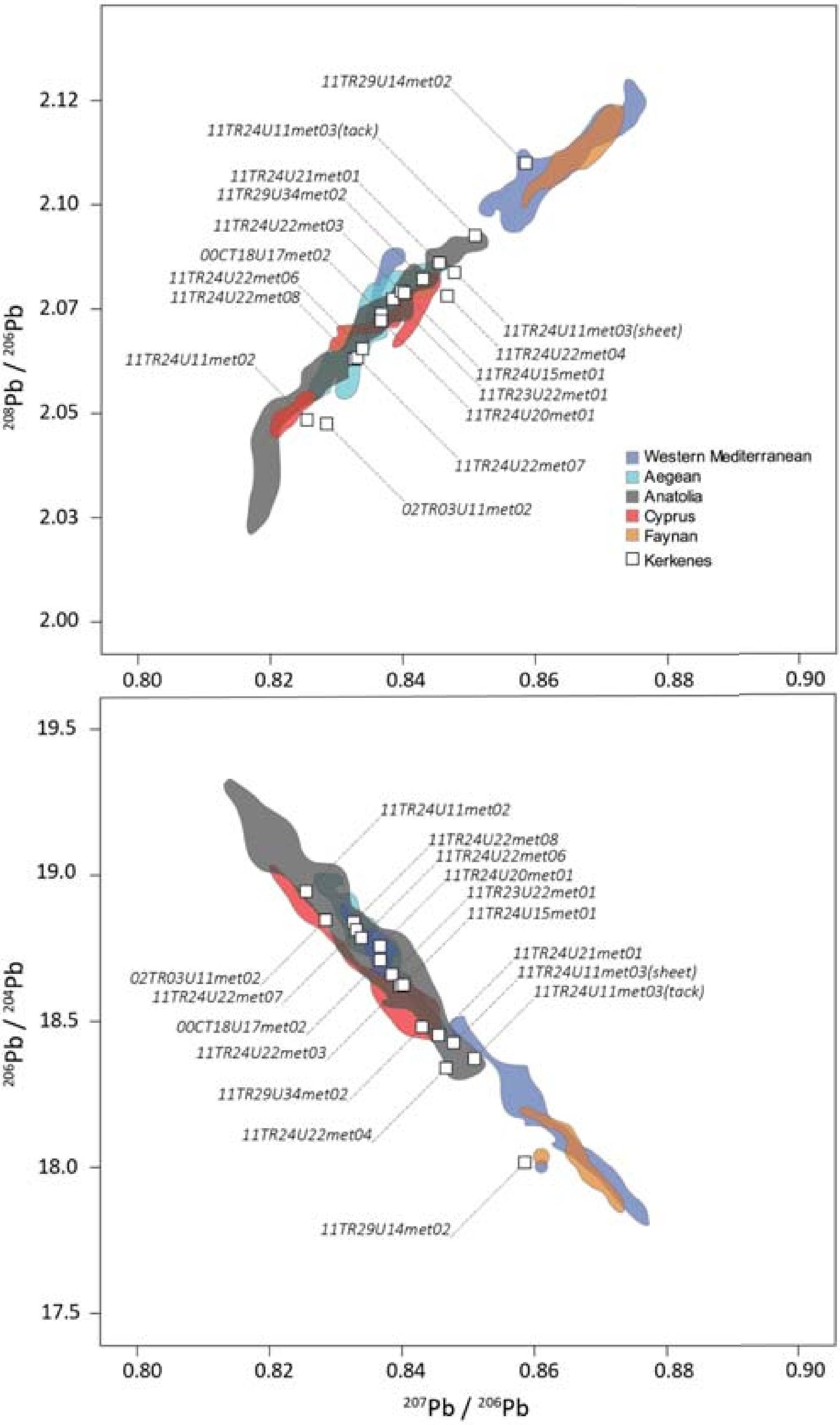


Figure 6.2: Preliminary lead isotope biplots comparing known ores to select artifacts recovered from Iron Age contexts at Kerkenes Dağ.

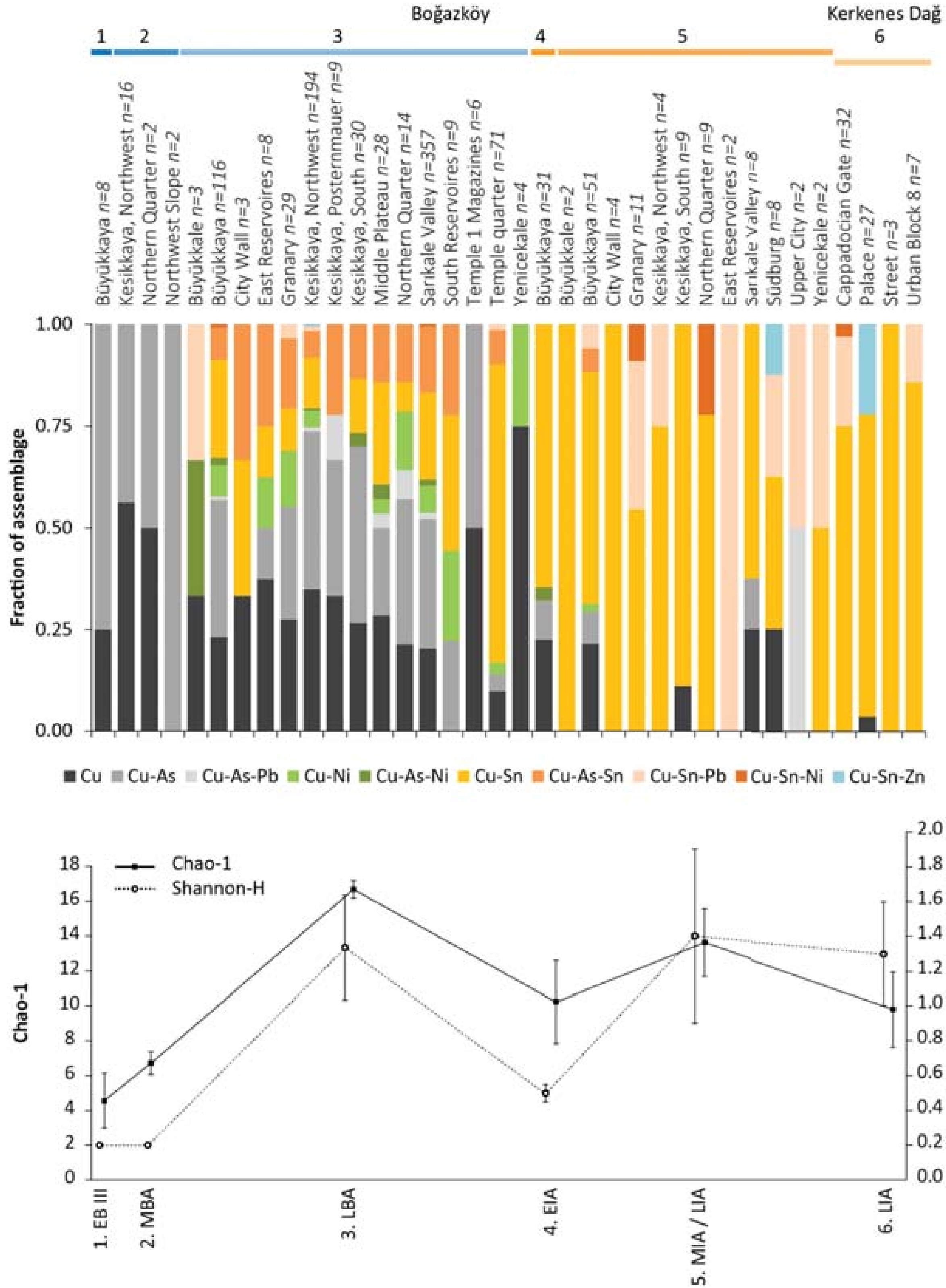


Figure 6.3: Diachronic change in abundance ratios of copper alloy types among finished goods across observed contexts (top) and type diversity measures (Chao-1 and Shannon-H) during each respective time period (bottom).

the Taurides (Figure 6.1)[3]. The obvious exception is a quarter piece of an oxhide ingot, which almost certainly produced from Cypriot copper from Apliki (Bo 79/206, Stos-Gale, et al. 1997: 117). In their attempts to monopolize all long-distance trade and elite craft production, rulers effectively placed exotic and high value added goods within a cultural system of status.

Categorical status can be observed within the bronze industries and consumption profiles of Hittite Anatolia. On the one hand, consumption profiles associated with residential contexts at Boğazköy demonstrate a reproducible pattern showing that around a quarter of the copper consumed was unalloyed. A further quarter to third of these assemblages consists of arsenical copper. Copper alloyed with tin, which was most likely procured through long-distance exchange, comprises between a quarter and third of these assemblages. The reverse pattern is observed among temple contexts, where finished goods produced from tin bronzes dominate over 75% of the assemblage (see Figure 6.2). This result is consistent with temple inventory lists that document the accumulation of tin bronze as part of a wealth finance system.

After the collapse of the Hittite Empire ca. 1200 BC, the reemergence of polities in central Anatolia ushered in a novel political system during the 9th century BC. Much less is known about the organization of the political economy at this time, but investigations at Gordion, which was probably the center of the expanding Phrygian state, suggest that elites adopted a drastically different fiscal system. Unlike at Boğazköy-Hattuša, where significant investments in storage demonstrate a large-scale staple finance system, no such structures are known to Gordion or later at Kerkenes Dağ. Yet at Gordion, archaeobotanical research has however demonstrated an intensification of agricultural and pastoral production that coincides with the rise of the Phrygian state (Marston 2012; Miller, et al. 2009). The intensive production of staple goods

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[3] Lead isotope analysis is a well-accepted method to provenance a range of materials. Methods of analysis and the results for several objects used in this dissertation are further described in Appendix D. Previously published ore data are referenced therein.

would no doubt have served to support an expanding political system, yet we know very little how staple goods were provisioned by the state, presumably through a state controlled system of land tenure and taxation.

Further investigations support a fiscal system that was primarily sponsored the production and trade of status goods (Voigt and Henrickson 2000a: 50). This is demonstrated at Gordion, where the centralized production of textiles associated with elite structures at the site (Burke 2010, 2011). The increased presence of exotic goods, including vessels produced of fine ceramic, glass, and bronze, further attest to the centrality of long-distance trade. Perhaps most striking are the scores of massive tumuli, which included the burials of single individuals together with unprecedented high value burial goods (Kohler 1995; Young 1981). Mid to Late Iron Age cremation burials in the lower town of Boğazköy also attest to the inclusion of exotic status goods, including bronze fibulae and vessels, jewelry produced of precious metals, some of which included in finely crafted cremation urns (Boehmer 1979; Genz forthcoming). This pronounced differentiation of elites, especially based on the emphasis on foreign connections and exotic materials, further supports the role of wealth finance among polities during the Iron Age in central Anatolia.

A similar pattern is observed at Kerkenes Dağ; however, to date there are no production contexts yet discovered aside from a large oven found in a residential context of the southern city that was interpreted to be used for bread production (Schmidt 1929: 234-237). Furthermore, the large monumental tumuli that surround the city, if indeed dated synchronically with the city, likely attest to a similar differentiation of elites and political economy. High value crafted goods found in the city, including a finely carved ivory plaque from Urban Block 8 (Dusinberre 2002) and gold/electrum ornament (Summers in press; Summers and Summers 2012), among few other examples of ivory and precious metals, suggest that communities at the city maintained relationships with polities in western Anatolia and, indirectly, the Mediterranean world. The repertoire of pottery from Kerkenes Dağ demonstrates the local provisioning of several sources or workshops within central Anatolia (Kealhofer, et al. 2010), yet little to no evidence exists for any transport of exotic transport vessels. The pottery of Middle and Late Iron Age Boğazköy demonstrates a similar limitation, thus supporting the idea that perishable trade goods contained in vessels must have declined since the Bronze Age (Kealhofer, et al. 2009: 296). There is however an increase in exotic table wares at Boğazköy during the Mid to Late Iron Age.

Data from the copper alloy analyses however suggest that tin bronze was almost exclusively consumed relative to most other alloy types (Figure 6.2). This pattern is similar to analyses completed on Late Assyrian copper alloys from Nimrud (Curtis 2013) and other analyses of 8th century BC copper alloys from Phrygia and Urartu (Atasoy and Buluç 1982; Çukur and Kunç 1989; Hirao and Enomoto 1993; Hirao and Enomoto 1997; Hughes, et al. 1981; Twilley 1996), where tin was probably imported. Lead isotope analyses of select Kerkenes objects indicate that copper was provisioned from at least four separate source areas in Anatolia, including the Pontides, central and eastern Taurides, and north central Anatolian sources (Figure 6.2). A single sample of a scroll headed pin however is inconsistent with most known Anatolian ores and is isotopically and compositionally similar to ores from the western Mediterranean, including Sardinia and Spain, and possibly also Oman. Unlike copper metal from Hittite Anatolia, which appears mostly to have been provisioned from local sources and also those from Cyprus, Late Iron Age communities at Kerkenes Dağ were able to participate in a much more broad system of metal exchange that extended from the western Mediterranean to southern Mesopotamia (Sherratt and Sherratt 1993). Evidence from these analyses also suggest that trade of Pontic copper reached Kerkenes Dağ, which are currently absent from analyses of the Hittite copper alloys from Boğazköy but have been documented for the second millennium contexts elsewhere at Middle Bronze Age Kültepe (Lehner 2014a) and Late Bronze Age Kaman-Kalehöyük (Enomoto and Hirao 1999; Hirao and Enomoto 1994; Hirao, et al. 1992).

Figure 6.3 further distills how technological diversity among copper alloys is represented within the observed assemblages over time. Alloy type abundance measures, which are simple ratios of the subtotal assemblage, provide an excellent measure of alloy preference. This approach remains underutilized because modern techniques are only beginning to move beyond the select analysis of samples to more comprehensive approaches such as completed in this dissertation. This consumption profile indicates the behavioral choices in aggregate that individuals made given available alloy types. Here it is possible to observe the effects of context on consumption profiles. The distinguishing characteristic of the Late Bronze Age assemblages is, as mentioned above, the difference between temple contexts and residential contexts elsewhere in the city, especially those well represented at the Sarıkale Valley and the residential sector northwest of Kesikkaya. Tin bronze, which is a well-accepted marker of long-distance trade and status, is particularly well represented among the temple assemblages. The transition into the Iron Age is accompanied with a rapid decline in the consumption of arsenical copper and their exclusive replacement with tin bronze, leaded tin bronze, and early brass metal. This development demonstrates how metalsmiths had increasing access to exotic resources like tin to produce well-crafted alloys in quantities that were not apparently reached during earlier periods.

Two further statistic measures were calculated to determine the relative diversity of all possible alloys per time period. These measures include the Chao-1 and Shannon-H statistics. The Chao-1 measure is a non-parametric estimator of paradigmatic class richness, which is the number of different possible classes, given a sample population (Eren et al. 2012). The Shannon-H diversity index measure of diversity accounts for class abundance and evenness in a subset population. Both measures were computed using PAST (Hammer et al. 2001). These measures demonstrate similar significant patterns and empirically support the positive relationship between polity size and technological diversity (Kline and Boyd 2010). During the Late Bronze Age, a rapid increase in both alloy class richness and diversity is followed by a decline during the Early Iron Age and a subsequent rise during the reestablishment of polity at Boğazköy.

An independent line of evidence also comes from Iron Age pottery from these prominent regional centers. Analyses of ceramic bulk composition from Gordion, Boğazköy, and Kerkenes Dağ, collectively demonstrate a positive relationship with political complexity (Grave, et al. 2009; Kealhofer, et al. 2009; Kealhofer, et al. 2010). The authors of this research, correctly in my view, logically connect increases in compositional group types with a florescence in trade and a rise in political complexity. Figure 6.4 demonstrates this relationship using absolute type counts and Shannon-H diversity. The emergence of political complexity, especially documented in the pottery and metal assemblages from these regional centers, is therefore intimately connected to the craft economy.

6.4 Conclusion

Here I argued that the emergence and development of metal technologies, specifically copper metallurgy, are intrinsically linked to the strategies that states employed in the

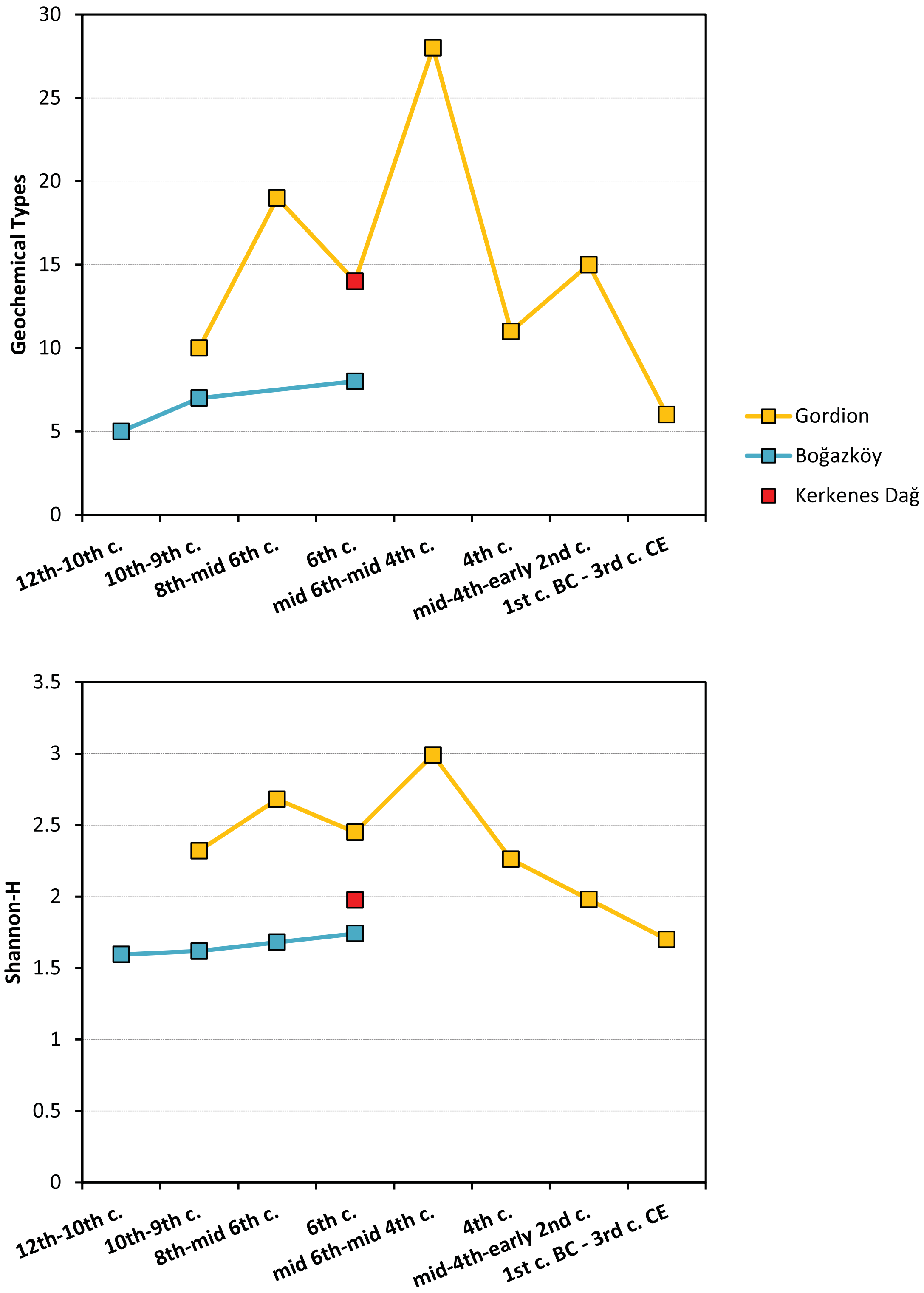

Figure 6.4: Diversity indices of geochemical groups of pottery from Gordion, Boğazköy, and Kerkenes Dağ through time (data from Grave, et al. 2009; Kealhofer, et al. 2009; Kealhofer, et al. 2010); (top) absolute geochemical type frequency, (bottom) Shannon-H diversity, correcting for sample size and evenness among the sample groups.

organization of political and economic activities. By delineating the locations of production activities, including acquisition, primary, and secondary production, it is clear that by the end of the 3rd millennium BC, labor specialization was widespread and geographically situated. Instead of workshops performing most activities, pronounced divisions of labor were supported by long-distance exchange. These labor divisions helped support the development of wealth finance strategies that were widely adopted by the time of the Old Assyrian trade. Part of the strategy of Hittite domination appears to have asserted control over these wealth financing strategies. Furthermore, in an effort to create territorial dominance, the Hittite state developed an elaborate staple financing strategy that served to simultaneously integrate agricultural zones and to finance large-scale military activities. This is also reflected in the compositional and isotopic profiles of analyzed objects in this study, which point towards a widespread and diverse copper technology that is unlike its counterparts elsewhere in the Near East and Aegean regions. After the decline of the Hittite state, smaller states reemerged once again with elites who attempted to dominate the region through control of long-distance trade in modified wealth finance system. Compositional and isotopic data demonstrate that the polity at Kerkenes Dağ was capable of acquiring resources from most major copper source areas in Anatolia, in addition to a single example of bronze that appears to match sources in the western Mediterranean. Yet despite the diversity of sources, copper technologies at Kerkenes Dağ are almost entirely limited to tin bronze technology, further suggesting that long-distance trade and wealth finance structured the political economy.

This work serves to demonstrate not only the interrelation of strategies of economic and political expansion but also how these strategies are reflected in changes in labor organization and trade. In north central Anatolia, which witnessed several periods of expansion, this is observed through proxies within the variations of copper metal technology and the transformations evident in economic networks which supplied producers and consumers over time. During the Bronze Age, a proliferation of metal alloy and form types develops; however, this sociotechnic transformation appears to be dominated by a regional inter-Anatolian network of copper trade. During the Iron Age, metal alloy types decrease, but the network of copper commodity trade increases in size. This is further demonstrated by the near exclusive consumption of tin bronze, highlighting how the trade of foreign commodities into central Anatolia, and thereby large-scale cooperation within a craft economy, developed alongside the emergence of polities in the region.

APPENDIX A: OBJECT CONTEXTUAL DATA

Contextual data for each object, where available, are listed for each object and sample in the tables below. Each object has a unique inventory number, and in some cases, also a Mannheim number (MA- X) which refers to the lab inventory in use at the Curt-Engelhorn-Zentrum Archäometrie. Context from Boğazköy is described here in one of two ways. First, for earlier excavations including materials from P. Neve's excavations, contexts are described either in terms of location or are directly cited from published final excavation volumes. Objects from earlier excavations at Boğazköy have been published, and their descriptions and contexts are contained within excavation volumes. These include R. Boehmer's small finds volumes concerning excavations from 1952-1969 (1972) and excavations in the Lower City from 1970-1978 (1979). Contextual information of P. Neve's excavations in the Upper City, including excavations at the Temple Quarter, Südburg and Nişantepe, has also been graciously provided by S. Herbordt ahead of publication. Where contextual information was not available, representing only a very small fraction of the entire study, objects were designated a time period based on well-understood regional typology.

For later excavations at Boğazköy by Seeher and then Schachner, contexts were numerically coded and their detailed descriptions can be found in publication or within the project archives. Detailed information and access to select objects from excavations at Büyükkaya (1993-1998), the Northwest Slope of Büyükkale (1998-2000), the vicinity around the Eastern Reservoirs (1996-1998), and the Southern Reservoirs (2000-2001) were also courteously made available by Jürgen Seeher and Ayşe Baykal-Seeher (final publication of excavations at Büyükkaya and the Southern Reservoirs are forthcoming; Baykal-Seeher 2006; Seeher 2006b).

Objects from excavations in the western Upper City (2001-2009), including excavations in the Sarıkale Valley, the Middle Plateau, and Yenicekale, were also made available by J. Seeher and A. Schachner. The final publication of these objects is forthcoming.

Objects from excavations at Kerkenes Dağ have their contexts coded within the object numbering format, where the trench (TR) and unit (U) numbers are provided. Given the understood development and short one period chronology at Kerkenes, we can assume all objects from this study date to sometime between the 7th-6th centuries BC.

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
BOĞAZKÖY					
EARLY BRONZE AGE					
	Bo 96/38	Büyükkaya	Pin, conical	Cu-As	347/411.59
	Bo 97/98	Büyükkaya	Pin, nodular	Cu	347/410.294
	ETD 97/196	Büyükkaya	Pin, indeterminate	Cu-As	348/410.48
	ETD 97/206	Büyükkaya	Wire, round section	Cu-As	347/410.194
	ETD 97/213	Büyükkaya	Awl	Cu-As	348/310.44
	ETD 97/219	Büyükkaya	Pin, shaft fragment	Cu-As	347/410.230
	ETD 97/221	Büyükkaya	Awl	Cu	348/410.50
	ETD 98/12	Büyükkaya	Eye needle, fragment	Cu-As	348/411.113
MIDDLE BRONZE AGE					
MA-132227	Bo 10/199	Lower City - Kesikkaya, Northwest	Awl	Cu-As	57
MA-132259	Bo 10/332	Lower City - Kesikkaya, Northwest	Pin, lenticular	Cu-As	74
MA-132246	Bo 10/341	Lower City - Kesikkaya, Northwest	Awl	Cu-As	74
MA-132250	Bo 10/482	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	112
MA-132303	Bo 11/590	Lower City - Kesikkaya, Northwest	Ingot, planoconvenx	Cu	71
	Bo 13/445	Lower City - Kesikkaya, Northwest	Pin, lamellar	Cu-As	11
	Bo 13/450	Lower City - Kesikkaya, Northwest	Socketed pike	Cu	31
	Bo 13/458	Lower City - Kesikkaya, Northwest	Pin, unique	Cu-As	33
	Bo 13/459	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	33
	Bo 13/462	Lower City - Kesikkaya, Northwest	Pin, disc	Cu-As	33
	Bo 13/463	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	33
	Bo 13/564	Lower City - Kesikkaya, Northwest	Pin, square	Cu-As	43
	Bo 13/569	Lower City - Kesikkaya, Northwest	Socketed pike	Cu	49
	Bo 13/631	Lower City - Kesikkaya, Northwest	Pin, nodular	Cu	57

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 13/668	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	49
	Bo 13/670	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	49
MA-132546	Bo 143/l	Lower City - Northern Quarter	Staff blade	Cu-As	Boehmer 1972: n. 59
MA-132560	Bo 345/h	Lower City - Northern Quarter	Staff blade	Cu-As	Boehmer 1972: n. 60
MA-132557	Bo 348/h	Lower City - Northern Quarter	Knife, flat and curved	Cu	Boehmer 1972: n. 256
MA-132556	Bo 311/s	Northwest Slope - Northwest Slope	Spearpoint	Cu-As	Boehmer 1972: n. 199
MA-132558	Bo 400/s	Northwest Slope - Northwest Slope	Staff blade	Cu-As	Boehmer 1972: n. 57
LATE BRONZE AGE					
MA-132188	Bo 284/e	Büyükkale	Belt sheet	Cu-As-Ni	Boehmer 1972: n. 179
MA-132189	Bo 284/e	Büyükkale	Belt sheet, gold wire	Au	Boehmer 1972: n. 179
MA-132180	Bo 477/d	Büyükkale	Shaft-hole axe	Cu-Sn-Pb	Boehmer 1972: n. 17
MA-136322	Boehmer 1972: Nr. 190	Büyükkale	Ingot, planoconvenx	Cu	Boehmer 1972: n. 190
MA-132553	Bo 254/k	Büyükkaya	Shaft-hole axe	Cu-As-Sn	Boehmer 1972: n. 18
	Bo 92/225	Büyükkale	Figurine	Cu-Sn	P/14
	Bo 94/1	Büyükkaya	Pin, lenticular	Cu-Ni	355/430.54
	Bo 94/109	Büyükkaya	Pendant, lunulae	Cu-As-Ni	356/432.38
	Bo 94/113	Büyükkaya	Pin, square	Cu-As	355/428.17
	Bo 94/116	Büyükkaya	Awl	Cu-As	355/428.94
	Bo 94/14	Büyükkaya	Pin, rolled	Cu-As	354/430.9
	Bo 94/141	Büyükkaya	Arrowhead, lance-form	Cu	357/431.67
	Bo 94/20	Büyükkaya	Pin, unique	Cu-As	356/431.11
	Bo 94/21	Büyükkaya	Pin, double headed	Cu-Sn	356/431.13
	Bo 94/28	Büyükkaya	Arrowhead, stemmed	Cu-Sn	355/430.57
	Bo 94/36	Büyükkaya	Awl	Cu-As-Sn	354/430.98
	Bo 94/37	Büyükkaya	Edged chisel	Cu-Sn	354/430.90

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 94/4	Büyükkaya	Arrowhead, stemmed	Cu	355/430.12
	Bo 94/40	Büyükkaya	Pin, fungiform	Cu-As-Pb	355/430.175
	Bo 94/57	Büyükkaya	Pin, disc	Cu-Sn	355/430.270
	Bo 94/76	Büyükkaya	Pin, disc	Cu-As	354/430.146
	Bo 94/9	Büyükkaya	Pendant, lunulae	Cu	355/430.49
	Bo 95/100	Büyükkaya	Rod	Cu-Sn	352/427.122
	Bo 95/111	Büyükkaya	Spiral	Cu-Sn	355/431.41
	Bo 95/113	Büyükkaya	Pin, incised disc	Cu-Ni	355/427.104
	Bo 95/119	Büyükkaya	Pin, pyramidal	Cu-As-Sn	354/427.110
	Bo 95/25	Büyükkaya	Flat axe, indeterminate	Cu-Sn	354/427.44
	Bo 95/27	Büyükkaya	Pin, disc	Cu-As	354/427.58
	Bo 95/41	Büyükkaya	Arrowhead, stemmed	Cu-Sn	355/431.106
	Bo 95/76	Büyükkaya	Pin, incised disc	Cu	355/427.61
	Bo 95/80	Büyükkaya	Indeterminate	Cu-As-Ni	350/427.34
	Bo 95/82	Büyükkaya	Pin, disc	Cu	352/427.96
	Bo 95/95	Büyükkaya	Flat axe, indeterminate	Cu-Sn	353/422.43
	Bo 96/120	Büyükkaya	Winged axe	Cu-As-Sn	347/410.139
	Bo 96/34	Büyükkaya	Pin, nodular	Cu-Sn	356/427.114
	Bo 96/36	Büyükkaya	Spiral	Cu-Sn	355/426.27
	Bo 96/48	Büyükkaya	Insert, axe-shaped	Cu-As-Sn	354/421.122
	Bo 97/101	Büyükkaya	Pin, conical	Cu-As	353/421.205
	Bo 97/102	Büyükkaya	Pendant, decorated sheet	Cu-Ni	345-7/413-5.65
	Bo 97/16	Büyükkaya	Figurine	Cu-Sn	352/420.502
	Bo 97/18	Büyükkaya	Awl	Cu-As	348/411.36
	Bo 97/19	Büyükkaya	Awl	Cu-As	353/421.254
	Bo 97/23	Büyükkaya	Pin, fungiform	Cu-As	348/410.15

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 97/24	Büyükkaya	Awl	Cu-As	348/411.54
	Bo 97/27	Büyükkaya	Pin, lamellar	Cu-As	348/411.66
	Bo 97/33	Büyükkaya	Pin, lamellar disc	Cu-Ni	345-7/413-5.245
	Bo 97/37	Büyükkaya	Pin, nodular	Cu	348/411.41
	Bo 98/13	Büyükkaya	Staff blade	Cu	348/410.165
	ETD 94/127	Büyükkaya	Eye needle, fragment	Cu-Ni	356/431.25
	ETD 94/191	Büyükkaya	Pin, rolled	Cu-Sn	356/431.44
	ETD 94/192	Büyükkaya	Bead	Cu	356/431.41
	ETD 94/198	Büyükkaya	Eye needle, fragment	Cu-As	357/431.26
	ETD 94/215	Büyükkaya	Ring, wire	Cu-Ni	357/431.29
	ETD 94/217	Büyükkaya	Eye needle, fragment	Cu-Ni	354/430.101
	ETD 94/234	Büyükkaya	Pin, shaft fragment	Cu-As	355/430.214
	ETD 94/246	Büyükkaya	Awl	Cu-As	356/431.56
	ETD 94/248	Büyükkaya	Eye needle	Cu	356/431.65
	ETD 94/263	Büyükkaya	Edged chisel	Cu	357/431.26
	ETD 94/356	Büyükkaya	Arrowhead, stemmed	Cu-Sn	354-355/430.170
	ETD 94/4	Büyükkaya	Wire, round section	Cu-As-Sn	355/430.10
	ETD 94/460	Büyükkaya	Pendant, indeterminate	Cu-Sn	356/431.153
	ETD 94/471	Büyükkaya	Awl	Cu-Sn	357/431.46
	ETD 94/479a	Büyükkaya	Awl	Cu-As	354/430.159
	ETD 94/479b	Büyükkaya	Indeterminate	Cu-Sn	354/430.159
	ETD 94/481	Büyükkaya	Pin, shaft fragment	Cu-As	356/431.69
	ETD 94/482	Büyükkaya	Awl	Cu-As	355/431.69
	ETD 94/486	Büyükkaya	Awl	Cu	355/430.265
	ETD 94/6	Büyükkaya	Awl	Cu-Sn	355/430.10
	ETD 94/7	Büyükkaya	Awl	Cu-As	355/430.10

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	ETD 95/212a	Büyükkaya	Awl	Cu-As-Sn	355/427.100
	ETD 95/212b	Büyükkaya	Eye needle, fragment	Cu-Sn	355/427.100
	ETD 95/228A	Büyükkaya	Wire, round section	Cu-As	350/427.67
	ETD 95/228B	Büyükkaya	Awl	Cu-Sn	350/427.67
	ETD 95/228C	Büyükkaya	Awl	Cu-Sn	350/427.67
	ETD 95/228D	Büyükkaya	Awl	Cu	350/427.67
MA-136329	ETD 95/231	Büyükkaya	Sheet ring	Cu-Ni	352/427-428.83
	ETD 95/232	Büyükkaya	Eye needle, fragment	Cu-As	355/427.165
	ETD 95/262	Büyükkaya	Awl	Cu-As-Sn	355/427.103
	ETD 95/269	Büyükkaya	Pin, lenticular	Cu	356/430.170
	ETD 95/272	Büyükkaya	Awl	Cu-Sn	395/432.54
	ETD 95/283	Büyükkaya	Pin, conical	Cu-As	355/427.149
	ETD 95/284A	Büyükkaya	Pendant, decorated sheet	Cu-Ni	355/432.52
	ETD 95/284B	Büyükkaya	Pendant, decorated sheet	Cu-Sn	355/432.52
	ETD 95/83	Büyükkaya	Pin, lamellar disc	Cu-As	357/431.155
	ETD 96/32	Büyükkaya	Arrowhead, stemmed	Cu	354/421.48
	ETD 96/33	Büyükkaya	Awl	Cu	359/428.6
	ETD 96/34	Büyükkaya	Pin, nodular	Cu	355/427.135
	ETD 96/35	Büyükkaya	Pin, shaft fragment	Cu-Sn	359/428.14
	ETD 96/36	Büyükkaya	Awl	Cu-As	356/427.54
	ETD 96/37	Büyükkaya	Awl	Cu	347/410.6
	ETD 96/41	Büyükkaya	Awl	Cu	359/428.16
	ETD 96/42	Büyükkaya	Awl	Cu	355/427.184
	ETD 96/43	Büyükkaya	Awl	Cu-As-Sn	359/429.5
	ETD 96/45	Büyükkaya	Arrowhead, indeterminate	Cu-As	356/427.209
	ETD 96/54	Büyükkaya	Rod	Cu	359/428.8

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	ETD 96/62	Büyükkaya	Awl	Cu	344/301.38
	ETD 97/212	Büyükkaya	Awl	Cu-As	359/426.41
	ETD 97/218	Büyükkaya	Awl	Cu-As	348/411.35
	ETD 97/229	Büyükkaya	Rod	Cu-As	353/421.180
	ETD 97/233	Büyükkaya	Awl	Cu-As	354/421.180
	ETD 97/240	Büyükkaya	Awl	Cu-As	352/420.86
	ETD 97/241	Büyükkaya	Pin, shaft fragment	Cu-As	348/410.27
	ETD 97/242	Büyükkaya	Insert, hammer-shaped	Cu-Sn	345/413.40
	ETD 97/243	Büyükkaya	Awl	Cu	358/426.5
	ETD 97/246	Büyükkaya	Arrowhead, sheet	Cu	352/420.419
	ETD 97/251	Büyükkaya	Axe or hatchet, indeterminate	Cu-Sn	353/421.194
	ETD 97/255	Büyükkaya	Pin, incised lamellar disc	Cu-As	347/427.14
	ETD 97/256	Büyükkaya	Awl	Cu-As	345/413.83
	ETD 97/257	Büyükkaya	Awl	Cu-As	347/412.2
	ETD 97/268	Büyükkaya	Awl	Cu-As	347/415.P3
	ETD 98/06	Büyükkaya	Eye needle	Cu-Sn	353/420.347
	ETD 98/07	Büyükkaya	Tube, sheet	Cu-Sn-Ni	305/346.10
	ETD 98/09	Büyükkaya	Tool, indeterminate	Cu-As	346/414.663
	ETD 98/11	Büyükkaya	Eye needle, fragment	Cu	349/410.158
	ETD 98/13	Büyükkaya	Eye needle, fragment	Cu	345/414.335
	ETD 98/16	Büyükkaya	Tool, indeterminate	Cu-As	348/410.108
	ETD 98/18	Büyükkaya	Pin, lenticular	Cu	346/413.736
MA-136321	ETD 98/21	Büyükkaya	Pendant, indeterminate	Cu-As	348/410.164
	ETD 98/22	Büyükkaya	Awl	Cu	343/414.436
	ETD 98/23	Büyükkaya	Edged chisel	Cu-As	346/413.638
	ETD 99/88	Granary	Awl	Cu-Sn-Pb	309/341.25

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 13/125	Lower City - City Wall	Pin, disc	Cu-As-Sn	0
	Bo 13/655	Lower City - City Wall	Edged chisel	Cu	0
	Bo 13/803	Lower City - City Wall	Indeterminate	Cu-Sn	380
	Bo 09/780	Lower City - Kesikkaya, Northwest	Pin, nodular	Cu-Pb	381
	Bo 09/1057	Lower City - Kesikkaya, Northwest	Pin, lamellar	Cu	615
	Bo 09/1063	Lower City - Kesikkaya, Northwest	Awl	Cu	604
	Bo 09/1074	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu	611
MA-136336	Bo 09/1095	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	630
	Bo 09/1131	Lower City - Kesikkaya, Northwest	Knife, indeterminate	Cu	1130
	Bo 09/1177	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu	1128
	Bo 09/118	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu-Sn	115
	Bo 09/121	Lower City - Kesikkaya, Northwest	Pin, lenticular	Cu	66
	Bo 09/125	Lower City - Kesikkaya, Northwest	Wire, round section	Cu-As	55
	Bo 09/140	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu	69
	Bo 09/148	Lower City - Kesikkaya, Northwest	Ring, wire	Cu-As	81
	Bo 09/150	Lower City - Kesikkaya, Northwest	Eye needle	Cu	81
	Bo 09/156	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-Sn	71
	Bo 09/194	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-As	91
	Bo 09/198	Lower City - Kesikkaya, Northwest	Indeterminate	Cu-As	103
	Bo 09/211	Lower City - Kesikkaya, Northwest	Wire, round section	Cu	115
	Bo 09/212	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-Sn	115
	Bo 09/274	Lower City - Kesikkaya, Northwest	Wire, round section	Cu-As	128
	Bo 09/278	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-Sn	128
	Bo 09/282	Lower City - Kesikkaya, Northwest	Awl	Cu-Sn	130
	Bo 09/283	Lower City - Kesikkaya, Northwest	Ring, wire	Cu-As	128
	Bo 09/284	Lower City - Kesikkaya, Northwest	Arrowhead, stemmed	Cu	127

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 09/285	Lower City - Kesikkaya, Northwest	Eye needle	Cu	127
	Bo 09/293	Lower City - Kesikkaya, Northwest	Awl	Cu	127
	Bo 09/298	Lower City - Kesikkaya, Northwest	Pin, nodular	Cu-As	131
	Bo 09/321	Lower City - Kesikkaya, Northwest	Arrowhead, lance-form	Cu	142
	Bo 09/322	Lower City - Kesikkaya, Northwest	Awl	Cu-As	141
	Bo 09/324	Lower City - Kesikkaya, Northwest	Ring, wire	Cu	141
	Bo 09/325	Lower City - Kesikkaya, Northwest	Pin, lenticular	Cu-Sn	142
	Bo 09/351	Lower City - Kesikkaya, Northwest	Pin, disc	Cu-Sn	144
MA-136326	Bo 09/355	Lower City - Kesikkaya, Northwest	Pin, lenticular	Cu-Ni	144
	Bo 09/376	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	154
	Bo 09/377	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	154
	Bo 09/378	Lower City - Kesikkaya, Northwest	Pin, incised disc	Cu-As	154
	Bo 09/398	Lower City - Kesikkaya, Northwest	Awl	Cu-As	157
	Bo 09/400	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu	159
	Bo 09/404	Lower City - Kesikkaya, Northwest	Eye needle	Cu-Sn	159
	Bo 09/405	Lower City - Kesikkaya, Northwest	Pin, conical	Cu-As	160
	Bo 09/420	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu	165
	Bo 09/457	Lower City - Kesikkaya, Northwest	Awl	Cu-As	178
	Bo 09/461	Lower City - Kesikkaya, Northwest	Eye needle	Cu	175
	Bo 09/484	Lower City - Kesikkaya, Northwest	Pin, lamellar	Cu-As	193
	Bo 09/499	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-As-Sn	204
	Bo 09/503	Lower City - Kesikkaya, Northwest	Knife, indeterminate	Cu	301
	Bo 09/504	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-Sn	301
	Bo 09/511	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu-Ni	301
	Bo 09/53	Lower City - Kesikkaya, Northwest	Sheet, indeterminate	Cu	20
	Bo 09/583	Lower City - Kesikkaya, Northwest	Pin, lenticular	Cu-As	331

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 09/656	Lower City - Kesikkaya, Northwest	Pin, nodular	Cu-As	352
	Bo 09/660	Lower City - Kesikkaya, Northwest	Sheet, indeterminate	Cu-As	353
	Bo 09/686	Lower City - Kesikkaya, Northwest	Arrowhead, stemmed	Cu-Sn	361
	Bo 09/687	Lower City - Kesikkaya, Northwest	Pin, disc	Cu-As-Sn	361
	Bo 09/699	Lower City - Kesikkaya, Northwest	Pin, disc	Cu-As	354
	Bo 09/715	Lower City - Kesikkaya, Northwest	Pin, pyramidal	Cu-As-Sn	362
	Bo 09/775	Lower City - Kesikkaya, Northwest	Edged chisel	Cu	390
	Bo 09/797	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu-Ni	404
	Bo 09/803	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	407
	Bo 09/811	Lower City - Kesikkaya, Northwest	Pin, lenticular	Cu-As-Sn	403
	Bo 09/827	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu-Pb	507
	Bo 09/835	Lower City - Kesikkaya, Northwest	Eye needle	Cu	511
	Bo 09/880	Lower City - Kesikkaya, Northwest	Eye needle	Cu	532
MA-136338	Bo 09/972	Lower City - Kesikkaya, Northwest	Pin, rolled	Cu-Ni	591
	Bo 09/991	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	598
MA-132213	Bo 10/13	Lower City - Kesikkaya, Northwest	Awl	Cu-As	1
MA-132244	Bo 10/186	Lower City - Kesikkaya, Northwest	Sheet, indeterminate	Cu-As	47
MA-132267	Bo 10/189	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu-Sn	53
MA-132232	Bo 10/190	Lower City - Kesikkaya, Northwest	Eye needle	Cu-As	47
MA-132209	Bo 10/20	Lower City - Kesikkaya, Northwest	Awl	Cu-As-Sn	6
MA-132229	Bo 10/233	Lower City - Kesikkaya, Northwest	Awl	Cu-As	69
MA-132230	Bo 10/236	Lower City - Kesikkaya, Northwest	Awl	Cu-Sn	69
MA-132219	Bo 10/238	Lower City - Kesikkaya, Northwest	Pin, incised disc	Cu-As	68
MA-132211	Bo 10/24	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-Sn	0
MA-132231	Bo 10/242	Lower City - Kesikkaya, Northwest	Eye needle	Cu-As	68
MA-132220	Bo 10/243	Lower City - Kesikkaya, Northwest	Pin, disc	Cu	69

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-132242	Bo 10/244	Lower City - Kesikkaya, Northwest	Pin, disc	Cu	69
MA-132241	Bo 10/249	Lower City - Kesikkaya, Northwest	Pin, square	Cu	68
MA-132266	Bo 10/250	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu-As-Sn	68
MA-132240	Bo 10/251	Lower City - Kesikkaya, Northwest	Pin, conical	Cu-As	68
MA-132245	Bo 10/254	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	67
MA-132239	Bo 10/257	Lower City - Kesikkaya, Northwest	Arrowhead, indeterminate	Cu	99
MA-132238	Bo 10/282	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-As	73
MA-132237	Bo 10/287	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu-As	78
MA-132235	Bo 10/305	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu	83
MA-132236	Bo 10/307	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu	83
MA-132233	Bo 10/323	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-As	177
MA-132234	Bo 10/343	Lower City - Kesikkaya, Northwest	Knife, indeterminate	Cu-As	64
MA-132224	Bo 10/37	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-Ni	8
MA-132268	Bo 10/372	Lower City - Kesikkaya, Northwest	Eye needle	Cu	92
MA-132226	Bo 10/38	Lower City - Kesikkaya, Northwest	Ring, wire	Cu-As	8
MA-132269	Bo 10/389	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu	89
MA-132247	Bo 10/391	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu-As	89
MA-132248	Bo 10/392	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu-As	89
MA-132270	Bo 10/393	Lower City - Kesikkaya, Northwest	Awl	Cu-Sn	89
MA-132264	Bo 10/394	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu-As	89
MA-132249	Bo 10/402	Lower City - Kesikkaya, Northwest	Waste, casting	Cu	89
MA-132272	Bo 10/404	Lower City - Kesikkaya, Northwest	Eye needle	Cu-As	89
MA-132271	Bo 10/416	Lower City - Kesikkaya, Northwest	Indeterminate	Cu-As-Ni	87
MA-132251	Bo 10/456	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu-As	99
	Bo 10/492	Lower City - Kesikkaya, Northwest	Pin, disc	Cu	99
MA-132260	Bo 10/496	Lower City - Kesikkaya, Northwest	Indeterminate	Cu-Sn	107

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-132223	Bo 10/53	Lower City - Kesikkaya, Northwest	Tube, sheet	Cu-Sn-Pb	13
MA-132208	Bo 10/59	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu-As	15
MA-132214	Bo 10/64	Lower City - Kesikkaya, Northwest	Indeterminate	Cu-As-Pb	15
MA-132228	Bo 10/843	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu-As-Sn	520
MA-132276	Bo 10/846	Lower City - Kesikkaya, Northwest	Indeterminate	Cu-Sn-Zn	523
MA-132252	Bo 10/853	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu-Sn	509
MA-132280	Bo 10/893	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-As-Sn	545
MA-132221	Bo 10/904	Lower City - Kesikkaya, Northwest	Pin, lenticular	Cu-As	552
MA-132279	Bo 10/928	Lower City - Kesikkaya, Northwest	Edged chisel	Cu	555
MA-132215	Bo 10/935	Lower City - Kesikkaya, Northwest	Full-handled dagger	Cu-As	563
MA-132217	Bo 10/935	Lower City - Kesikkaya, Northwest	Full-handled dagger, rivet	Cu-As	563
MA-132295	Bo 11/492	Lower City - Kesikkaya, Northwest	Arrowhead, stemmed	Cu-As	54
MA-132296	Bo 11/502	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu-As	56
MA-132292	Bo 11/522	Lower City - Kesikkaya, Northwest	Awl	Cu-As	
MA-132297	Bo 11/527	Lower City - Kesikkaya, Northwest	Indeterminate	Cu-As	59
	Bo 11/535	Lower City - Kesikkaya, Northwest	Wire, round section	Cu	
MA-132290	Bo 11/591	Lower City - Kesikkaya, Northwest	Nail	Cu-As	64
	Bo 12/06	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-As-Sn	
	Bo 13/304	Lower City - Kesikkaya, Northwest	Awl	Cu-Sn	0
	Bo 13/305	Lower City - Kesikkaya, Northwest	Sheet, indeterminate	Cu	0
	Bo 13/327	Lower City - Kesikkaya, Northwest	Awl	Cu-As-Sn	4
	Bo 13/328	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	4
	Bo 13/340	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-As	6
	Bo 13/342	Lower City - Kesikkaya, Northwest	Spiral	Cu-As	7
	Bo 13/344	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-As	7
	Bo 13/346	Lower City - Kesikkaya, Northwest	Pin, lamellar	Cu-Sn	7

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 13/351	Lower City - Kesikkaya, Northwest	Ring, wire	Cu-Sn-Pb	6
	Bo 13/363	Lower City - Kesikkaya, Northwest	Eye needle	Cu-As	8
	Bo 13/364	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	7
	Bo 13/377	Lower City - Kesikkaya, Northwest	Arrowhead, indeterminate	Cu	13
	Bo 13/381	Lower City - Kesikkaya, Northwest	Flat axe, indeterminate	Cu-Sn	14
	Bo 13/382	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	8
	Bo 13/388	Lower City - Kesikkaya, Northwest	Knife, indeterminate	Cu-As	8
	Bo 13/392	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-As	8
	Bo 13/393	Lower City - Kesikkaya, Northwest	Pin, lenticular	Cu-As-Sn	16
	Bo 13/396	Lower City - Kesikkaya, Northwest	Eye needle	Cu-As	15
	Bo 13/398	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-As-Sn	16
	Bo 13/403	Lower City - Kesikkaya, Northwest	Ring, wire	Cu-Sn	16
	Bo 13/413	Lower City - Kesikkaya, Northwest	Pin, indeterminate	Cu-Ni	18
	Bo 13/418	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	15
	Bo 13/419	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu-As	15
	Bo 13/421	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-As	0
	Bo 13/425	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-As	18
	Bo 13/426	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	18
	Bo 13/449	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	0
	Bo 13/466	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-As	32
	Bo 13/471	Lower City - Kesikkaya, Northwest	Ring, wire	Cu	32
	Bo 13/472	Lower City - Kesikkaya, Northwest	Ring, wire	Cu	Bo10.99
	Bo 13/473	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	30
	Bo 13/476	Lower City - Kesikkaya, Northwest	Pin, pyramidal	Cu-As	35
	Bo 13/479	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	30
	Bo 13/488	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	38

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 13/492	Lower City - Kesikkaya, Northwest	Pin, disc	Cu-As	99
	Bo 13/499	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-As	0
	Bo 13/500	Lower City - Kesikkaya, Northwest	Eye needle	Cu-As	38
	Bo 13/520	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	41
	Bo 13/527	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	59
	Bo 13/529	Lower City - Kesikkaya, Northwest	Pin, square	Cu-As	41
	Bo 13/535	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-As	40
	Bo 13/538	Lower City - Kesikkaya, Northwest	Pin, square	Cu-As	41
	Bo 13/543	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	20
	Bo 13/548	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	42
	Bo 13/568	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu-As	43
	Bo 13/573	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu-As	52
	Bo 13/585	Lower City - Kesikkaya, Northwest	Eye needle	Cu-As	70
	Bo 13/586	Lower City - Kesikkaya, Northwest	Pin, pyramidal	Cu-As	56
	Bo 13/587	Lower City - Kesikkaya, Northwest	Awl	Cu-Sn	55
	Bo 13/589	Lower City - Kesikkaya, Northwest	Pin, pyramidal	Cu-As	43
	Bo 13/591	Lower City - Kesikkaya, Northwest	Awl	Cu-As	64
	Bo 13/592	Lower City - Kesikkaya, Northwest	Eye needle	Cu	43
	Bo 13/595	Lower City - Kesikkaya, Northwest	Eye needle	Cu	71
	Bo 13/606	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	59
	Bo 13/610	Lower City - Kesikkaya, Northwest	Waste, casting	Cu-As	
	Bo 13/618	Lower City - Kesikkaya, Northwest	Sheet, indeterminate	Cu-As-Sn	70
	Bo 13/620	Lower City - Kesikkaya, Northwest	Awl	Cu-As-Pb	5
	Bo 13/622	Lower City - Kesikkaya, Northwest	Ring, wire	Cu-Sn	60
	Bo 13/622?	Lower City - Kesikkaya, Northwest	Eye needle	Cu	74
	Bo 13/623	Lower City - Kesikkaya, Northwest	Sheet, indeterminate	Cu-Sn	60

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 13/624	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu-As	43
	Bo 13/625	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu-As-Sn-Pb	43
	Bo 13/626	Lower City - Kesikkaya, Northwest	Eye needle	Cu-As	43
	Bo 13/628	Lower City - Kesikkaya, Northwest	Indeterminate	Cu-Sn	60
	Bo 13/632	Lower City - Kesikkaya, Northwest	Pin, square	Cu-As	43
	Bo 13/633	Lower City - Kesikkaya, Northwest	Edged chisel	Cu-As	0
	Bo 13/639	Lower City - Kesikkaya, Northwest	Eye needle	Cu-As	43
	Bo 13/642	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	43
	Bo 13/643	Lower City - Kesikkaya, Northwest	Pin, pyramidal	Cu	43
	Bo 13/646	Lower City - Kesikkaya, Northwest	Sheet, indeterminate	Cu	43
	Bo 13/648	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	67
	Bo 13/659	Lower City - Kesikkaya, Northwest	Eye needle, fragment	Cu	0
	Bo 13/664	Lower City - Kesikkaya, Northwest	Pin, fungiform	Cu-As	0
	Bo 13/677	Lower City - Kesikkaya, Northwest	Indeterminate	Cu-Ni	8
	Bo 13/678	Lower City - Kesikkaya, Northwest	Indeterminate	Cu	6
	Bo 13/679	Lower City - Kesikkaya, Northwest	Indeterminate	Cu-Ni	6
	Bo 13/680	Lower City - Kesikkaya, Northwest	Indeterminate	Cu-As	16
	Bo 13/681	Lower City - Kesikkaya, Northwest	Pin, shaft fragment	Cu	20
MA-132210	Bo 10/1512	Lower City - Kesikkaya, Posternmauer	Pin, shaft fragment	Cu-As-Sn	304
MA-132207	Bo 10/507	Lower City - Kesikkaya, Posternmauer	Pin, shaft fragment	Cu	301
MA-132212	Bo 10/544	Lower City - Kesikkaya, Posternmauer	Edged chisel	Cu-As-Sn	310
MA-132222	Bo 10/554	Lower City - Kesikkaya, Posternmauer	Eye needle, fragment	Cu-As	530
MA-132273	Bo 10/558	Lower City - Kesikkaya, Posternmauer	Pin, nodular	Cu-As	331
MA-132263	Bo 10/566	Lower City - Kesikkaya, Posternmauer	Pin, indeterminate	Cu-As	314
MA-132274	Bo 10/574	Lower City - Kesikkaya, Posternmauer	Pin, shaft fragment	Cu	336
MA-132298	Bo 11/909	Lower City - Kesikkaya, Posternmauer	Nail	Cu	603

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 13/588	Lower City - Kesikkaya, Posternmauer	Pin, pyramidal	Cu-As-Pb	56
MA-132253	Bo 10/1232	Lower City - Kesikkaya, South	Pin, indeterminate	Cu-As-Sn	723
MA-132243	Bo 10/1234	Lower City - Kesikkaya, South	Eye needle, fragment	Cu	723
MA-132277	Bo 10/1277	Lower City - Kesikkaya, South	Eye needle	Cu-As	746
MA-132254	Bo 10/1282	Lower City - Kesikkaya, South	Pin, indeterminate	Cu-As	752
MA-132255	Bo 10/1283	Lower City - Kesikkaya, South	Indeterminate	Cu-Sn	750
MA-132258	Bo 10/1291	Lower City - Kesikkaya, South	Hook	Cu-As-Sn	757
MA-132257	Bo 10/1292	Lower City - Kesikkaya, South	Eye needle, fragment	Cu-As	738
MA-132261	Bo 10/1294	Lower City - Kesikkaya, South	Edged chisel	Cu-As-Sn	738
MA-132262	Bo 10/1295	Lower City - Kesikkaya, South	Pin, indeterminate	Cu-As	738
MA-132256	Bo 10/1297	Lower City - Kesikkaya, South	Pin, shaft fragment	Cu-As-Sn	758
MA-132278	Bo 10/1302	Lower City - Kesikkaya, South	Pin, rolled	Cu-As	758
MA-132284	Bo 11/15	Lower City - Kesikkaya, South	Pin, pyramidal	Cu-As	603
MA-132294	Bo 11/18	Lower City - Kesikkaya, South	Nail	Cu	605
MA-132286	Bo 11/4	Lower City - Kesikkaya, South	Pin, square	Cu-As	303
MA-132293	Bo 11/42	Lower City - Kesikkaya, South	Indeterminate	Cu-Sn	311
MA-132289	Bo 11/65	Lower City - Kesikkaya, South	Nail	Cu-As	338
	Bo 11/8	Lower City - Kesikkaya, South	Pin, disc	Cu	307
	Bo 13/101	Lower City - Kesikkaya, South	Pin, shaft fragment	Cu-As	331
	Bo 13/116	Lower City - Kesikkaya, South	Wire, round section	Cu	338
	Bo 13/122	Lower City - Kesikkaya, South	Arrowhead, lance-form	Cu-As	338
	Bo 13/135	Lower City - Kesikkaya, South	Arrowhead, stemmed and spurred	Cu-As	342
	Bo 13/177	Lower City - Kesikkaya, South	Pin, shaft fragment	Cu-Sn	357
	Bo 13/18	Lower City - Kesikkaya, South	Awl	Cu-As	306
	Bo 13/204	Lower City - Kesikkaya, South	Awl	Cu-Sn	353
	Bo 13/238	Lower City - Kesikkaya, South	Awl	Cu-As	367

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-136341	Bo 13/39	Lower City - Kesikkaya, South	Pin, lamellar	Cu-As-Ni	323
	Bo 13/61	Lower City - Kesikkaya, South	Indeterminate	Cu	0
	Bo 13/64	Lower City - Kesikkaya, South	Awl	Cu	316
	Bo 13/76	Lower City - Kesikkaya, South	Indeterminate	Cu	323
	Bo 13/82	Lower City - Kesikkaya, South	Edged chisel	Cu	304
MA-132185	Bo 170/h	Lower City - Northern Quarter	Flat axe, lugged	Cu-As	Boehmer 1972: n. 24
MA-132183	Bo 171/h	Lower City - Northern Quarter	Flat axe, indeterminate	Cu-Sn	Boehmer 1972: n. 25
MA-132187	Bo 173/h	Lower City - Northern Quarter	Arrowhead, lance-form	Cu-As	Boehmer 1972: n. 203
MA-132190	Bo 216/p	Lower City - Northern Quarter	Figurine	Cu-As-Pb	Boehmer 1972: n. 170
	Bo 503/o	Lower City - Northern Quarter	Sheet, decorated	Cu-Ni	Boehmer 1972: n. 169
	Bo 73/141	Lower City - Northern Quarter	Arrowhead, stemmed and spurred	Cu-As-Sn	J/20-I/1, foundation pit of the robbed out wall.
	Bo 73/167	Lower City - Northern Quarter	Full-handled dagger	Cu	J/19-I/10, from debris under the stone rubble over the wall of House 11
	Bo 74/7	Lower City - Northern Quarter	Arrowhead, lance-form	Cu-As	J/20 ridge between II/2 and II/2-NW
	Bo 77/146	Lower City - Northern Quarter	Saw	Cu	K/20-III/3, House/basin 43, under the stone rubble over the floor, directly in front of the SW-wall of the basin
MA-132173	Bo 77/385a	Lower City - Northern Quarter	Figurine	Cu-As	K/20-IV/3 north, in the northeastern pithos wall. terraced house adjacent to Temple 1
MA-132172	Bo 77/385b	Lower City - Northern Quarter	Figurine	Cu	K/20-IV/3 north, in the northeastern pithos wall. terraced house adjacent to Temple 1
MA-132184	Bo 91/h	Lower City - Northern Quarter	Staff blade	Cu-As-Sn	Boehmer 1972: n. 64
MA-132186	Bo 95/h	Lower City - Northern Quarter	Arrowhead, lance-form	Cu-As	Boehmer 1972: n. 828
MA-132218	Bo 10/1409	Lower City - Temple 1 Magazines	Edged chisel	Cu-As	907
MA-132265	Bo 10/1425	Lower City - Temple 1 Magazines	Edged chisel	Cu-As	914
MA-132288	Bo 11/1203	Lower City - Temple 1 Magazines	Arrowhead, stemmed and spurred	Cu	904
MA-132283	Bo 11/1205	Lower City - Temple 1 Magazines	Eye needle, fragment	Cu	904
MA-132282	Bo 11/1215	Lower City - Temple 1 Magazines	Arrowhead, sheet	Cu-As	908
MA-132291	Bo 11/1223	Lower City - Temple 1 Magazines	Awl	Cu	912

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	ETD 99/54	Northwest Slope - Granary	Sheet, indeterminate	Cu-Ni	310/343.16
	ETD 99/55	Northwest Slope - Granary	Awl	Cu	309/343.52
	ETD 99/57	Northwest Slope - Granary	Awl	Cu-Ni	309/343.103
	ETD 99/58	Northwest Slope - Granary	Eye needle	Cu	308/343.16
	ETD 99/59	Northwest Slope - Granary	Awl	Cu-Sn	309/344.145
	ETD 99/60	Northwest Slope - Granary	Wire, round section	Cu	309/343.34
	ETD 99/67	Northwest Slope - Granary	Eye needle, fragment	Cu-As	308/343.68
	ETD 99/68	Northwest Slope - Granary	Wire, round section	Cu	311/342.8
	ETD 99/69	Northwest Slope - Granary	Eye needle, fragment	Cu	309/343.180
	ETD 99/70	Northwest Slope - Granary	Pin, shaft fragment	Cu-As	310/343.45
	ETD 99/71	Northwest Slope - Granary	Awl	Cu-As	309/343.36
	ETD 99/73	Northwest Slope - Granary	Awl	Cu-As-Sn	309/343.16
	ETD 99/75	Northwest Slope - Granary	Sheet, indeterminate	Cu-Ni	311/342.14
	ETD 99/76	Northwest Slope - Granary	Eye needle, fragment	Cu-As	309/343.225
	ETD 99/80	Northwest Slope - Granary	Wire, round section	Cu-As-Sn	311/342.30
	ETD 99/81	Northwest Slope - Granary	Indeterminate	Cu-As-Sn	311/342.2
	ETD 99/82	Northwest Slope - Granary	Indeterminate	Cu-As	311/342.2
	ETD 99/83	Northwest Slope - Granary	Awl	Cu-As-Sn	311/342.2
	ETD 99/85	Northwest Slope - Granary	Pin, shaft fragment	Cu-Sn	311/342.2
	ETD 99/86	Northwest Slope - Granary	Awl	Cu-As	311/342.23
	ETD 99/87	Northwest Slope - Granary	Awl	Cu-As	309/341.28
	ETD 99/89	Northwest Slope - Granary	Wire, round section	Cu	308/346.26
	ETD 99/90	Northwest Slope - Granary	Wire, round section	Cu-Sn	308/346.26
	ETD 99/92	Northwest Slope - Granary	Eye needle, fragment	Cu	308/346.48
	ETD 99/93	Northwest Slope - Granary	Arrowhead, stemmed	Cu-As	308/344.11
	ETD 99/94	Northwest Slope - Granary	Eye needle, fragment	Cu	311/342.50

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	ETD 99/95	Northwest Slope - Granary	Eye needle, fragment	Cu-Ni	311/342.54
	ETD 99/96	Northwest Slope - Granary	Awl	Cu-As-Sn	311/342.42
	Bo 07/2742	Northwest Slope - Middle Plateau	Eye needle, fragment	Cu-As-Pb	1578
MA-132179	Bo 645/t	Northwest Slope - Northwest Slope	Knife, flat and curved	Cu-As-Sn	Boehmer 1972: n. 258
	ETD 96/39	Upper City - East reservoirs	Awl	Cu	344/300.28
	ETD 96/44	Upper City - East reservoirs	Awl	Cu	346/303.40
	ETD 96/47	Upper City - East reservoirs	Eye needle	Cu-As	244/301.34
	ETD 96/50	Upper City - East reservoirs	Insert, hammer-shaped	Cu-Sn	344/308.6
	ETD 96/51	Upper City - East reservoirs	Ring, wire	Cu-As-Sn	344/303.6
	ETD 96/53	Upper City - East reservoirs	Sheet, indeterminate	Cu-Ni	344/301.33
	ETD 96/59	Upper City - East reservoirs	Eye needle	Cu	342/299.12
	ETD 96/61	Upper City - East reservoirs	Awl	Cu-As-Sn	342/299.21
MA-136337	Dowel_1	Upper City - King's Gate	Dowel	Cu-As	Sample taken in situ from the dowel fastening two cut cyclopean blocks of the interior jamb of the southern gate tower (described in Puchstein 1912: 67).
	10-1-92	Upper City – near to Lion's Gate	Sword	Cu-Sn	Neve 1993: 648-652, Ünal et al. 1992
	Bo 91/2414	Upper City - Nişantepe	Shaft-hole axe	Cu-Sn	M/12-a/2 (NW)
	ETD 00/10	Upper City - South reservoirs	Wire, round section	Cu-As-Sn	293/255.3
	ETD 00/11	Upper City - South reservoirs	Eye needle, fragment	Cu-As	298/252.21
	ETD 00/16	Upper City - South reservoirs	Sheet, indeterminate	Cu-Sn	298/252.12
	ETD 00/17	Upper City - South reservoirs	Waste, casting	Cu-Sn	292/256.5
	ETD 00/6	Upper City - South reservoirs	Pin, unique	Cu-Sn	295/254.6
	ETD 00/7	Upper City - South reservoirs	Eye needle, fragment	Cu-As	295/254.13
	ETD 00/8	Upper City - South reservoirs	Wire, round section	Cu-Ni	298/252.10
	ETD 00/9	Upper City - South reservoirs	Eye needle, fragment	Cu-As-Sn	298/253.20
	ETD 98/15	Upper City - South reservoirs	Wire, round section	Cu-Ni	305/346.22
	Bo 89/41	Upper City - Südburg	Figurine	Cu-Sn-Pb	N/21-g/1, northwestern section of the Südburg, in

Mannheim Number	**Object Number**	**Location**	**Object Type**	**Alloy type**	**Context (number or description)**
					rubble with fired brick over the western wall of the Hittite West House.
	Bo 78/113	Upper City - Temple quarter	Stylus	Cu-Sn	Temple 6, Room 30a
MA-132196	Bo 79/206	Upper City - Temple quarter	Ingot, oxhide	Cu	House 2; L/7-g/5 south, located immediately in front of the inside of the northern wall of the "Uraltkellers" 40cm below the surface and stone collapse (Müller-Karpe, in Neve 1980: 301,303-304; Stos-Gale, et al. 1997: 111, n. TU174).
	Bo 81/8	Upper City - Temple quarter	Pin, conical	Cu-Sn	
MA-132563	Bo 82/102	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 7, Room 25
MA-132562	Bo 82/103	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 7, Room 8
MA-132301	Bo 82/109a	Upper City - Temple quarter	Arrowhead, stemmed	Cu	Temple 7, Room 24
MA-132534	Bo 82/109b	Upper City - Temple quarter	Arrowhead, stemmed	Cu	Temple 7, Room 24
MA-132176	Bo 82/112	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 7, Room 25
MA-132182	Bo 82/138	Upper City - Temple quarter	Flat axe, lugged	Cu-Sn	Temple 7, Room 9
MA-132565	Bo 82/139	Upper City - Temple Quarter	Sickle	Cu-As-Sn-Pb	Temple 7
MA-132175	Bo 82/140	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 7, Room 9
MA-132181	Bo 82/141	Upper City - Temple quarter	Knife, flat and curved	Cu-As-Sn	Temple 7, Room 9
	Bo 82/148	Upper City - Temple quarter	Sickle	Cu	Temple 7, Room 9
	Bo 83/220	Upper City - Temple quarter	Pin, rolled	Cu-Sn	Temple 9
	Bo 83/310	Upper City - Temple quarter	Pin, rolled	Cu-Sn	Temple 9, Room 27
	Bo 83/442	Upper City - Temple quarter	Arrowhead, lance-form	Cu-As	Temple 11
	Bo 83/444	Upper City - Temple quarter	Arrowhead, lance-form	Cu-As	Temple 9 , Room 27
	Bo 83/450	Upper City - Temple quarter	Full-handled dagger	Cu	Temple 9, Room 27
MA-132578	Bo 83/580	Upper City - Temple quarter	Arrowhead, lance-form	Cu-Sn	Temple 12
MA-132582	Bo 83/712	Upper City - Temple quarter	Arrowhead, stemmed	Cu-Sn	Temple 12
MA-136323	Bo 83/819	Upper City - Temple quarter	Ingot, planoconvenx	Cu	Temple 7
	Bo 83/889	Upper City - Temple quarter	Arrowhead, stemmed and spurred	Cu-Sn	Temple 12

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 84/22	Upper City - Temple quarter	Figurine	Cu-Sn	Temple 8
	Bo 84/341	Upper City - Temple quarter	Pin, conical	Cu-Sn	M/8-h/3
	Bo 84/531	Upper City - Temple quarter	Stylus	Cu-Sn	Temple 8
MA-132178	Bo 84/551	Upper City - Temple quarter	Wrapped socket axe	Cu-Sn	Temple 5
	Bo 84/563	Upper City - Temple quarter	Figurine	Cu-Sn	Temple 4
	Bo 85/117	Upper City - Temple quarter	Pin, incised disc	Cu-Ni	M/8-b/8
	Bo 85/144	Upper City - Temple quarter	Edged chisel	Cu-Sn	Temple 20
	Bo 85/153	Upper City - Temple quarter	Pin, rolled	Cu-Sn	House 21, Room 12
MA-132299	Bo 85/449	Upper City - Temple quarter	Flat axe, indeterminate	Cu-Sn	
	Bo 85/515	Upper City - Temple quarter	Arrowhead, lance-form	Cu	Temple 26
MA-132300	Bo 85/71	Upper City - Temple quarter	Indeterminate	Cu-Sn	
MA-132587	Bo 86/101	Upper City - Temple quarter	Arrowhead, stemmed and spurred	Cu-As-Sn	M/7-a/10
	Bo 86/168	Upper City - Temple quarter	Armor plate	Cu-Sn	House 26
	Bo 86/282	Upper City - Temple quarter	Arrowhead, lance-form	Cu-As-Sn	House 26
MA-132586	Bo 86/321	Upper City - Temple quarter	Arrowhead, stemmed and spurred	Cu	House 26
	Bo 86/411	Upper City - Temple quarter	Hook	Cu-Sn	M/7-g/9
MA-136343	Bo 86/427	Upper City - Temple quarter	Armor plate	Cu-Ni	House 34, Room 3
	Bo 86/431	Upper City - Temple quarter	Eye needle	Cu-As	M/6-f/1
MA-132177	Bo 86/94	Upper City - Temple quarter	Wrapped socket axe	Cu-Sn	House 31
	Herbordt Kat Ify-39 (12); Bo 82-214b	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (14); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (15); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (16); Bo 82-214a	Upper City - Temple quarter	Armor plate	Cu-As-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (2); Bo 82-214b	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Herbordt Kat Ify-39 (20); Bo 82-314a	Upper City - Temple Quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (22); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (23); Bo 82-214b	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (24); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (25); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (26); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (27); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (28); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-As-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (29); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (3); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (32); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (35); Bo 82-214b	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (36); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (39); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (4); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (41); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (42); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (43); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (44); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Herbordt Kat Ify-39 (45); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (51); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (6); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (7); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-As-Sn	Temple 9, Room 1
	Herbordt Kat Ify-39 (8); Bo 82-314a	Upper City - Temple quarter	Armor plate	Cu-Sn	Temple 9, Room 1
	scale 9	Upper City - Temple quarter	Armor plate	Cu-Sn	Inventory ID not preserved, probably part of the cache of armor plates discovered in Temple 9, Room 1.
	Bo 82/19	Upper City - Yerkapı	Pin, lamellar	Cu-Sn	found in the debris over the lower stair section on the eastern slope of Yerkapı.
MA-132308	Bo 06/1058	Upper City West - Middle Plateau	Pin, incised disc	Cu-As-Ni	521
	Bo 06/1115	Upper City West - Middle Plateau	Arrowhead, indeterminate	Cu-Sn	533
	Bo 06/1133	Upper City West - Middle Plateau	Pin, shaft fragment	Cu-Sn	549
MA-132323	Bo 06/1141	Upper City West - Middle Plateau	Arrowhead, stemmed and spurred	Cu-As-Sn	543
MA-132408	Bo 06/1148	Upper City West - Middle Plateau	Pin, incised disc	Cu-As	546
	Bo 07/2668	Upper City West - Middle Plateau	Eye needle	Cu	1543
	Bo 07/2685	Upper City West - Middle Plateau	Awl	Cu-Sn	1521
	Bo 07/2690	Upper City West - Middle Plateau	Pin, conical	Cu-Sn	1552
	Bo 07/2691	Upper City West - Middle Plateau	Rod	Cu-As	1552
	Bo 07/2748	Upper City West - Middle Plateau	Pin, conical	Cu-As-Sn	1582
	Bo 07/2819	Upper City West - Middle Plateau	Eye needle, fragment	Cu	1595
MA-136342	Bo 08/1510	Upper City West - Middle Plateau	Pin, incised disc	Cu-Ni	1503
	Bo 08/1544	Upper City West - Middle Plateau	Pin, shaft fragment	Cu	1516
	Bo 08/358	Upper City West - Middle Plateau	Pin, lenticular	Cu	153
	Bo 08/359	Upper City West - Middle Plateau	Pin, rolled	Cu-As-Sn	153
	Bo 08/393	Upper City West - Middle Plateau	Wire, round section	Cu-Sn	172

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 08/403	Upper City West - Middle Plateau	Awl	Cu-Sn	15
	Bo 08/415	Upper City West - Middle Plateau	Pin, shaft fragment	Cu-As	177
	Bo 08/826	Upper City West - Middle Plateau	Awl	Cu	807
	Bo 08/892	Upper City West - Middle Plateau	Eye needle	Cu	811
	Bo 08/914	Upper City West - Middle Plateau	Edged chisel	Cu-As	0
	Bo 08/931	Upper City West - Middle Plateau	Awl	Cu	843
	Bo 08/934	Upper City West - Middle Plateau	Ornament	Cu	848
	Bo 08/952	Upper City West - Middle Plateau	Pin, lenticular	Cu-As	853
	Bo 09/54	Upper City West - Middle Plateau	Eye needle	Cu-As	0
	Bo 09/64	Upper City West - Middle Plateau	Wire, round section	Cu-Sn	24
	Bo 09/73	Upper City West - Middle Plateau	Insert, hammer-shaped	Cu-As-Sn	29
	Bo 02/39	Upper City West - Sarıkale Valley	Arrowhead, stemmed and spurred	Cu-Sn	found on the floor context of a structure in 292/309
	Bo 02/41	Upper City West - Sarıkale Valley	Arrowhead, lance-form	Cu	292/309.60
	Bo 02/45	Upper City West - Sarıkale Valley	Shouldered axe	Cu-As-Sn	292/304.107
	Bo 02/49	Upper City West - Sarıkale Valley	Knife, flat and straight	Cu	292/309.67
	Bo 02/50	Upper City West - Sarıkale Valley	Indeterminate	Cu	292/308.72
	Bo 02/55	Upper City West - Sarıkale Valley	Knife, flat and curved	Cu	found on the floor context of a structure in 292/309
	Bo 03/21	Upper City West - Sarıkale Valley	Arrowhead, lance-form	Cu	291/309.61
	Bo 03/41	Upper City West - Sarıkale Valley	Insert, axe-shaped	Cu-Sn	291/305.79
	Bo 04/30	Upper City West - Sarıkale Valley	Arrowhead, stemmed	Cu-As-Sn	293/305.71
	Bo 04/32	Upper City West - Sarıkale Valley	Arrowhead, lance-form	Cu	293/307.118
	Bo 04/34	Upper City West - Sarıkale Valley	Awl	Cu-As	293/306.210
	Bo 05/13	Upper City West - Sarıkale Valley	Seal	Cu, composite	293/305.293; Herbordt 2006: 184.
	Bo 05/21	Upper City West - Sarıkale Valley	Arrowhead, indeterminate	Cu	
	Bo 05/23	Upper City West - Sarıkale Valley	Arrowhead, indeterminate	Cu	
	Bo 05/25	Upper City West - Sarıkale Valley	Knife, flat and straight	Cu-As	293/306.290

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 05/29	Upper City West - Sarıkale Valley	Stylus	Cu-Sn	293/305.252
	Bo 05/30	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Sn	294/306.97
	Bo 05/31	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	
	Bo 05/33	Upper City West - Sarıkale Valley	Pin, rolled	Cu-As-Sn	
	Bo 05/34	Upper City West - Sarıkale Valley	Pin, rolled	Cu-As	
	Bo 05/36	Upper City West - Sarıkale Valley	Pin, conical	Cu-As-Sn	
	Bo 05/38	Upper City West - Sarıkale Valley	Pin, disc	Cu-As	
	Bo 05/51	Upper City West - Sarıkale Valley	Knife, indeterminate	Cu-As-Sn	
MA-132461	Bo 06/1018	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	230
	Bo 06/1039	Upper City West - Sarıkale Valley	Awl	Cu-Sn	230
MA-132359	Bo 06/106	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Pb	21
MA-132343	Bo 06/108	Upper City West - Sarıkale Valley	Pendant, decorated sheet	Cu-Ni	31
MA-132433	Bo 06/124	Upper City West - Sarıkale Valley	Pin, conical	Cu	22
MA-132339	Bo 06/127	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	22
MA-132387	Bo 06/1302	Upper City West - Sarıkale Valley	Pin, indeterminate	Cu-As	703
MA-132428	Bo 06/1342	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	712
MA-132533	Bo 06/1359	Upper City West - Sarıkale Valley	Eye needle	Cu	724
MA-132385	Bo 06/1364	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	724
MA-132529	Bo 06/137	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu-As	42
MA-132532	Bo 06/1378	Upper City West - Sarıkale Valley	Tweezers	Cu-As	730
	Bo 06/1387	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As	729
MA-132328	Bo 06/1395	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As	736
MA-132306	Bo 06/1397	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	729
MA-132464	Bo 06/1399	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	734
MA-132334	Bo 06/1439	Upper City West - Sarıkale Valley	Pin, fungiform	Cu-As	752
MA-132379	Bo 06/1440	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	752

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-132450	Bo 06/1446	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-As-Pb	752
MA-132327	Bo 06/1449	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	752
MA-132369	Bo 06/1458	Upper City West - Sarıkale Valley	Eye needle	Cu-As	756
MA-132386	Bo 06/1464	Upper City West - Sarıkale Valley	Eye needle	Cu-As	756
MA-132522	Bo 06/1465	Upper City West - Sarıkale Valley	Pin, incised disc	Cu-As	756
MA-132316	Bo 06/1469	Upper City West - Sarıkale Valley	Pin, lenticular	Cu	760
MA-132331	Bo 06/1481	Upper City West - Sarıkale Valley	Ring, wire	Cu-As-Sn	1481
MA-132456	Bo 06/1483	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-As	751
MA-132442	Bo 06/1497	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Pb	756
MA-132384	Bo 06/1500	Upper City West - Sarıkale Valley	Ring, wire	Cu	756
MA-132449	Bo 06/1506	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	195
MA-132366	Bo 06/1508	Upper City West - Sarıkale Valley	Pin, disc	Cu-Sn	184
MA-132319	Bo 06/1512	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	198
MA-132392	Bo 06/1513	Upper City West - Sarıkale Valley	Armor plate	Cu-Sn	196
MA-132397	Bo 06/153	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	24
MA-132312	Bo 06/156	Upper City West - Sarıkale Valley	Pin, indeterminate	Cu-Ni	25
MA-132500	Bo 06/1563	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Sn	216
MA-132452	Bo 06/1565	Upper City West - Sarıkale Valley	Pin, indeterminate	Cu-Sn	219
MA-132478	Bo 06/1567	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As	216
MA-132470	Bo 06/1576	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	187
MA-132498	Bo 06/1582	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	0
MA-132474	Bo 06/1599	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	233
MA-132437	Bo 06/160	Upper City West - Sarıkale Valley	Awl	Cu-Sn	27
MA-132350	Bo 06/1600	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	231
MA-132444	Bo 06/1601	Upper City West - Sarıkale Valley	Insert, hammer-shaped	Cu-Sn	231
MA-132406	Bo 06/1609	Upper City West - Sarıkale Valley	Arrowhead, lance-form	Cu-As-Sn	237

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-132325	Bo 06/1614	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	236
MA-132400	Bo 06/1616	Upper City West - Sarıkale Valley	Indeterminate	Cu	230
MA-132373	Bo 06/164	Upper City West - Sarıkale Valley	Indeterminate	Cu	24
MA-132465	Bo 06/1654	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Pb	253
MA-132473	Bo 06/1654_2	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	253
MA-132338	Bo 06/1656	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	255
MA-132505	Bo 06/166	Upper City West - Sarıkale Valley	Pin, pyramidal	Cu	24
MA-132502	Bo 06/168	Upper City West - Sarıkale Valley	Eye needle	Cu	0
MA-132371	Bo 06/1688	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	260
MA-132429	Bo 06/1694	Upper City West - Sarıkale Valley	Awl	Cu-Sn	260
MA-132445	Bo 06/1715	Upper City West - Sarıkale Valley	Eye needle	Cu	272
MA-132463	Bo 06/1716	Upper City West - Sarıkale Valley	Indeterminate	Cu	269
MA-132311	Bo 06/172	Upper City West - Sarıkale Valley	Indeterminate	Cu-Ni	28
MA-132499	Bo 06/1730	Upper City West - Sarıkale Valley	Pin, unique	Cu	278
MA-132383	Bo 06/1739	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	280
MA-132476	Bo 06/1742	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Sn	280
MA-132439	Bo 06/1751	Upper City West - Sarıkale Valley	Pin, unique	Cu-As	284
MA-132466	Bo 06/1753	Upper City West - Sarıkale Valley	Awl	Cu-Sn	283
MA-132203	Bo 06/1754	Upper City West - Sarıkale Valley	Knife, flat and curved	Cu-Sn	284
MA-132398	Bo 06/1755	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Sn	0
MA-132330	Bo 06/1758	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	289
MA-132430	Bo 06/1758_2	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	289
MA-132421	Bo 06/1759	Upper City West - Sarıkale Valley	Awl	Cu-As-Sn	284
MA-132352	Bo 06/1762	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As	283
MA-132335	Bo 06/1763	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Sn	291
MA-132394	Bo 06/1764	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	291

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-132489	Bo 06/1768	Upper City West - Sarıkale Valley	Awl	Cu-As-Sn	291
MA-132372	Bo 06/1771	Upper City West - Sarıkale Valley	Insert, hammer-shaped	Cu-Sn	291
MA-132471	Bo 06/1802	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-As	428
MA-132310	Bo 06/1803	Upper City West - Sarıkale Valley	Pin, indeterminate	Cu-As-Ni	428
MA-132348	Bo 06/1806	Upper City West - Sarıkale Valley	Eye needle	Cu	429
MA-132401	Bo 06/1817	Upper City West - Sarıkale Valley	Eye needle	Cu	426
MA-132472	Bo 06/1825	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Sn	436
MA-132357	Bo 06/1834	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	419
MA-132475	Bo 06/1835	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	447
MA-132443	Bo 06/1837	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	447
MA-132382	Bo 06/1844	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	449
	Bo 06/1874	Upper City West - Sarıkale Valley	Awl	Cu-Sn	419
MA-132309	Bo 06/189	Upper City West - Sarıkale Valley	Eye needle	Cu-Ni	30
MA-132377	Bo 06/1933	Upper City West - Sarıkale Valley	Nail	Cu-As	1
MA-132434	Bo 06/1954	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	6
MA-132367	Bo 06/1957	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu-Au-Ag	1
MA-132477	Bo 06/2009	Upper City West - Sarıkale Valley	Seal	Cu-Sn	767
MA-132358	Bo 06/2016	Upper City West - Sarıkale Valley	Indeterminate	Cu	767
MA-132493	Bo 06/2019	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	767
MA-132501	Bo 06/2028	Upper City West - Sarıkale Valley	Eye needle	Cu-As	901
MA-132356	Bo 06/2036	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Sn	901
MA-132305	Bo 06/2037	Upper City West - Sarıkale Valley	Indeterminate	Cu-Ni	901
MA-132318	Bo 06/2039	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	901
MA-132321	Bo 06/2049	Upper City West - Sarıkale Valley	Insert, hammer-shaped	Cu-Sn	903
MA-132454	Bo 06/2056	Upper City West - Sarıkale Valley	Eye needle	Cu	905
MA-132361	Bo 06/207	Upper City West - Sarıkale Valley	Pin, indeterminate	Cu-As-Sn	47

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-132414	Bo 06/2075	Upper City West - Sarıkale Valley	Awl	Cu-As-Sn	905
MA-132487	Bo 06/2089	Upper City West - Sarıkale Valley	Awl	Cu-As	909
MA-132418	Bo 06/2090	Upper City West - Sarıkale Valley	Eye needle	Cu-As	909
MA-132525	Bo 06/2094	Upper City West - Sarıkale Valley	Arrowhead, lance-form	Cu-As	912
MA-132410	Bo 06/210	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	47
MA-132482	Bo 06/2103	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	0
MA-132354	Bo 06/2110	Upper City West - Sarıkale Valley	Eye needle	Cu-Ni	912
MA-132322	Bo 06/212	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	42
MA-132315	Bo 06/2127	Upper City West - Sarıkale Valley	Pin, nodular	Cu-As-Sn	920
MA-132480	Bo 06/2130	Upper City West - Sarıkale Valley	Pin, rolled	Cu-As	1012
MA-132488	Bo 06/2142	Upper City West - Sarıkale Valley	Eye needle	Cu-As	920
MA-132419	Bo 06/215	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Sn	43
MA-132479	Bo 06/2152	Upper City West - Sarıkale Valley	Pin, conical	Cu-Ni	775
MA-132332	Bo 06/2153	Upper City West - Sarıkale Valley	Eye needle	Cu-As	920
MA-132492	Bo 06/2182	Upper City West - Sarıkale Valley	Knife, flat and straight	Cu	767
MA-132417	Bo 06/2192	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As-Sn	911
MA-132415	Bo 06/2229	Upper City West - Sarıkale Valley	Pin, lenticular	Cu	911
MA-132497	Bo 06/223	Upper City West - Sarıkale Valley	Pin, conical	Cu-As	0
MA-132523	Bo 06/2236	Upper City West - Sarıkale Valley	Pin, disc	Cu-As	779
MA-132425	Bo 06/2237	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As	779
MA-132375	Bo 06/2244	Upper City West - Sarıkale Valley	Eye needle	Cu-As	933
	Bo 06/2251	Upper City West - Sarıkale Valley	Edged chisel	Cu	
MA-132403	Bo 06/2253	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As-Sn	766
MA-132494	Bo 06/2263	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	766
	Bo 06/2269	Upper City West - Sarıkale Valley	Arrowhead, lance-form	Cu	766
MA-132345	Bo 06/2294	Upper City West - Sarıkale Valley	Awl	Cu-Sn	937

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-132342	Bo 06/2298	Upper City West - Sarıkale Valley	Ring, wire	Cu-Sn-Ni	941
	Bo 06/23	Upper City West - Sarıkale Valley	Sheet, decorated	Cu	1
	Bo 06/2350	Upper City West - Sarıkale Valley	Ring, wire	Cu-As-Sn	765
MA-132462	Bo 06/2359	Upper City West - Sarıkale Valley	Pin, indeterminate	Cu	948
MA-132304	Bo 06/2361	Upper City West - Sarıkale Valley	Indeterminate	Cu-Ni	948
MA-132351	Bo 06/2376	Upper City West - Sarıkale Valley	Eye needle	Cu-As	950
MA-132317	Bo 06/2378	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-As	950
MA-132344	Bo 06/239	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Sn	73
MA-132363	Bo 06/2398	Upper City West - Sarıkale Valley	Eye needle	Cu-As	967
MA-132411	Bo 06/2400	Upper City West - Sarıkale Valley	Arrowhead, stemmed and spurred	Cu-Sn	971
MA-132364	Bo 06/2403	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As	970
MA-132355	Bo 06/2409	Upper City West - Sarıkale Valley	Eye needle	Cu	970
MA-132453	Bo 06/241	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-Sn	73
MA-132508	Bo 06/242	Upper City West - Sarıkale Valley	Eye needle	Cu-As-Sn	74
MA-132346	Bo 06/2428	Upper City West - Sarıkale Valley	Sheet ring	Cu-Ni	971
MA-132402	Bo 06/250	Upper City West - Sarıkale Valley	Indeterminate	Cu	74
MA-132340	Bo 06/254	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	17
MA-132468	Bo 06/257	Upper City West - Sarıkale Valley	Armor plate	Cu-Sn	17
MA-132349	Bo 06/258	Upper City West - Sarıkale Valley	Indeterminate	Cu	17
MA-132409	Bo 06/259	Upper City West - Sarıkale Valley	Edged chisel	Cu-Sn	82
MA-132486	Bo 06/265	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-As-Sn	17
MA-132483	Bo 06/266	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-As	17
MA-132485	Bo 06/267	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Sn	17
MA-132484	Bo 06/268	Upper City West - Sarıkale Valley	Indeterminate	Cu	17
MA-132469	Bo 06/268_2	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	17
MA-132381	Bo 06/272	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-Sn	68

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-132491	Bo 06/274	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	43
MA-132423	Bo 06/284	Upper City West - Sarıkale Valley	Awl	Cu-Sn	301
MA-132337	Bo 06/293	Upper City West - Sarıkale Valley	Eye needle	Cu-As	302
MA-132391	Bo 06/305	Upper City West - Sarıkale Valley	Pin, indeterminate	Cu-As	30
MA-132448	Bo 06/313	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	53
MA-132376	Bo 06/314	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	54
MA-132320	Bo 06/317	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As-Sn	54
MA-132324	Bo 06/319	Upper City West - Sarıkale Valley	Ring, wire	Cu-As-Sn	28
MA-132395	Bo 06/326	Upper City West - Sarıkale Valley	Edged chisel	Cu-Sn	29
MA-132506	Bo 06/353	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Sn	57
MA-132459	Bo 06/368	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	318
MA-132496	Bo 06/410	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	39
MA-132495	Bo 06/413	Upper City West - Sarıkale Valley	Pin, nodular	Cu-As-Sn	39
MA-132326	Bo 06/415	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	39
MA-132507	Bo 06/417	Upper City West - Sarıkale Valley	Pin, disc	Cu	39
MA-132404	Bo 06/429	Upper City West - Sarıkale Valley	Awl	Cu-As	403
MA-132440	Bo 06/440	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	406
MA-132336	Bo 06/441	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-As	406
MA-132341	Bo 06/454	Upper City West - Sarıkale Valley	Awl	Cu-Sn	411
MA-132431	Bo 06/476	Upper City West - Sarıkale Valley	Pin, pyramidal	Cu-As-Sn	413
MA-132518	Bo 06/486	Upper City West - Sarıkale Valley	Arrowhead, stemmed and spurred	Cu-As-Sn	419
MA-132438	Bo 06/489	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-As	421
MA-132307	Bo 06/492	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu-Ni	404
MA-132333	Bo 06/499	Upper City West - Sarıkale Valley	Eye needle	Cu-As	429
MA-132389	Bo 06/500	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As	128
MA-132426	Bo 06/506	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-As-Sn	74

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-132368	Bo 06/513	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	121
MA-132446	Bo 06/514	Upper City West - Sarıkale Valley	Pin, conical	Cu-As-Sn	121
MA-132347	Bo 06/521	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu-As	124
MA-132413	Bo 06/532	Upper City West - Sarıkale Valley	Eye needle	Cu-As-Sn	125
MA-132422	Bo 06/533	Upper City West - Sarıkale Valley	Awl	Cu-As-Sn	0
MA-132362	Bo 06/548	Upper City West - Sarıkale Valley	Awl	Cu-Sn	80
MA-132313	Bo 06/549	Upper City West - Sarıkale Valley	Pin, rolled	Cu-Ni	80
MA-132374	Bo 06/555	Upper City West - Sarıkale Valley	Pin, rolled	Cu-As	131
MA-132390	Bo 06/563	Upper City West - Sarıkale Valley	Eye needle	Cu-As	139
MA-132441	Bo 06/567	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu	123
MA-132481	Bo 06/578	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-Sn	130
MA-132420	Bo 06/585	Upper City West - Sarıkale Valley	Eye needle	Cu-As	145
MA-132412	Bo 06/608	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Sn	157
MA-132467	Bo 06/617	Upper City West - Sarıkale Valley	Pin, rolled	Cu-Sn	148
MA-132460	Bo 06/635	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Sn	171
MA-132451	Bo 06/647	Upper City West - Sarıkale Valley	Arrowhead, stemmed and spurred	Cu-As-Sn	170
MA-132329	Bo 06/649	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Sn	175
MA-132432	Bo 06/661	Upper City West - Sarıkale Valley	Eye needle	Cu-As	175
MA-132416	Bo 06/668	Upper City West - Sarıkale Valley	Arrowhead, stemmed and spurred	Cu-As	179
MA-132365	Bo 06/673	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	178
MA-132455	Bo 06/677	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu-As-Sn	175
MA-132353	Bo 06/680	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Sn	175
MA-132314	Bo 06/69	Upper City West - Sarıkale Valley	Wire, round section	Cu-Sn-Ni	6
MA-132427	Bo 06/711	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	89
MA-132490	Bo 06/735	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	316
MA-132458	Bo 06/740	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	319

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
MA-132201	Bo 06/753	Upper City West - Sarıkale Valley	Sheet, decorated	Cu-Sn	306
MA-132447	Bo 06/770	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	319
MA-132396	Bo 06/773	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	318
MA-132360	Bo 06/78	Upper City West - Sarıkale Valley	Eye needle	Cu-As	16
MA-132378	Bo 06/819	Upper City West - Sarıkale Valley	Indeterminate	Cu-As-Sn	336
MA-132399	Bo 06/82	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	17
MA-132424	Bo 06/83	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	18
MA-132436	Bo 06/861	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	82
MA-132435	Bo 06/93	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-As-Sn	18
MA-132457	Bo 06/97	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	23
	Bo 07/1225	Upper City West - Sarıkale Valley	Ring, wire	Cu-As-Ni	611
	Bo 07/1288	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu	624
	Bo 07/1301	Upper City West - Sarıkale Valley	Awl	Cu-As	629
	Bo 07/1720	Upper City West - Sarıkale Valley	Awl	Cu-Sn	709
	Bo 07/1745	Upper City West - Sarıkale Valley	Awl	Cu-Sn	720
	Bo 07/1755	Upper City West - Sarıkale Valley	Awl	Cu	722
	Bo 07/1802	Upper City West - Sarıkale Valley	Pin, lamellar	Cu-As	740
	Bo 07/1810	Upper City West - Sarıkale Valley	Pin, disc	Cu-As-Sn	741
	Bo 07/1818	Upper City West - Sarıkale Valley	Wire, round section	Cu-Ni	745
	Bo 07/1821	Upper City West - Sarıkale Valley	Awl	Cu-Ni	745
	Bo 07/1860	Upper City West - Sarıkale Valley	Pin, disc	Cu-As-Sn	758
MA-136335	Bo 07/1871	Upper City West - Sarıkale Valley	Ring, wire	Cu-Ni	761
	Bo 07/1874	Upper City West - Sarıkale Valley	Sheet, decorated	Cu-As	761
	Bo 07/1920	Upper City West - Sarıkale Valley	Pin, indeterminate	Cu-As-Sn	777
	Bo 07/1921	Upper City West - Sarıkale Valley	Pin, indeterminate	Cu-As	777
	Bo 07/1936	Upper City West - Sarıkale Valley	Pin, fungiform	Cu-As-Sn	781

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 07/2045	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	1006
	Bo 07/2054	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Sn	1006
	Bo 07/2055	Upper City West - Sarıkale Valley	Eye needle	Cu	1006
	Bo 07/2079	Upper City West - Sarıkale Valley	Pin, incised disc	Cu-As-Ni	1018
	Bo 07/2087	Upper City West - Sarıkale Valley	Eye needle	Cu-As-Pb	1020
	Bo 07/2089	Upper City West - Sarıkale Valley	Awl	Cu-Sn	1018
	Bo 07/2093	Upper City West - Sarıkale Valley	Pin, incised disc	Cu-As	1013
MA-136332	Bo 07/2101	Upper City West - Sarıkale Valley	Pin, disc	Cu-Ni	1019
	Bo 07/2104	Upper City West - Sarıkale Valley	Pin, lamellar disc	Cu-As	1021
	Bo 07/2121	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	1030
	Bo 07/2129	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-Sn	1027
	Bo 07/2130	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu	1027
	Bo 07/2143	Upper City West - Sarıkale Valley	Awl	Cu	1039
MA-136331	Bo 07/2149	Upper City West - Sarıkale Valley	Ornament	Cu-As-Ni	1030
MA-136328	Bo 07/2151	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-Ni	1030
	Bo 07/2154	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-As	1035
	Bo 07/2200	Upper City West - Sarıkale Valley	Pin, fungiform	Cu-Sn	1050
MA-136333	Bo 07/2204	Upper City West - Sarıkale Valley	Pin, fungiform	Cu-Ni	1053
	Bo 07/2211	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu	1053
	Bo 07/2215	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu	1053
	Bo 07/2221	Upper City West - Sarıkale Valley	Pin, disc	Cu-As	1053
	Bo 07/2224	Upper City West - Sarıkale Valley	Pin, incised disc	Cu-As	1053
	Bo 07/2227	Upper City West - Sarıkale Valley	Eye needle	Cu-As	1053
	Bo 07/2228	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Ni	1053
	Bo 07/2235	Upper City West - Sarıkale Valley	Pin, disc	Cu-As	1057
	Bo 07/2239	Upper City West - Sarıkale Valley	Ring, wire	Cu-Sn	1053

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 07/2240	Upper City West - Sarıkale Valley	Eye needle	Cu	1053
	Bo 07/2252	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu	1053
	Bo 07/2256	Upper City West - Sarıkale Valley	Pin, disc	Cu-As-Sn	1060
	Bo 07/2258	Upper City West - Sarıkale Valley	Eye needle	Cu	1059
	Bo 07/2260	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	1061
	Bo 07/2269	Upper City West - Sarıkale Valley	Awl	Cu-As-Sn	1046
	Bo 07/2272	Upper City West - Sarıkale Valley	Pin, conical	Cu	1059
	Bo 07/2305	Upper City West - Sarıkale Valley	Pin, conical	Cu-As-Sn-Ni	1074
	Bo 07/2354	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-Sn	1079
	Bo 07/2397	Upper City West - Sarıkale Valley	Wire, round section	Cu-As	1078
	Bo 07/2422	Upper City West - Sarıkale Valley	Pin, disc	Cu-As-Sn	1120
	Bo 07/2445	Upper City West - Sarıkale Valley	Awl	Cu	0
	Bo 07/2456	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	1124
	Bo 07/2458	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu	1124
	Bo 07/2460	Upper City West - Sarıkale Valley	Pin, disc	Cu-As	1125
	Bo 07/2470	Upper City West - Sarıkale Valley	Wire, round section	Cu-As	1125
	Bo 07/2471	Upper City West - Sarıkale Valley	Edged chisel	Cu-As-Sn	1134
	Bo 07/2483	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	1104
	Bo 07/2484	Upper City West - Sarıkale Valley	Awl	Cu-As-Sn	1141
	Bo 07/2637	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu	1523
	Bo 07/2707	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu-Ni	1560
MA-132197	Bo 07/29	Upper City West - Sarıkale Valley	Arrowhead, stemmed	Cu-Sn	764
	Bo 07/3402	Upper City West - Sarıkale Valley	Arrowhead, stemmed	Cu	1142
	Bo 07/3431	Upper City West - Sarıkale Valley	Awl	Cu-As-Sn	1163
	Bo 07/3440	Upper City West - Sarıkale Valley	Pin, lenticular	Cu	1168
	Bo 07/3441	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As	1168

Mannheim Number	**Object Number**	**Location**	**Object Type**	**Alloy type**	**Context (number or description)**
	Bo 07/3444	Upper City West - Sarıkale Valley	Sheet, decorated	Cu-As	1170
	Bo 07/3457	Upper City West - Sarıkale Valley	Pin, unique	Cu-As	1172
	Bo 07/3460	Upper City West - Sarıkale Valley	Hammer	Cu-As	1170
	Bo 07/3481	Upper City West - Sarıkale Valley	Eye needle	Cu	1180
	Bo 07/3484	Upper City West - Sarıkale Valley	Awl	Cu-As-Sn	1180
	Bo 07/3490	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-As	1180
	Bo 07/3509	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-As	1143
	Bo 07/3571	Upper City West - Sarıkale Valley	Insert, hammer-shaped	Cu-Sn	1080
MA-136334	Bo 07/3594	Upper City West - Sarıkale Valley	Pendant, decorated sheet	Cu-Ni	1201
	Bo 07/3606	Upper City West - Sarıkale Valley	Pin, conical	Cu	1207
	Bo 07/3693	Upper City West - Sarıkale Valley	Edged chisel	Cu-Sn	1229
	Bo 07/3694	Upper City West - Sarıkale Valley	Edged chisel	Cu-Sn	1229
	Bo 07/3723	Upper City West - Sarıkale Valley	Awl	Cu-Sn	1234
MA-136325	Bo 07/3735	Upper City West - Sarıkale Valley	Arm ring	Cu-Ni	1221
	Bo 07/3739	Upper City West - Sarıkale Valley	Insert, axe-shaped	Cu-As-Sn	1149
	Bo 07/3798	Upper City West - Sarıkale Valley	Pin, pyramidal	Cu-As	1172
	Bo 07/3803	Upper City West - Sarıkale Valley	Pin, nodular	Cu-Sn	1221
	Bo 07/3811	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-As	1221
	Bo 07/3816	Upper City West - Sarıkale Valley	Wire, round section	Cu-As	1221
	Bo 08/100	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-As	27
MA-132199	Bo 08/101	Upper City West - Sarıkale Valley	Seal	Cu-As-Sn	30
	Bo 08/102	Upper City West - Sarıkale Valley	Pin, fungiform	Cu	25
	Bo 08/105	Upper City West - Sarıkale Valley	Ring, wire	Cu-As-Sn	0
	Bo 08/132	Upper City West - Sarıkale Valley	Ring, wire	Cu-Sn	37
	Bo 08/134	Upper City West - Sarıkale Valley	Insert, hammer-shaped	Cu-Sn	36
	Bo 08/140	Upper City West - Sarıkale Valley	Pin, fungiform	Cu-As-Sn	37

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 08/143	Upper City West - Sarıkale Valley	Ring, wire	Cu-Ni	37
	Bo 08/1511	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu-Sn	1502
	Bo 08/156	Upper City West - Sarıkale Valley	Eye needle	Cu-As	43
MA-132549	Bo 08/16	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	
	Bo 08/160	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As-Sn	43
	Bo 08/197	Upper City West - Sarıkale Valley	Pin, fungiform	Cu	49
	Bo 08/212	Upper City West - Sarıkale Valley	Pin, nodular	Cu-As	49
MA-132205	Bo 08/217	Upper City West - Sarıkale Valley	Knife, flat and curved	Cu-As	67
MA-132198	Bo 08/227	Upper City West - Sarıkale Valley	Flat axe, lugged	Cu-As-Sn	67
MA-132206	Bo 08/229	Upper City West - Sarıkale Valley	Arrowhead, stemmed	Cu-Sn	68
	Bo 08/236	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As	68
	Bo 08/25	Upper City West - Sarıkale Valley	Eye needle	Cu	7
	Bo 08/255	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-As-Sn	83
	Bo 08/258	Upper City West - Sarıkale Valley	Awl	Cu-As	52
MA-136324	Bo 08/264	Upper City West - Sarıkale Valley	Eye needle	Cu-Ni	78
	Bo 08/27	Upper City West - Sarıkale Valley	Eye needle	Cu-As-Sn	2
	Bo 08/28	Upper City West - Sarıkale Valley	Eye needle	Cu-Sn	2
	Bo 08/300	Upper City West - Sarıkale Valley	Edged chisel	Cu-As	Q2
	Bo 08/36	Upper City West - Sarıkale Valley	Eye needle	Cu-As	11
	Bo 08/37	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	2
	Bo 08/42	Upper City West - Sarıkale Valley	Pin, fungiform	Cu-As-Pb	10
	Bo 08/43	Upper City West - Sarıkale Valley	Pin, shaft fragment	Cu-As-Sn	3
	Bo 08/44	Upper City West - Sarıkale Valley	Pin, disc	Cu-As	10
MA-132552	Bo 08/5	Upper City West - Sarıkale Valley	Pin, nodular	Cu-As	
	Bo 08/53	Upper City West - Sarıkale Valley	Eye needle	Cu-As-Sn	11
	Bo 08/57	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	17

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 08/66	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu-As-Sn	20
	Bo 08/69	Upper City West - Sarıkale Valley	Eye needle	Cu-Sn	20
	Bo 08/73	Upper City West - Sarıkale Valley	Edged chisel	Cu-As	20
	Bo 08/77	Upper City West - Sarıkale Valley	Awl	Cu-As	23
	Bo 08/841	Upper City West - Sarıkale Valley	Awl	Cu	853
	Bo 08/859	Upper City West - Sarıkale Valley	Indeterminate	Cu	814
	Bo 08/87	Upper City West - Sarıkale Valley	Pin, lenticular	Cu-As	25
	Bo 08/884	Upper City West - Sarıkale Valley	Sheet, indeterminate	Cu	822
MA-132204	Bo 08/9	Upper City West - Sarıkale Valley	Pendant, lunulae	Cu-As-Ni	0
	Bo 08/966	Upper City West - Sarıkale Valley	Wire, round section	Cu	859
	Bo 07/519	Upper City West - Yenicekale	Sheet, indeterminate	Cu	503
	Bo 07/523	Upper City West - Yenicekale	Sheet, indeterminate	Cu	505
MA-136328	Bo 07/576	Upper City West - Yenicekale	Ornament	Cu-Ni	505
	Bo 07/578	Upper City West - Yenicekale	Sheet, indeterminate	Cu	515
	Bo 07/591	Upper City West - Yenicekale	Edged chisel	Cu-As-Sn-Pb	525
EARLY IRON AGE					
	Bo 96/31	Büyükkaya	Socketed chisel	Cu-As-Sn-Pb	353/421.82
	Bo 96/45	Büyükkaya	Pin, rolled	Cu-Sn	353/421.72
	Bo 96/85	Büyükkaya	Tweezers	Cu-Sn	353/420.107
	Bo 97/25	Büyükkaya	Arrowhead, stemmed and spurred	Cu-As-Sn-Pb	352/421.182
	Bo 97/26	Büyükkaya	Awl	Cu-Sn	352/420.385
	Bo 97/31	Büyükkaya	Arrowhead, stemmed	Cu-Sn	353/420.257
	Bo 97/35	Büyükkaya	Pin, lamellar disc	Cu-As-Ni	352/421.192
	Bo 97/38	Büyükkaya	Horse bit	Cu-As-Sn	352/421.172
	Bo 97/87	Büyükkaya	Knife, flat and curved	Cu-Sn	353/420.326

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 97/90	Büyükkaya	Edged chisel	Cu-Sn	353/420.330
	Bo 97/93	Büyükkaya	Rivet	Au	352/421.294
	Bo 97/93	Büyükkaya	Rivet	Cu	352/421.294
	Bo 97/94	Büyükkaya	Knife, flat and straight	Cu-Sn	352/420.507
	Bo 97/97	Büyükkaya	Flat axe, lugged	Cu	352/420.454
	Bo 97/99	Büyükkaya	Axe or hatchet, indeterminate	Cu-Sn	352/420.391
	ETD 96/31	Büyükkaya	Pin, indeterminate	Cu-As	354/427.178
	ETD 96/38	Büyükkaya	Pin, nodular	Cu-Sn	352/421.68
	ETD 96/46	Büyükkaya	Pin, shaft fragment	Cu	352/421.62
	ETD 97/197	Büyükkaya	Ring, wire	Cu-Sn	352/420.535
	ETD 97/198	Büyükkaya	Eye needle, fragment	Cu-Sn	352/420.390
	ETD 97/203	Büyükkaya	Pin, shaft fragment	Cu-Sn	352/420.479
	ETD 97/215	Büyükkaya	Pin, indeterminate	Cu	352/426.344
	ETD 97/225	Büyükkaya	Awl	Cu-Sn	353/420.292
	ETD 97/235	Büyükkaya	Pin, indeterminate	Cu	352/420.394
	ETD 97/236	Büyükkaya	Waste, casting	Cu-Sn	352/421.170
	ETD 97/239	Büyükkaya	Waste, casting	Cu-Sn	352/421.220
	ETD 97/245	Büyükkaya	Sheet, indeterminate	Cu	353/420.289
	ETD 97/253	Büyükkaya	Arrowhead, indeterminate	Cu-As	352/420.443
	ETD 97/261	Büyükkaya	Awl	Cu-Sn	352/420.301
	ETD 97/265	Büyükkaya	Awl	Cu-Sn	353/420.242
	ETD 97/273	Büyükkaya	Tool, indeterminate	Cu-Sn	352/420.323
	ETD 97/340A	Büyükkaya	Pin, lenticular	Cu-Sn	352/420.364
	ETD 97/340B	Büyükkaya	Awl	Cu-Sn	352/420.364
	ETD 97/340C	Büyükkaya	Awl	Cu-As	352/420.364
	ETD 97/340D	Büyükkaya	Awl	Cu	352/420.364

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	ETD 98/04	Büyükkaya	Sheet, indeterminate	Cu-Sn	352/420.353
MIDDLE / LATE IRON AGE					
MA-132554	Bo 307/n	Büyükkale	Fibula	Cu-Sn	Boehmer 1972: n. 87
MA-132559	Bo 443/i/3	Büyükkale	Bilobate socketed arrowhead	Cu-Sn	Boehmer 1972: n. 890
	Bo 94/122	Büyükkaya	Pin, nodular	Cu	356/430.16
	Bo 94/32	Büyükkaya	Ingot, ring	Cu-As-Sn	357/431.3
	Bo 94/35	Büyükkaya	Pin, nodular	Cu	354/430.48
	Bo 95/12	Büyükkaya	Toggle Pin	Cu-Sn	354/428.98
	Bo 95/126	Büyükkaya	Fibula	Cu-Sn	355/431.260
	Bo 95/13	Büyükkaya	Fibula	Cu-As-Sn	357/431.145
	Bo 95/69	Büyükkaya	Ingot, rod	Cu-Sn-Pb	352/427.50
	Bo 96/67	Büyükkaya	Fibula	Cu-Sn	356/427.169
	Bo 97/30	Büyükkaya	Indeterminate	Cu-Sn	353/420.329
	ETD 94/125	Büyükkaya	Eye needle, fragment	Cu-Sn	356/431.22
	ETD 94/126	Büyükkaya	Pin, shaft fragment	Cu-Sn	356/431.22
	ETD 94/178	Büyükkaya	Wire, round section	Cu-Sn	355/430.90
	ETD 94/19	Büyükkaya	Ring, wire	Cu	355/430.27
	ETD 94/211	Büyükkaya	Wire, round section	Cu-Ni	357/431.16
	ETD 94/212	Büyükkaya	Wire, round section	Cu	357/431.16
	ETD 94/241	Büyükkaya	Rivet	Cu-Sn-Pb	355/430.225
	ETD 94/261	Büyükkaya	Fibula	Cu	356/432.3
	ETD 94/284	Büyükkaya	Ingot, rod	Cu-Sn	355/428.16
	ETD 94/330	Büyükkaya	Pin, shaft fragment	Cu-Sn	357/431.117
	ETD 94/390	Büyükkaya	Eye needle	Cu-Sn	355/428.91
	ETD 94/463	Büyükkaya	Ring, wire	Cu-Sn-Ni-Ag	356/431.142

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	ETD 94/470	Büyükkaya	Bead	Cu-Sn	354/430.134
	ETD 94/475	Büyükkaya	Awl	Cu-As-Sn	357/431.82
	ETD 94/483	Büyükkaya	Awl	Cu-Sn	355/430.276
	ETD 94/5	Büyükkaya	Wire, round section	Cu-Sn	355/430.10
	ETD 95/268	Büyükkaya	Waste, casting	Cu-Sn	352/427-428.29
	ETD 96/25	Büyükkaya	Pin, double headed	Cu-Sn	344/303.4
	ETD 96/26	Büyükkaya	Pendant, indeterminate	Cu-Sn-Pb	356/427.122
	ETD 96/48	Büyükkaya	Wire, round section	Cu-As	352/421.28
	ETD 96/49	Büyükkaya	Sheet, indeterminate	Cu-Sn	346/410.14
	ETD 96/52	Büyükkaya	Wire, square section	Cu	353/427.16
	ETD 96/56	Büyükkaya	Rod	Cu	347/410.36
	ETD 97/195	Büyükkaya	Awl	Cu-Sn	347/428.9
	ETD 97/202A	Büyükkaya	Awl	Cu	348/414.3
	ETD 97/202B	Büyükkaya	Pin, shaft fragment	Cu-Sn	348/414.3
	ETD 97/209	Büyükkaya	Indeterminate	Cu-Sn	347/415.P18
	ETD 97/211	Büyükkaya	Indeterminate	Cu	346/430.22
	ETD 97/227	Büyükkaya	Pin, nodular	Cu-As	359/426.40
	ETD 97/231	Büyükkaya	Indeterminate	Cu-Sn	347/415.P9
	ETD 97/232	Büyükkaya	Ring, wire	Cu-Sn	347/412.7
	ETD 97/234	Büyükkaya	Awl	Cu-As	352/420.76
	ETD 97/238	Büyükkaya	Eye needle	Cu-Sn	357/427.24
	ETD 97/259	Büyükkaya	Awl	Cu-Sn	345/413.102
	ETD 97/262	Büyükkaya	Ring, wire	Cu-Sn	352/420.5
	ETD 97/269	Büyükkaya	Sheet, indeterminate	Cu-Sn	347/410.148
	ETD 97/271	Büyükkaya	Spiral	Cu-Sn	357/427.9
	ETD 97/272	Büyükkaya	Indeterminate	Cu	352/420.17

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	ETD 97/341	Büyükkaya	Toggle Pin	Cu-Sn	347/428.7
	ETD 98/08	Büyükkaya	Wire, round section	Cu-Sn	346/413.498
	ETD 98/10	Büyükkaya	Fibula	Cu-As	345/413.330
	ETD 98/20	Büyükkaya	Ring, wire	Cu-Sn	348/414.450
	ETD 98/26	Büyükkaya	Fibula	Cu	347/414.664
	Bo 99/17	Granary	Bilobate socketed arrowhead	Cu-Sn-Pb	309/343.2
	Bo 99/18	Granary	Bilobate socketed arrowhead, barbed	Cu-Sn-Pb	311/344.11
	Bo 99/19	Granary	Bilobate socketed arrowhead, barbed	Cu-Sn-Pb	309/343.43
	ETD 99/65	Granary	Sheet, indeterminate	Cu-Sn-Pb	309/344.98
MA-132281	Bo 11/14	Kesikkaya - Kesikkaya, South	Bilobate socketed arrowhead, barbed	Cu-As-Sn-Pb	0
	Bo 12/08	Lower City - City Wall	Fibula	Cu-Sn	0
	Bo 13/103	Lower City - City Wall	Sheet, decorated	Cu-Sn	0
	Bo 13/29	Lower City - City Wall	Sheet, decorated	Cu-Sn	0
	Bo 13/6	Lower City - City Wall	Sheet, decorated	Cu-Sn	0
	Bo 09/1064	Lower City - Kesikkaya, Northwest	Fibula	Cu-Sn	604
	Bo 09/1712	Lower City - Kesikkaya, Northwest	Fibula	Cu-Sn-Pb	645
MA-132225	Bo 10/9	Lower City - Kesikkaya, Northwest	Pin, double headed	Cu-Sn	2
	Bo 11/35	Lower City - Kesikkaya, South	Eye needle	Cu-Sn	305
	Bo 13/10	Lower City - Kesikkaya, South	Awl	Cu-Sn	302
	Bo 13/113	Lower City - Kesikkaya, South	Pin, shaft fragment	Cu-Sn	339
	Bo 13/119	Lower City - Kesikkaya, South	Wire, round section	Cu-Sn	343
	Bo 13/130	Lower City - Kesikkaya, South	Indeterminate	Cu-Sn	342
	Bo 13/198	Lower City - Kesikkaya, South	Wire, round section	Cu-Sn	367
	Bo 13/42	Lower City - Kesikkaya, South	Bilobate socketed arrowhead, barbed	Cu-Sn	313
	Bo 13/65	Lower City - Kesikkaya, South	Wire, round section	Cu	338

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	Bo 13/97	Lower City - Kesikkaya, South	Rod	Cu-Sn	322
MA-132561	Bo 554/p	Lower City - Northern Quarter	Fibula	Cu-Sn	Boehmer 1972: n. 161
	Bo 73/57b	Lower City - Northern Quarter	Fibula	Cu-Sn	J/19-20; Phrygian urn grave 2/73; Neve 1975: 95
	Bo 73/57c	Lower City - Northern Quarter	Fibula	Cu-Sn	J/19-20; Phrygian urn grave 2/73; Neve 1975: 95
	Bo 73/59b	Lower City - Northern Quarter	Fibula	Cu-Sn-Ni	J/19 temple terrace, Phrygian urn grave 3/73; Neve 1975: 95
	Bo 73/59c	Lower City - Northern Quarter	Fibula	Cu-Sn-Ni	J/19 tempel terrace, Phrygian Urn Grave 3/73; Neve 1975: 95
	Bo 73/59d	Lower City - Northern Quarter	Fibula	Cu-Sn	J/19 Phrygian pithos burial (3/73); Neve 1975: 95
	Bo 73/77	Lower City - Northern Quarter	Fibula	Cu-Sn	J/19-20, trench I/8, over the stone debris, 1.5m northwest of urn 2/73; Neve 1975: 95
MA-132194	Bo 861/t	Lower City - Northern Quarter	Socketed lance	Cu-Sn	Boehmer 1972: n. 207
MA-132191	Bo 864/t	Lower City - Northern Quarter	Sheet, decorated	Cu-Sn	Boehmer 1972: n. 171
	ETD 99/61	Northwest Slope - Granary	Wire, round section	Cu-Sn	309/343.100
	ETD 99/62	Northwest Slope - Granary	Eye needle, fragment	Cu-Sn	308/343.51
	ETD 99/63	Northwest Slope - Granary	Fibula	Cu-Sn	309/343.84
	ETD 99/64	Northwest Slope - Granary	Eye needle, fragment	Cu-Sn	309/342.57
	ETD 99/66	Northwest Slope - Granary	Wire, round section	Cu-Sn	310/343.33
	ETD 99/77	Northwest Slope - Granary	Wire, round section	Cu-Sn	308/342.17
	ETD 99/91	Northwest Slope - Granary	Sheet, indeterminate	Cu-Sn-Ni	309/343.102
	Bo 07/566	Northwest Slope - Yenicekale	Fibula	Cu-Sn-Pb	515
	1-106-85	Upper City	Bilobate socketed arrowhead, barbed	Cu-As-Sn-Pb	
	1-42-88	Upper City	Trilobate socketed arrowhead	Cu-As-Pb	
	1-85-89	Upper City	Bilobate socketed arrowhead	Cu-Sn-Pb	
	ETD 96/11	Upper City - East reservoirs	Fibula	Cu-Sn-Pb	341/299.7
	ETD 96/55	Upper City - East reservoirs	Bilobate socketed arrowhead	Cu-Sn-Pb	347/303.2
	Bo 88/37	Upper City - Nişantepe	Fibula	Cu-Sn	M/12-d/7
	1-3-88	Upper City - Südburg	Bilobate socketed arrowhead, barbed	Cu-Sn-Pb	

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	1-2430-91	Upper City - Südburg	Fibula	Cu-Sn-Zn	
	Bo 89/128	Upper City - Südburg	Toggle Pin	Cu-Sn-Pb	N/12-h/6
	Bo 89/29	Upper City - Südburg	Ornament	Cu	N/12-k/6
	Bo 89/31	Upper City - Südburg	Tweezers	Cu-Sn	N/12-f/2
	Bo 89/99	Upper City - Südburg	Toggle Pin	Cu	O/12-g/5-6
	1-1990-81	Upper City - Yerkapı	Pin, double headed	Cu-Sn	found during restoration of the Yerkapı complex.
	Bo 05/28	Upper City West - Sarıkale Valley	Tweezers	Cu-Sn	
MA-132393	Bo 06/1639	Upper City West - Sarıkale Valley	Indeterminate	Cu-Sn	230
MA-132380	Bo 06/1765	Upper City West - Sarıkale Valley	Indeterminate	Cu-As	283
MA-132200	Bo 06/233	Upper City West - Sarıkale Valley	Fibula	Cu	0
MA-132405	Bo 06/2330	Upper City West - Sarıkale Valley	Eye needle, fragment	Cu	944
MA-132370	Bo 06/515	Upper City West - Sarıkale Valley	Insert, hammer-shaped	Cu-Sn	78
MA-132512	Bo 06/561	Upper City West - Sarıkale Valley	Ring, wire	Cu-Sn	131
	Bo 07/1325	Upper City West - Sarıkale Valley	Fibula	Cu-Sn	636
	Bo 07/508	Upper City West - Yenicekale	Sheet, indeterminate	Cu-Sn	501
KERKENES DAĞ					
LATE IRON AGE					
	00CT11U01met01	Cappadocian Gate	Tack	Cu-Sn	CT11 U01
	00CT50U02met01	Cappadocian Gate	Tweezers	Cu-Sn	CT50 U02
	00CT51U01met01	Cappadocian Gate	Fibula	Cu-Sn	CT51 U01
MA-132591	02TR03U11met02	Cappadocian Gate	Sheet, indeterminate	Cu-Sn	TR03 U11
	02TR04U04met03	Cappadocian Gate	Eye needle, fragment	Cu-Sn-Ni	TR04 U04

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	09CAPPU00met01	Cappadocian Gate	Pin, double headed	Cu-Sn	CAPP U00
MA-132600	10TR13U14met02	Cappadocian Gate	Sheet, indeterminate	Cu-Sn	TR13 U14
	10TR13U16met01	Cappadocian Gate	Bilobate socketed arrowhead, barbed	Cu-Sn-Pb	TR13 U16
MA-132620	11TR23U08met01	Cappadocian Gate	Bilobate socketed arrowhead, barbed	Cu-Sn-Pb	TR23 U08
MA-132601	11TR23U11met01	Cappadocian Gate	Trilobate socketed arrowhead	Cu-Sn-Pb	TR23 U11
MA-132607	11TR23U12met01	Cappadocian Gate	Sheet, indeterminate	Cu-Sn	TR23 U12
MA-132597	11TR23U21met01	Cappadocian Gate	Sheet, indeterminate	Cu-Sn	TR23 U21
MA-132594	11TR23U22met01	Cappadocian Gate	Pin, double headed	Cu-Sn	TR23 U22
	11TR23U36met01	Cappadocian Gate	Pin, double headed	Cu-Sn	TR23 U36
	11TR24U06met01	Cappadocian Gate	Pin, shaft fragment	Cu-Sn-Pb	TR24 U06
MA-132629	11TR24U11met01	Cappadocian Gate	Sheet, indeterminate	Cu-Sn-Pb	TR24 U11
MA-132631	11TR24U11met02	Cappadocian Gate	Nail	Cu-Sn	TR24 U11
MA-132626	11TR24U11met03	Cappadocian Gate	Nail	Cu-Sn	TR24 U11
MA-132615	11TR24U11met03	Cappadocian Gate	Sheet, indeterminate	Cu-Sn	TR24 U11
MA-133069	11TR24U11met04	Cappadocian Gate	Trilobate socketed arrowhead	Cu-Sn-Pb	TR24 U11
MA-132593	11TR24U11met05	Cappadocian Gate	Sheet, indeterminate	Cu-Sn	TR24 U11
MA-132608	11TR24U15met01	Cappadocian Gate	Pin, double headed	Cu-Sn	TR24 U15
MA-132612	11TR24U17met01	Cappadocian Gate	Tack	Cu-Sn	TR24 U17
MA-132624	11TR24U20met01	Cappadocian Gate	Pin, double headed	Cu-Sn	TR24 U20
MA-132606	11TR24U21met01	Cappadocian Gate	Pin, double headed	Cu-Sn	TR24 U21
MA-132613	11TR24U21met02	Cappadocian Gate	Tool, indeterminate	Cu-As-Sn-Pb	TR24 U21
MA-132619	11TR24U22met03	Cappadocian Gate	Spiral	Cu-Sn	TR24 U22
MA-132622	11TR24U22met04	Cappadocian Gate	Pin, double headed	Cu-Sn	TR24 U22
MA-132614	11TR24U22met06	Cappadocian Gate	Pin, tulip	Cu-Sn	TR24 U22
MA-132605	11TR24U22met07	Cappadocian Gate	Pin, tulip	Cu-Sn	TR24 U22
MA-132596	11TR24U22met08	Cappadocian Gate	Pin, tulip	Cu-Sn-Pb	TR24 U22

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	11TR30U10met01	Cappadocian Gate	Pin, indeterminate	Cu-Sn	TR30 U10
	03TR06U12met01	Megaron	Trilobate socketed arrowhead, barbed	Cu-Sn-Pb	TR06 U12
MA-132625	00CT18U17met01	Palace	Pin, double headed	Cu-Sn	CT18 U17
MA-132604	00CT18U17met02	Palace	Pin, shaft fragment	Cu-Sn	CT18 U17
MA-132630	02TR01U02met01	Palace	Sheet, decorated	Cu-Sn	TR01 U02
MA-132628	02TR01U02met02	Palace	Sheet, decorated	Cu-Sn	TR01 U02
	02TR01U02met04	Palace	Nail	Cu-Sn	TR01 U02
	02TR01U07met01	Palace	Sheet, indeterminate	Cu-Sn-Zn	TR01 U07
	02TR01U07met02	Palace	Sheet, indeterminate	Cu-Sn-Zn	TR01 U07
	02TR02U04met01	Palace	Sheet, indeterminate	Cu-Sn	TR02 U04
	02TR02U10met08	Palace	Ring, wire	Cu-Sn	TR02 U10
	02TR02U10met09	Palace	Ring, wire	Cu-Sn	TR02 U10
	02TR02U10met11	Palace	Band	Cu-Sn-Zn	TR02 U10
	03TR05U02met03	Palace	Nail	Cu-Sn	TR05 U02
MA-132599	04TR11U14met01	Palace	Waste, casting	Cu-Sn	TR11 U14
MA-132598	04TR15U01met01	Palace	Sheet, indeterminate	Cu-Sn	TR15 U01
	04TR16U15met03	Palace	Sheet, indeterminate	Cu-Sn	TR16 U15
	05TR15U09met01	Palace	Sheet, indeterminate	Cu-Ag	TR15 U09
	05TR15U14met02	Palace	Pin, double headed	Cu-Sn	TR15 U14
	05TR16U17met02	Palace	Wire, square section, twisted	Cu-Sn	TR16 U17
	05TR16U17met03	Palace	Wire, square section	Cu-Sn	TR16 U17
	05TR17U12met01	Palace	Ornament	Cu-Sn-Zn	TR17 U12
	05TR17U14met01	Palace	Rivet	Cu-Sn-Zn	TR17 U14
	05TR17U14met01	Palace	Sheet, decorated	Cu-Sn-Zn	TR17 U14
MA-132627	05TR17U14met02	Palace	Sheet, indeterminate	Cu-Sn	TR17 U14
	05TR17U14met06	Palace	Sheet, indeterminate	Cu-Sn	TR17 U14

Mannheim Number	Object Number	Location	Object Type	Alloy type	Context (number or description)
	05TR21U09met03	Palace	Nail	Cu	TR21 U09
	05TR21U12met01	Palace	Nail	Cu-Sn	TR21 U12
	05TR21U17met01	Palace	Nail	Cu-Sn	TR21 U17
	96TT17U05met01	Palace	Nail	Cu-Sn	TT17 U05
	96ST05U07met02	South West	Tweezers	Cu-Sn	ST05 U07
MA-132611	04TT25U08met01	Street	Pin, shaft fragment	Cu-Sn	TT25 U08
MA-132609	04TT25U08met02	Street	Wire, round section	Cu-Sn	TT25 U08
MA-132590	07TT27U05met01	Street	Pin, double headed	Cu-Sn	TT27 U05
MA-132595	07TT31U04met01	Street	Fibula	Cu-Sn	TT31 U04
MA-132623	11TR29U14met02	Urban Block 8	Pin, scroll	Cu-Sn	TR29 U14
MA-132618	11TR29U32met01	Urban Block 8	Bilobate socketed arrowhead, barbed	Cu-Sn-Pb	TR29 U32
MA-132621	11TR29U34met02	Urban Block 8	Indeterminate	Cu-Sn	TR29 U34
MA-132617	11TR29U34met03	Urban Block 8	Sheet, indeterminate	Cu-Sn	TR29 U34
MA-132616	96TT15U13met05	Urban Block 8	Pin, shaft fragment	Cu-Sn	TT15 U13
MA-132602	97TT15U00met01	Urban Block 8	Band	Cu-Sn	TT15 U00
MA-132603	98TT21U01met02	Urban Block 8	Pin, shaft fragment	Cu-Sn	TT21 U01

APPENDIX B: EDXRF RESULTS

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%	Te wt.%	Se wt.%	Mn wt.%
BOĞAZKÖY																
MIDDLE BRONZE AGE																
MA-132227	Bo 10/199	97	0.139	1.45	0.235	0.085	*b.d.*	0.687	0.086	0.092	0.012	0.048	0.015	0.004	0.002	0.002
MA-132259	Bo 10/332	97	0.045	1.95	0.238	0.256	0.037	0.643	0.031	0.044	0.007	0.024	0.007	0.004	0.001	0.001
MA-132246	Bo 10/341	96	0.830	1.50	0.166	0.195	0.006	0.865	0.131	0.100	0.030	0.025	0.016	0.029	*b.d.*	0.002
MA-132250	Bo 10/482	100	0.006	0.166	0.024	0.072	0.003	0.032	0.034	0.041	0.004	0.034	0.001	0.002	0.014	*b.d.*
MA-132303	Bo 11/590	100	0.005	0.036	0.023	0.081	0.001	0.040	0.008	0.016	0.001	0.027	*b.d.*	0.001	0.007	*b.d.*
LATE BRONZE AGE																
MA-132188	Bo 284/e	94	0.347	1.36	0.024	1.04	0.020	0.134	0.019	0.057	0.012	0.228	2.450	0.010	0.008	*b.d.*
MA-132189	Bo 284/e	5	0.354	0.014	0.075	0.029	*b.d.*	0.205	0.377	0.146	*b.d.*	7.312	86.652	0.037	*b.d.*	*b.d.*
MA-132180	Bo 477/d	90	5.38	0.331	4.13	0.034	0.015	0.080	0.038	0.050	0.013	0.016	0.004	0.012	0.005	*b.d.*
MA-136322	Boehmer 1972: Nr. 190	99	0.011	0.086	0.030	0.522	0.004	0.077	*b.d.*	0.007	0.001	0.023	*b.d.*	0.000	*b.d.*	*b.d.*
MA-136329	ETD 95/231	82	0.028	0.688	0.007	13.08	0.562	3.15	0.048	0.055	0.004	0.025	0.003	0.003	*b.d.*	0.005
MA-136321	ETD 98/21	72	0.045	26.92	0.348	0.156	0.003	0.176	0.113	0.262	0.013	0.014	*b.d.*	*b.d.*	0.003	0.002
MA-136336	Bo 09/1095	99	0.006	0.095	0.031	0.129	0.049	0.270	*b.d.*	0.005	*b.d.*	0.022	*b.d.*	0.004	*b.d.*	*b.d.*
MA-136326	Bo 09/355	81	0.039	1.01	0.018	15.83	0.501	1.11	0.096	0.073	0.001	0.022	0.013	0.007	0.001	*b.d.*
MA-136338	Bo 09/972	68	0.423	0.167	0.002	22.43	2.70	5.79	0.042	0.009	*b.d.*	0.002	*b.d.*	0.003	*b.d.*	*b.d.*
MA-132213	Bo 10/13	97	0.928	1.33	0.157	0.130	0.006	0.365	0.009	0.043	0.018	0.031	0.002	0.001	0.003	*b.d.*
MA-132244	Bo 10/186	98	0.004	1.43	0.012	0.036	*b.d.*	0.287	*b.d.*	0.053	0.004	0.007	*b.d.*	0.007	0.009	*b.d.*
MA-132267	Bo 10/189	93	4.64	0.551	0.456	0.066	0.004	0.783	0.060	0.027	0.010	0.035	0.005	0.013	0.007	0.015
MA-132232	Bo 10/190	97	0.041	1.14	0.199	0.726	0.092	0.439	0.067	0.034	0.001	0.013	0.004	0.003	0.004	*b.d.*
MA-132209	Bo 10/20	95	3.36	1.46	0.131	0.051	0.001	0.278	0.004	0.059	0.005	0.020	0.001	0.005	0.007	*b.d.*
MA-132229	Bo 10/233	94	0.324	2.93	0.063	0.318	0.010	1.06	0.044	0.764	0.034	0.042	0.005	*b.d.*	0.004	*b.d.*
MA-132230	Bo 10/236	93	3.86	0.771	0.505	0.237	0.069	0.984	0.123	0.091	0.040	0.086	0.024	0.009	0.005	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%	Te wt.%	Se wt.%	Mn wt.%
MA-132219	Bo 10/238	97	0.058	1.52	0.126	0.137	0.010	1.37	0.053	0.041	0.006	0.022	0.005	*b.d.*	0.002	*b.d.*
MA-132211	Bo 10/24	93	6.59	0.457	0.038	0.078	0.005	0.122	0.001	0.028	0.001	0.005	0.004	0.004	0.006	*b.d.*
MA-132231	Bo 10/242	96	0.038	2.06	1.51	0.110	0.017	0.249	0.167	0.087	0.008	0.026	0.041	0.006	0.006	*b.d.*
MA-132220	Bo 10/243	98	0.028	0.886	0.042	0.110	0.008	0.518	0.019	0.046	0.013	0.030	0.002	0.001	0.003	*b.d.*
MA-132242	Bo 10/244	98	0.081	0.838	0.089	0.107	0.005	0.531	0.203	0.087	0.041	0.035	0.051	*b.d.*	0.010	0.001
MA-132241	Bo 10/249	99	0.024	0.543	0.053	0.137	0.007	0.384	0.159	0.117	*b.d.*	0.054	*b.d.*	*b.d.*	*b.d.*	*b.d.*
MA-132266	Bo 10/250	92	4.56	1.74	0.586	0.074	0.004	0.986	0.090	0.060	0.015	0.023	0.015	0.008	0.002	0.013
MA-132240	Bo 10/251	95	0.033	2.63	0.408	0.075	0.008	1.01	0.226	0.116	0.011	0.024	0.088	0.009	0.004	0.002
MA-132245	Bo 10/254	99	0.011	0.012	0.008	0.015	0.004	0.413	0.682	0.035	0.004	0.028	0.121	0.009	0.008	*b.d.*
MA-132239	Bo 10/257	100	0.012	0.050	0.016	0.066	0.001	0.048	0.019	0.029	0.006	0.010	0.005	0.002	0.001	*b.d.*
MA-132238	Bo 10/282	97	0.049	2.08	0.118	0.129	0.001	0.394	0.119	0.117	0.033	0.101	0.020	*b.d.*	0.008	0.002
MA-132237	Bo 10/287	96	0.089	2.60	0.433	0.136	0.004	1.00	0.073	0.065	0.002	0.021	0.015	*b.d.*	0.001	0.008
MA-132235	Bo 10/305	99	0.019	0.551	0.117	0.066	0.004	0.137	0.110	0.048	0.009	0.012	0.038	0.014	0.008	0.001
MA-132236	Bo 10/307	99	0.030	0.572	0.106	0.076	*b.d.*	0.162	0.078	0.035	0.013	0.010	0.065	0.002	0.001	*b.d.*
MA-132233	Bo 10/323	98	0.012	1.74	0.156	0.052	0.004	0.304	0.108	0.035	0.004	0.010	0.036	0.009	0.014	*b.d.*
MA-132234	Bo 10/343	97	0.045	1.91	0.056	0.112	0.006	0.269	0.032	0.025	0.017	0.036	*b.d.*	0.002	0.003	*b.d.*
MA-132224	Bo 10/37	87	0.038	0.523	0.122	11.23	0.172	0.644	0.024	0.050	0.014	0.036	0.004	0.003	*b.d.*	*b.d.*
MA-132268	Bo 10/372	99	0.020	0.366	0.039	0.063	*b.d.*	0.114	0.045	0.037	*b.d.*	0.037	*b.d.*	*b.d.*	0.008	0.002
MA-132226	Bo 10/38	98	0.024	0.511	0.054	0.275	0.012	0.720	0.090	0.066	0.013	0.095	0.036	*b.d.*	0.006	0.005
MA-132269	Bo 10/389	99	0.011	0.296	0.077	0.035	0.011	0.166	0.119	0.062	0.010	0.009	0.029	*b.d.*	0.005	0.005
MA-132247	Bo 10/391	95	0.030	3.56	0.468	0.045	0.004	0.971	0.157	0.107	0.019	0.024	0.011	0.002	0.005	*b.d.*
MA-132248	Bo 10/392	97	0.001	1.68	0.065	0.409	0.001	0.397	0.172	0.257	0.010	0.014	0.018	0.004	*b.d.*	0.003
MA-132270	Bo 10/393	89	8.91	0.826	0.270	0.178	0.004	0.165	0.100	0.076	0.015	0.021	0.016	0.008	0.005	*b.d.*
MA-132264	Bo 10/394	98	0.018	1.02	0.076	0.395	0.031	0.470	0.095	0.081	0.004	0.050	0.007	0.004	0.002	*b.d.*
MA-132249	Bo 10/402	99	0.020	0.150	0.055	0.093	0.066	0.595	0.126	0.055	*b.d.*	0.035	0.015	0.008	*b.d.*	*b.d.*
MA-132272	Bo 10/404	96	0.356	2.09	0.440	0.315	0.025	0.437	0.127	0.074	0.011	0.035	0.016	0.016	0.004	*b.d.*
MA-132271	Bo 10/416	85	0.031	1.24	0.044	11.39	0.451	1.97	0.108	0.038	0.010	0.023	0.025	0.011	0.002	0.003
MA-132251	Bo 10/456	98	0.022	1.31	0.075	0.067	0.003	0.217	0.088	0.091	0.017	0.039	0.031	0.006	0.006	*b.d.*

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MA-132260	Bo 10/496	94	4.28	0.805	0.135	0.248	0.031	0.426	0.140	0.053	*b.d.*	0.012	0.010	0.003	0.005	*b.d.*
MA-132223	Bo 10/53	87	8.03	0.219	4.04	0.119	0.004	0.337	0.139	0.107	*b.d.*	0.123	0.036	0.007	0.002	0.009
MA-132208	Bo 10/59	98	0.151	1.25	0.064	0.110	0.001	0.199	0.016	0.061	0.018	0.029	0.003	0.002	0.006	*b.d.*
MA-132214	Bo 10/64	95	0.074	1.67	2.03	0.237	0.008	0.913	0.057	0.065	0.018	0.060	0.011	0.006	0.001	*b.d.*
MA-132228	Bo 10/843	95	1.81	2.15	0.242	0.487	0.047	0.465	0.038	0.036	0.020	0.035	0.004	0.002	0.003	*b.d.*
MA-132276	Bo 10/846	91	6.73	0.551	0.252	0.051	0.002	0.132	1.169	0.028	0.022	0.054	0.124	*b.d.*	0.014	*b.d.*
MA-132252	Bo 10/853	94	3.48	0.895	1.06	0.050	0.004	0.472	0.164	0.121	0.022	0.109	0.052	0.014	0.004	*b.d.*
MA-132280	Bo 10/893	93	3.52	1.84	0.394	0.147	0.008	0.530	0.379	0.150	0.018	0.050	0.152	0.012	0.022	0.003
MA-132221	Bo 10/904	97	0.466	1.56	0.160	0.324	*b.d.*	0.240	0.047	0.053	0.010	0.018	0.009	*b.d.*	0.002	*b.d.*
MA-132279	Bo 10/928	98	0.038	0.570	0.344	0.053	*b.d.*	0.351	0.198	0.110	0.017	0.096	0.107	0.002	0.016	0.036
MA-132215	Bo 10/935	98	0.009	1.10	0.033	0.059	0.021	0.804	0.045	0.031	*b.d.*	0.013	0.012	0.002	0.004	*b.d.*
MA-132217	Bo 10/935	98	0.039	0.766	0.067	0.062	0.001	0.699	0.107	0.075	0.027	0.030	0.053	0.011	*b.d.*	0.001
MA-132295	Bo 11/492	97	0.064	1.12	0.140	0.064	0.016	0.459	0.278	0.150	0.042	0.033	0.135	*b.d.*	0.008	0.007
MA-132296	Bo 11/502	97	0.026	1.09	0.017	0.177	0.050	0.702	0.479	0.186	0.015	0.022	0.138	0.007	0.023	0.006
MA-132292	Bo 11/522	95	0.061	2.97	0.164	0.074	0.011	0.320	0.839	0.255	0.035	0.022	0.125	0.008	0.003	*b.d.*
MA-132297	Bo 11/527	97	0.098	1.05	0.123	0.089	0.008	0.354	0.385	0.454	0.072	0.064	0.030	*b.d.*	0.003	*b.d.*
MA-132290	Bo 11/591	98	0.033	1.35	0.045	0.131	0.004	0.154	0.075	0.088	0.016	0.035	0.020	0.006	*b.d.*	*b.d.*
MA-132210	Bo 10/1512	90	6.85	2.01	0.332	0.128	0.011	0.315	0.005	0.090	0.011	0.041	0.001	0.002	0.004	*b.d.*
MA-132207	Bo 10/507	99	0.008	0.497	0.037	0.082	0.006	0.409	0.026	0.027	0.004	0.021	0.009	0.002	0.010	*b.d.*
MA-132212	Bo 10/544	90	7.13	2.08	0.334	0.128	0.013	0.365	0.047	0.100	0.010	0.043	0.005	0.003	0.005	*b.d.*
MA-132222	Bo 10/554	97	0.282	1.83	0.045	0.053	0.002	0.523	0.069	0.153	0.022	0.094	0.046	0.038	0.011	*b.d.*
MA-132273	Bo 10/558	97	0.023	1.98	0.245	0.048	0.010	0.812	0.011	0.042	0.007	0.031	0.006	0.001	0.009	*b.d.*
MA-132263	Bo 10/566	98	0.064	1.21	0.056	0.153	0.009	0.463	0.066	0.109	0.023	0.076	0.008	0.008	0.003	0.001
MA-132274	Bo 10/574	99	0.019	0.392	0.036	0.011	0.003	0.471	0.431	0.001	0.003	0.021	0.095	*b.d.*	0.008	*b.d.*
MA-132298	Bo 11/909	98	0.008	0.202	0.098	0.073	0.005	1.32	*b.d.*	0.007	0.003	0.012	0.004	0.002	*b.d.*	0.001
MA-132253	Bo 10/1232	94	2.72	1.01	1.03	0.040	0.002	0.497	0.093	0.085	0.021	0.091	0.020	0.010	0.004	0.001
MA-132243	Bo 10/1234	99	0.036	0.231	0.025	0.037	0.009	0.314	0.160	0.093	0.012	0.006	0.048	0.034	0.015	0.007
MA-132277	Bo 10/1277	97	0.118	1.63	0.282	0.169	0.008	0.262	0.054	0.030	0.005	0.048	0.006	*b.d.*	0.001	*b.d.*

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MA-132254	Bo 10/1282	98	0.044	1.07	0.191	0.051	0.003	0.505	0.043	0.064	0.010	0.035	0.003	0.006	0.002	*b.d.*
MA-132255	Bo 10/1283	93	4.81	0.972	0.101	0.145	0.006	0.702	0.069	0.035	*b.d.*	0.041	0.011	0.004	0.004	0.005
MA-132258	Bo 10/1291	94	3.24	1.58	0.241	0.041	0.002	0.714	0.086	0.057	0.004	0.016	0.026	0.006	0.009	*b.d.*
MA-132257	Bo 10/1292	97	0.882	1.10	0.074	0.052	*b.d.*	0.565	0.053	0.063	0.039	0.006	*b.d.*	*b.d.*	0.014	0.003
MA-132261	Bo 10/1294	92	6.10	1.56	0.191	0.030	0.005	0.336	0.124	0.050	0.011	0.017	0.015	0.016	0.007	*b.d.*
MA-132262	Bo 10/1295	97	0.304	2.20	0.174	0.061	0.001	0.341	0.051	0.058	0.010	0.049	0.016	*b.d.*	0.003	*b.d.*
MA-132256	Bo 10/1297	92	5.84	1.04	0.056	0.151	0.009	0.632	0.092	0.066	0.029	0.045	0.006	*b.d.*	0.008	0.001
MA-132278	Bo 10/1302	96	0.018	2.30	0.733	0.035	0.001	0.670	0.054	0.108	0.010	0.033	0.005	0.008	0.009	*b.d.*
MA-132284	Bo 11/15	93	0.049	5.20	0.135	0.076	*b.d.*	1.33	0.105	0.138	0.041	0.036	*b.d.*	*b.d.*	0.002	*b.d.*
MA-132294	Bo 11/18	99	0.071	0.197	0.022	0.090	*b.d.*	0.044	0.369	0.106	0.060	0.034	0.080	0.018	*b.d.*	*b.d.*
MA-132286	Bo 11/4	95	0.074	3.76	0.122	0.106	0.015	0.506	0.280	0.219	0.028	0.030	0.101	*b.d.*	0.006	0.005
MA-132293	Bo 11/42	86	11.89	0.937	0.149	0.112	0.009	0.382	0.034	0.079	0.007	0.023	0.006	0.008	0.007	*b.d.*
MA-132289	Bo 11/65	96	0.079	2.57	0.149	0.063	*b.d.*	0.689	0.047	0.074	0.009	0.037	0.007	0.006	*b.d.*	*b.d.*
MA-136341	Bo 13/39	89	0.071	1.07	0.054	6.01	0.221	3.47	*b.d.*	0.085	0.003	0.040	*b.d.*	0.005	0.002	*b.d.*
MA-132185	Bo 170/h	98	0.098	1.44	0.305	0.029	*b.d.*	0.298	0.076	0.095	0.040	0.047	0.007	0.002	0.009	*b.d.*
MA-132183	Bo 171/h	89	9.29	0.591	0.081	0.071	0.007	0.265	0.069	0.043	*b.d.*	0.095	0.014	0.006	0.001	0.002
MA-132187	Bo 173/h	97	0.081	1.32	0.130	0.138	0.011	0.339	0.433	0.159	0.006	0.058	0.092	0.006	0.002	*b.d.*
MA-132190	Bo 216/p	94	0.287	1.23	3.79	0.149	0.010	0.140	0.067	0.057	0.017	0.051	0.098	0.004	0.005	*b.d.*
MA-132173	Bo 77/385a	98		2.40												
MA-132172	Bo 77/385b	97	0.042	0.766	0.063	0.041	0.007	0.123	0.331	0.184	0.033	1.387	0.124	0.006	0.024	0.004
MA-132184	Bo 91/h	94	1.56	1.51	0.035	0.144	0.003	0.133	0.063	0.082	0.009	0.191	1.771	0.015	0.005	*b.d.*
MA-132186	Bo 95/h	97	0.098	2.52	0.102	0.138	0.002	0.152	0.005	0.126	0.006	0.033	0.003	*b.d.*	0.002	*b.d.*
MA-132218	Bo 10/1409	94	0.010	4.50	0.366	0.060	0.004	0.648	0.035	0.054	0.046	0.029	0.007	0.001	0.004	0.001
MA-132265	Bo 10/1425	96	0.054	2.17	0.260	0.370	0.015	0.795	0.187	0.104	0.006	0.022	0.032	*b.d.*	*b.d.*	*b.d.*
MA-132288	Bo 11/1203	98	0.096	0.975	0.018	0.067	*b.d.*	0.467	0.194	0.216	0.002	0.113	0.015	*b.d.*	*b.d.*	*b.d.*
MA-132283	Bo 11/1205	98	0.012	0.838	0.036	0.076	0.006	0.498	0.099	0.061	0.028	0.038	0.037	0.022	0.004	*b.d.*
MA-132282	Bo 11/1215	97	0.770	1.08	0.070	0.054	0.003	0.695	0.165	0.182	0.008	0.076	0.044	0.010	0.006	0.016
MA-132291	Bo 11/1223	98	0.024	0.388	0.068	0.139	0.025	0.554	0.253	0.127	0.021	0.004	0.013	0.022	*b.d.*	*b.d.*

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MA-132179	Bo 645/t	95	2.34	1.73	0.123	0.132	0.005	0.668	0.039	0.164	0.002	0.049	0.088	0.006	0.005	*b.d.*
MA-136337	Dowel_1	97	0.056	1.95	0.253	0.145	0.006	0.376	0.026	0.030	0.045	0.036	*b.d.*	0.023	0.003	0.009
MA-132196	Bo 79/206	95	0.073	0.326	0.034	0.036	0.061	3.73	0.401	0.142	0.008	0.016	0.155	0.001	0.029	*b.d.*
MA-132301	Bo 82/109a	99	0.017	0.270	0.065	0.053	0.004	0.272	0.221	0.101	0.010	0.015	0.049	0.014	0.013	*b.d.*
MA-132176	Bo 82/112	81	17.14	0.816	0.099	0.017	*b.d.*	0.250	0.018	0.262	0.002	0.008	0.003	0.009	0.014	*b.d.*
MA-132182	Bo 82/138	95	3.77	0.252	0.048	0.017	0.002	0.405	0.056	0.018	0.005	0.005	0.097	0.005	0.010	*b.d.*
MA-132175	Bo 82/140	83	16.12	0.364	0.012	0.007	0.001	0.519	0.029	0.010	0.001	0.002	0.003	0.006	0.013	0.003
MA-132181	Bo 82/141	93	4.09	1.58	1.26	0.012	0.002	0.202	0.001	0.042	0.001	0.004	0.011	0.007	0.009	*b.d.*
MA-136323	Bo 83/819	96	0.014	0.046	0.018	0.111	0.058	3.22	*b.d.*	0.031	*b.d.*	0.002	*b.d.*	0.011	0.066	0.012
MA-132178	Bo 84/551	96	1.72	0.929	0.058	0.320	0.006	0.359	0.016	0.038	0.004	0.088	0.004	0.002	0.012	*b.d.*
MA-132299	Bo 85/449	92	5.98	0.887	0.267	0.066	*b.d.*	0.351	0.547	0.176	0.027	0.018	0.101	*b.d.*	0.024	*b.d.*
MA-132300	Bo 85/71	85	13.81	0.357	0.040	0.016	0.002	0.258	*b.d.*	0.003	0.003	0.006	*b.d.*	0.003	0.010	*b.d.*
MA-136343	Bo 86/427	86	0.100	0.231	0.001	11.83	1.18	0.545	0.118	0.094	0.005	0.011	0.022	0.015	*b.d.*	0.002
MA-132177	Bo 86/94	89	10.08	0.524	0.091	0.032	0.029	0.434	0.051	0.193	0.008	0.005	0.009	0.008	0.005	*b.d.*
MA-132308	Bo 06/1058	87	0.032	1.67	0.059	9.02	0.278	1.26	0.005	0.145	0.039	0.051	0.004	0.016	0.002	*b.d.*
MA-132323	Bo 06/1141	80	14.56	3.93	0.257	0.058	*b.d.*	1.09	*b.d.*	0.107	0.006	0.005	*b.d.*	0.003	0.006	0.012
MA-132408	Bo 06/1148	97	0.068	1.26	0.686	0.097	*b.d.*	0.190	0.048	0.098	0.050	0.052	0.001	0.013	0.005	*b.d.*
MA-136342	Bo 08/1510	82	0.006	0.424	0.014	15.09	0.578	1.29	0.097	0.046	0.006	0.021	0.015	0.002	0.001	*b.d.*
MA-132461	Bo 06/1018	98	0.015	0.952	0.086	0.033	*b.d.*	0.308	0.059	0.080	0.011	0.004	0.024	0.006	0.013	0.002
MA-132359	Bo 06/106	92	0.020	4.13	2.07	0.101	0.020	1.20	0.133	0.126	0.012	0.036	0.018	0.003	0.002	0.002
MA-132343	Bo 06/108	89	0.692	0.269	0.024	8.39	0.855	0.441	0.254	0.025	0.002	0.002	0.041	*b.d.*	0.002	*b.d.*
MA-132433	Bo 06/124	99	0.234	0.547	0.196	0.033	*b.d.*	0.186	0.024	0.045	0.002	0.006	0.005	0.002	0.015	*b.d.*
MA-132339	Bo 06/127	89	9.83	0.369	0.051	0.005	*b.d.*	0.180	0.019	0.018	0.004	0.014	0.006	0.006	0.007	*b.d.*
MA-132387	Bo 06/1302	98	0.087	1.08	0.501	0.035	0.001	0.267	0.027	0.108	0.029	0.063	0.008	0.007	0.037	0.002
MA-132428	Bo 06/1342	85	13.20	0.465	0.808	0.037	0.001	0.366	0.082	0.057	0.012	0.053	0.011	0.001	0.002	*b.d.*
MA-132385	Bo 06/1364	97	0.041	1.68	0.172	0.051	0.002	0.324	0.134	0.154	0.029	0.078	0.058	0.010	0.001	0.008
MA-132328	Bo 06/1395	96	0.034	2.16	0.120	0.153	0.009	0.245	0.447	0.218	0.027	0.028	0.051	0.033	0.014	0.002
MA-132306	Bo 06/1397	89	0.319	7.72	0.156	0.767	0.016	1.09	0.181	0.208	0.013	0.083	0.035	0.011	0.014	0.004

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MA-132464	Bo 06/1399	97	0.067	1.27	0.571	0.045	0.001	0.258	0.156	0.341	0.037	0.087	0.036	0.008	0.009	*b.d.*
MA-132334	Bo 06/1439	91	0.416	0.695	0.746	0.102	0.054	0.469	3.494	1.442	0.030	0.280	0.932	0.314	0.003	0.006
MA-132379	Bo 06/1440	98	0.065	0.620	0.094	0.085	*b.d.*	0.707	0.260	0.151	0.016	0.046	0.075	*b.d.*	0.030	0.002
MA-132450	Bo 06/1446	93	0.574	0.740	1.86	0.309	0.003	3.23	0.113	0.096	0.036	0.004	0.028	0.001	0.004	0.026
MA-132327	Bo 06/1449	97	0.107	0.936	0.133	0.282	0.003	0.403	0.577	0.354	*b.d.*	0.050	0.195	0.011	0.019	0.002
MA-132369	Bo 06/1458	97	0.097	1.63	0.068	0.079	0.004	0.990	0.091	0.136	*b.d.*	0.034	0.019	*b.d.*	0.002	*b.d.*
MA-132386	Bo 06/1464	97	0.098	1.51	0.866	0.088	0.001	0.223	0.151	0.115	0.033	0.045	0.031	0.009	0.005	*b.d.*
MA-132316	Bo 06/1469	98	0.032	0.984	0.039	0.138	*b.d.*	0.133	0.094	0.118	0.019	0.148	0.030	0.014	0.018	0.005
MA-132331	Bo 06/1481	93	1.76	4.12	0.533	0.121	0.007	0.363	0.044	0.150	0.016	0.034	0.012	0.004	0.001	*b.d.*
MA-132456	Bo 06/1483	97	0.039	2.10	0.014	0.153	0.001	0.378	0.158	0.121	0.006	0.005	0.021	*b.d.*	0.011	*b.d.*
MA-132442	Bo 06/1497	99	0.009	0.931	0.106	0.070	*b.d.*	0.176	0.009	0.044	0.004	0.027	0.019	0.003	0.003	*b.d.*
MA-132384	Bo 06/1500	98	0.078	0.553	0.041	0.101	0.013	0.533	0.072	0.385	*b.d.*	0.008	0.008	0.003	0.003	*b.d.*
MA-132449	Bo 06/1506	99	0.015	0.629	0.060	0.018	0.002	0.087	0.061	0.073	0.007	0.003	0.015	0.005	0.014	*b.d.*
MA-132366	Bo 06/1508	84	14.32	0.876	0.122	0.036	0.003	0.219	0.057	0.083	0.007	0.012	0.009	0.007	0.009	*b.d.*
MA-132319	Bo 06/1512	94	4.85	0.722	0.004	0.046	0.004	0.371	*b.d.*	0.052	*b.d.*	0.005	0.054	0.002	0.010	*b.d.*
MA-132392	Bo 06/1513	85	13.93	0.428	0.176	0.021	*b.d.*	0.266	0.120	0.104	0.007	0.003	0.050	0.013	0.008	*b.d.*
MA-132397	Bo 06/153	97	0.318	1.87	0.270	0.111	0.001	0.299	0.020	0.166	0.012	0.039	0.004	0.004	0.010	*b.d.*
MA-132312	Bo 06/156	90	0.027	0.726	0.010	4.24	0.192	4.44	0.090	0.047	0.001	0.031	0.007	*b.d.*	0.001	*b.d.*
MA-132500	Bo 06/1563	92	5.11	1.53	0.163	0.276	*b.d.*	0.430	0.379	0.246	0.027	0.035	0.060	0.022	0.011	0.010
MA-132452	Bo 06/1565	86	12.45	0.636	0.166	0.062	0.001	0.297	0.007	0.032	0.023	0.048	0.003	*b.d.*	0.005	*b.d.*
MA-132478	Bo 06/1567	95	0.077	3.58	0.091	0.116	0.044	0.535	0.075	0.157	0.003	0.028	0.017	0.007	0.007	0.002
MA-132470	Bo 06/1576	98	0.096	1.25	0.280	0.091	0.006	0.281	0.143	0.128	0.021	0.048	0.038	0.011	0.005	*b.d.*
MA-132498	Bo 06/1582	93	0.041	5.65	0.150	0.161	0.007	1.05	0.062	0.140	*b.d.*	0.004	0.010	*b.d.*	0.001	0.004
MA-132474	Bo 06/1599	87	11.67	0.670	0.197	0.065	*b.d.*	0.062	*b.d.*	0.061	0.001	0.037	0.005	0.004	0.010	*b.d.*
MA-132437	Bo 06/160	92	7.13	0.162	0.054	0.028	*b.d.*	0.268	0.207	0.119	0.009	0.002	0.056	0.014	0.008	0.002
MA-132350	Bo 06/1600	98	0.046	1.19	0.038	0.407	0.009	0.308	0.019	0.047	0.001	0.028	0.004	0.001	0.006	*b.d.*
MA-132444	Bo 06/1601	82	15.71	0.966	0.079	0.635	0.021	0.265	0.067	0.042	0.005	0.006	0.014	0.008	0.012	*b.d.*
MA-132406	Bo 06/1609	85	12.23	1.62	0.217	0.023	*b.d.*	0.429	*b.d.*	0.112	0.012	0.049	0.010	0.002	0.007	*b.d.*

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MA-132325	Bo 06/1614	97	0.114	1.60	0.273	0.164	*b.d.*	0.441	0.066	0.098	0.027	0.034	*b.d.*	0.003	0.004	*b.d.*
MA-132400	Bo 06/1616	98	0.073	0.931	0.225	0.087	0.006	0.276	0.044	0.053	*b.d.*	0.010	0.032	0.004	0.008	*b.d.*
MA-132373	Bo 06/164	98	0.121	0.736	0.152	0.255	0.006	0.337	0.133	0.224	0.010	0.030	0.029	0.003	0.005	*b.d.*
MA-132465	Bo 06/1654	98	0.041	0.538	0.247	0.063	0.008	0.740	0.078	0.088	0.025	0.038	0.030	0.001	0.004	*b.d.*
MA-132473	Bo 06/1654_2	86	12.87	0.493	0.043	0.010	0.005	0.260	*b.d.*	0.031	0.002	0.006	0.003	0.006	0.017	0.001
MA-132338	Bo 06/1656	93	5.40	0.786	0.108	0.459	0.021	0.102	0.039	0.058	0.002	0.020	0.005	0.006	0.004	*b.d.*
MA-132502	Bo 06/168	99	0.028	0.287	0.044	0.052	0.014	0.358	0.258	0.070	0.013	0.009	0.051	0.012	0.010	0.004
MA-132371	Bo 06/1688	99	0.017	0.437	0.040	0.032	0.010	0.243	0.026	0.041	0.003	0.004	0.029	0.017	0.010	*b.d.*
MA-132429	Bo 06/1694	94	5.40	0.376	0.096	0.069	0.001	0.063	0.028	0.032	*b.d.*	0.018	0.047	0.008	0.004	*b.d.*
MA-132445	Bo 06/1715	98	0.030	0.626	0.035	0.085	0.038	0.500	0.413	0.226	0.026	*b.d.*	0.092	0.018	0.004	0.004
MA-132463	Bo 06/1716	99	0.160	0.537	0.033	0.029	*b.d.*	0.183	0.024	0.063	0.001	0.047	0.004	0.008	0.011	*b.d.*
MA-132311	Bo 06/172	83	0.069	0.197	0.042	13.42	1.67	1.37	0.219	0.086	0.020	0.017	0.051	0.012	*b.d.*	*b.d.*
MA-132499	Bo 06/1730	99	0.439	0.602	0.053	0.141	0.003	0.094	0.050	0.069	0.003	0.013	0.011	0.009	0.003	*b.d.*
MA-132383	Bo 06/1739	84	14.94	0.635	0.271	0.103	0.008	0.157	0.042	0.069	0.033	0.027	0.065	0.003	0.005	*b.d.*
MA-132476	Bo 06/1742	83	15.92	0.422	0.054	0.045	*b.d.*	0.091	0.002	0.042	0.004	0.013	0.008	0.001	0.010	*b.d.*
MA-132439	Bo 06/1751	93	0.078	5.92	0.158	0.096	*b.d.*	0.389	0.006	0.135	0.016	0.040	*b.d.*	0.004	0.003	*b.d.*
MA-132466	Bo 06/1753	85	13.25	0.699	0.162	0.052	0.003	0.366	0.111	0.094	0.018	0.021	0.009	*b.d.*	0.008	*b.d.*
MA-132203	Bo 06/1754	94	4.34	0.969	0.203	0.085	0.006	0.445	0.075	0.082	0.007	0.011	0.033	0.002	0.012	0.004
MA-132398	Bo 06/1755	86	12.30	1.41	0.117	0.048	0.004	0.274	0.099	0.121	0.009	0.020	0.025	0.011	0.009	0.002
MA-132330	Bo 06/1758	98	1.31	0.569	0.021	0.044	0.002	0.260	0.141	0.065	0.019	0.008	0.023	0.015	0.011	*b.d.*
MA-132430	Bo 06/1758_2	86	12.32	0.763	0.077	0.072	0.061	0.434	0.033	0.058	0.016	0.035	0.008	0.006	0.004	*b.d.*
MA-132421	Bo 06/1759	93	5.61	1.03	0.211	0.079	*b.d.*	0.230	0.026	0.090	0.003	0.033	0.030	0.005	0.003	*b.d.*
MA-132352	Bo 06/1762	98	0.060	1.53	0.107	0.053	*b.d.*	0.246	0.030	0.107	0.016	0.042	0.003	*b.d.*	0.006	*b.d.*
MA-132335	Bo 06/1763	98	1.03	0.465	0.053	0.074	0.005	0.435	0.029	0.041	0.005	0.004	0.005	0.013	0.011	*b.d.*
MA-132394	Bo 06/1764	98	0.061	1.47	0.178	0.138	0.017	0.277	0.044	0.186	0.005	0.065	0.005	*b.d.*	0.003	*b.d.*
MA-132489	Bo 06/1768	87	9.72	1.09	1.32	0.118	0.018	0.255	0.070	0.078	0.016	0.021	0.028	0.006	0.005	*b.d.*
MA-132372	Bo 06/1771	84	15.02	0.510	0.051	0.018	0.004	0.287	0.032	0.062	0.001	0.004	0.002	0.009	0.021	*b.d.*
MA-132471	Bo 06/1802	95	0.105	3.27	0.311	0.259	0.014	1.14	0.133	0.121	0.008	0.029	0.027	0.006	0.005	*b.d.*

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MA-132310	Bo 06/1803	87	0.140	1.31	0.131	4.79	0.096	5.75	*b.d.*	0.165	0.052	0.078	0.012	0.006	0.003	0.014
MA-132348	Bo 06/1806	99	0.008	0.653	0.178	0.036	0.001	0.420	0.023	0.134	0.006	0.004	0.005	0.006	0.012	*b.d.*
MA-132401	Bo 06/1817	97	0.152	0.799	0.048	0.980	0.045	0.692	0.160	0.076	0.012	0.013	0.059	0.003	0.006	*b.d.*
MA-132472	Bo 06/1825	93	3.05	1.54	0.242	0.438	0.020	1.60	0.085	0.118	0.012	0.006	0.021	0.014	0.012	*b.d.*
MA-132357	Bo 06/1834	94	3.92	0.803	0.138	0.073	0.002	0.530	0.083	0.060	0.001	0.004	0.049	0.003	0.015	0.001
MA-132475	Bo 06/1835	98	0.026	1.42	0.031	0.031	0.001	0.446	0.084	0.145	0.006	0.019	0.095	*b.d.*	0.005	*b.d.*
MA-132443	Bo 06/1837	99	0.007	0.288	0.014	0.028	*b.d.*	0.178	0.017	0.027	0.002	0.001	0.009	0.002	*b.d.*	*b.d.*
MA-132382	Bo 06/1844	97	0.213	1.26	0.362	0.096	0.002	0.321	0.105	0.137	0.002	0.028	0.030	0.004	0.003	*b.d.*
MA-132309	Bo 06/189	86	0.042	0.324	0.028	11.81	1.29	0.272	0.065	0.073	0.001	0.007	0.041	*b.d.*	0.002	*b.d.*
MA-132377	Bo 06/1933	97	0.240	1.61	0.056	0.104	*b.d.*	0.432	0.175	0.167	0.009	0.061	0.067	0.013	0.006	*b.d.*
MA-132434	Bo 06/1954	98	0.055	1.39	0.080	0.124	0.005	0.345	0.064	0.142	0.001	0.030	0.006	0.001	0.001	*b.d.*
MA-132477	Bo 06/2009	85	12.63	0.111	1.18	0.018	0.014	0.606	0.084	0.074	0.010	0.020	0.005	0.012	*b.d.*	0.003
MA-132358	Bo 06/2016	98	0.032	0.585	0.036	0.061	0.012	0.656	0.045	0.040	0.003	0.007	0.337	*b.d.*	0.010	*b.d.*
MA-132493	Bo 06/2019	94	0.018	4.22	0.154	0.071	0.015	0.842	0.079	0.130	0.015	0.026	0.029	0.013	0.004	*b.d.*
MA-132501	Bo 06/2028	97	0.067	1.86	0.205	0.114	0.003	0.362	0.098	0.128	0.015	0.024	0.017	0.010	*b.d.*	0.010
MA-132356	Bo 06/2036	87	11.60	0.885	0.045	0.116	0.007	0.201	0.098	0.093	0.007	0.021	0.037	0.001	0.006	*b.d.*
MA-132305	Bo 06/2037	86	0.191	0.133	0.020	11.08	0.350	1.76	*b.d.*	0.038	0.001	0.007	0.015	0.001	*b.d.*	0.003
MA-132318	Bo 06/2039	97	0.036	1.66	0.696	0.063	*b.d.*	0.433	0.037	0.066	0.040	0.024	*b.d.*	0.003	0.008	0.007
MA-132321	Bo 06/2049	91	7.75	0.727	0.141	0.066	0.008	0.106	0.078	0.095	0.004	0.013	0.010	0.013	0.005	*b.d.*
MA-132454	Bo 06/2056	98	0.422	0.884	0.093	0.102	0.006	0.235	0.126	0.127	0.005	0.032	0.022	0.005	0.001	*b.d.*
MA-132361	Bo 06/207	93	4.06	1.73	0.205	0.146	*b.d.*	0.212	0.168	0.169	0.022	0.034	0.043	0.001	0.010	0.001
MA-132414	Bo 06/2075	76	22.02	1.54	0.173	0.032	0.009	0.230	0.063	0.089	0.016	0.058	0.004	0.006	0.005	*b.d.*
MA-132487	Bo 06/2089	98	0.047	1.20	0.125	0.057	*b.d.*	0.279	0.038	0.062	0.017	0.029	0.007	*b.d.*	0.006	*b.d.*
MA-132418	Bo 06/2090	94	0.097	3.44	1.82	0.044	0.009	0.416	0.045	0.099	0.011	0.056	0.012	0.013	0.001	*b.d.*
MA-132525	Bo 06/2094	97	0.061	1.78	0.206	0.144	0.018	0.196	*b.d.*	0.278	0.002	0.040	*b.d.*	0.011	0.023	0.028
MA-132410	Bo 06/210	83	15.52	0.919	0.139	0.059	0.002	0.082	0.075	0.091	0.011	0.056	0.012	0.007	0.005	*b.d.*
MA-132482	Bo 06/2103	97	0.025	1.24	0.046	0.065	0.120	0.917	0.026	0.080	0.020	0.050	0.009	0.002	*b.d.*	*b.d.*
MA-132354	Bo 06/2110	97	0.068	0.643	0.149	1.01	0.046	0.837	0.055	0.028	0.002	0.004	0.014	0.001	0.005	*b.d.*

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MA-132322	Bo 06/212	90	8.40	0.669	0.113	0.027	0.002	0.216	0.036	0.043	0.004	0.004	0.007	0.002	0.006	*b.d.*
MA-132315	Bo 06/2127	89	8.08	1.68	0.125	0.108	0.002	0.399	*b.d.*	0.105	0.007	0.014	0.004	0.004	0.009	*b.d.*
MA-132480	Bo 06/2130	98	0.066	1.76	0.068	0.047	*b.d.*	0.100	0.029	0.087	0.046	0.050	0.015	0.012	0.005	*b.d.*
MA-132488	Bo 06/2142	98	0.239	1.37	0.194	0.081	0.003	0.131	0.108	0.121	0.007	0.023	0.041	0.014	0.005	*b.d.*
MA-132419	Bo 06/215	93	4.20	1.32	0.204	0.175	0.008	0.451	0.276	0.227	0.056	0.027	0.031	0.001	0.013	0.009
MA-132479	Bo 06/2152	89	0.147	0.975	0.319	8.22	0.241	0.583	*b.d.*	0.113	0.030	0.062	0.010	0.006	*b.d.*	*b.d.*
MA-132332	Bo 06/2153	98	0.103	1.61	0.024	0.038	*b.d.*	0.280	0.108	0.082	0.031	0.045	0.014	0.012	0.002	*b.d.*
MA-132492	Bo 06/2182	99	0.017	0.467	0.036	0.062	0.008	0.419	0.102	0.074	0.013	0.008	0.049	0.004	0.011	0.003
MA-132417	Bo 06/2192	90	6.32	1.75	0.173	0.104	0.012	1.26	0.216	0.171	0.015	0.025	0.066	0.021	0.006	*b.d.*
MA-132415	Bo 06/2229	99	0.034	0.421	0.029	0.049	0.003	0.260	0.065	0.038	0.012	0.006	0.019	0.013	0.002	*b.d.*
MA-132497	Bo 06/223	98	0.038	0.836	0.175	0.029	0.001	0.289	0.055	0.073	0.028	0.017	0.008	0.002	0.007	0.001
MA-132425	Bo 06/2237	97	0.185	1.61	0.219	0.124	0.002	0.439	0.065	0.096	0.033	0.045	0.025	0.006	0.006	0.001
MA-132375	Bo 06/2244	98	0.049	1.04	0.125	0.110	*b.d.*	0.329	0.162	0.135	0.014	0.021	0.057	0.002	0.005	*b.d.*
MA-132403	Bo 06/2253	94	1.09	2.77	0.630	0.400	0.023	0.590	0.032	0.080	0.047	0.069	*b.d.*	0.005	0.002	0.002
MA-132494	Bo 06/2263	98	0.018	1.46	0.143	0.034	0.002	0.116	0.175	0.151	0.015	0.038	0.022	0.014	0.012	0.005
MA-132345	Bo 06/2294	85	13.83	0.849	0.085	0.054	0.145	0.235	0.063	0.100	0.007	0.011	0.003	0.003	0.005	*b.d.*
MA-132342	Bo 06/2298	86	3.14	0.510	0.066	8.66	0.675	0.209	0.448	0.085	*b.d.*	0.012	0.103	*b.d.*	0.006	*b.d.*
MA-132462	Bo 06/2359	98	0.202	0.638	0.027	0.088	0.003	0.541	0.082	0.069	0.005	0.006	0.019	0.008	0.001	*b.d.*
MA-132304	Bo 06/2361	88	0.036	0.063	0.037	11.51	0.091	0.050	0.209	0.106	0.004	0.001	0.020	0.001	0.004	*b.d.*
MA-132351	Bo 06/2376	97	0.196	1.62	0.204	0.118	0.003	0.419	0.035	0.063	0.015	0.049	0.003	0.005	0.007	*b.d.*
MA-132317	Bo 06/2378	95	0.331	3.14	0.189	0.089	0.016	1.30	0.189	0.107	0.015	0.027	0.038	0.011	0.004	0.004
MA-132344	Bo 06/239	88	10.81	0.325	0.030	0.280	0.030	0.163	0.231	0.120	0.028	0.019	0.029	*b.d.*	0.007	0.007
MA-132363	Bo 06/2398	98	0.023	1.49	0.160	0.103	0.001	0.400	0.048	0.038	0.029	0.046	0.012	0.010	0.011	*b.d.*
MA-132411	Bo 06/2400	96	2.10	0.974	0.152	0.150	0.002	0.233	0.034	0.151	0.012	0.042	0.017	0.004	0.004	*b.d.*
MA-132364	Bo 06/2403	95	0.086	3.57	1.06	0.034	*b.d.*	0.291	0.054	0.150	0.129	0.072	*b.d.*	0.036	0.009	*b.d.*
MA-132355	Bo 06/2409	98	0.046	0.899	0.029	0.615	0.018	0.492	0.060	0.054	0.020	0.019	0.020	0.003	0.008	*b.d.*
MA-132453	Bo 06/241	97	2.28	0.219	0.074	0.030	0.002	0.296	0.237	0.129	0.018	0.001	*b.d.*	*b.d.*	0.005	0.002
MA-132346	Bo 06/2428	87	0.030	0.267	0.008	10.76	1.35	0.457	*b.d.*	0.016	0.001	0.006	*b.d.*	0.004	0.002	*b.d.*

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MA-132402	Bo 06/250	98	0.799	0.653	0.609	0.070	0.001	0.165	0.038	0.047	0.006	0.026	0.009	0.003	0.001	*b.d.*
MA-132340	Bo 06/254	97	1.73	0.552	0.169	0.039	0.002	0.264	0.035	0.092	0.005	0.008	0.028	0.001	0.015	*b.d.*
MA-132468	Bo 06/257	87	10.80	0.697	0.055	0.225	*b.d.*	0.505	0.326	0.169	0.015	0.022	0.036	0.006	0.003	*b.d.*
MA-132349	Bo 06/258	99	0.009	0.274	0.005	0.087	0.004	0.447	0.004	0.018	0.001	0.016	0.001	0.001	0.002	*b.d.*
MA-132409	Bo 06/259	89	9.93	0.295	0.010	0.012	0.001	0.071	0.123	0.095	0.005	0.005	0.025	0.014	0.004	*b.d.*
MA-132486	Bo 06/265	92	5.81	1.34	0.121	0.123	0.001	0.358	0.082	0.093	0.004	0.021	0.022	0.003	0.002	*b.d.*
MA-132483	Bo 06/266	97	0.199	1.47	0.810	0.054	0.013	0.318	0.066	0.105	0.043	0.110	0.006	0.007	0.002	*b.d.*
MA-132485	Bo 06/267	87	9.42	2.13	0.118	0.099	0.003	1.10	0.046	0.076	0.015	0.046	0.011	0.007	0.003	*b.d.*
MA-132484	Bo 06/268	99	0.040	0.455	0.024	0.292	0.006	0.255	0.140	0.116	0.003	0.009	0.042	0.002	0.005	*b.d.*
MA-132469	Bo 06/268_2	93	0.049	4.66	0.106	0.051	0.052	1.41	0.104	0.146	0.003	0.065	0.028	*b.d.*	0.002	0.002
MA-132381	Bo 06/272	90	8.21	0.661	0.188	0.040	0.005	0.747	0.083	0.084	0.008	0.007	0.018	0.009	0.005	0.006
MA-132491	Bo 06/274	97	0.184	1.48	0.244	0.275	*b.d.*	0.462	0.101	0.140	0.024	0.050	0.025	0.002	0.003	0.003
MA-132423	Bo 06/284	93	5.66	0.814	0.170	0.107	0.012	0.066	0.248	0.199	0.006	0.023	0.035	0.009	0.008	0.002
MA-132337	Bo 06/293	98	0.101	1.28	0.067	0.104	0.006	0.404	0.147	0.127	0.007	0.046	0.032	*b.d.*	0.006	*b.d.*
MA-132391	Bo 06/305	97	0.023	1.39	0.048	0.458	0.009	0.430	0.124	0.128	0.015	0.055	0.018	0.001	0.003	0.001
MA-132448	Bo 06/313	89	9.57	0.296	0.026	0.153	0.016	0.121	0.329	0.169	0.001	0.129	0.069	0.002	0.003	0.001
MA-132376	Bo 06/314	92	5.53	0.832	0.323	0.172	0.053	0.583	0.103	0.113	0.011	0.023	0.015	0.010	0.011	*b.d.*
MA-132320	Bo 06/317	80	14.03	3.11	0.372	0.206	0.026	1.18	0.396	0.267	0.007	0.052	0.056	*b.d.*	0.021	0.014
MA-132324	Bo 06/319	90	7.02	1.03	0.960	0.260	0.013	0.316	0.326	0.202	0.026	0.017	0.044	0.011	0.012	0.002
MA-132395	Bo 06/326	97	2.09	0.496	0.125	0.013	*b.d.*	0.141	0.023	0.097	0.007	0.011	0.005	0.010	0.014	*b.d.*
MA-132459	Bo 06/368	83	16.31	0.637	0.050	0.016	*b.d.*	0.298	0.069	0.070	*b.d.*	0.004	0.002	0.004	0.003	*b.d.*
MA-132496	Bo 06/410	97	0.104	1.65	0.778	0.039	0.006	0.333	0.180	0.243	0.037	0.053	0.027	*b.d.*	0.005	*b.d.*
MA-132495	Bo 06/413	95	1.08	1.92	0.139	0.145	0.005	0.896	0.207	0.176	*b.d.*	0.048	0.032	0.001	0.012	0.010
MA-132326	Bo 06/415	98	0.092	1.05	0.081	0.099	0.009	0.545	0.035	0.054	0.003	0.016	*b.d.*	*b.d.*	0.005	0.001
MA-132404	Bo 06/429	98	0.084	1.40	0.186	0.121	0.001	0.254	0.084	0.184	0.015	0.039	0.092	*b.d.*	0.006	*b.d.*
MA-132440	Bo 06/440	97	0.022	2.39	0.087	0.097	*b.d.*	0.193	0.105	0.182	0.018	0.049	0.019	*b.d.*	0.001	0.004
MA-132336	Bo 06/441	97	0.163	1.48	0.094	0.173	0.011	0.462	0.182	0.141	0.014	0.045	0.033	0.001	0.005	*b.d.*
MA-132341	Bo 06/454	95	0.272	3.68	0.354	0.121	0.014	0.519	0.028	0.121	0.055	0.058	0.024	0.008	0.008	0.001

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MA-132431	Bo 06/476	93	4.30	1.11	0.096	0.316	0.004	0.323	0.179	0.161	0.002	0.022	0.037	0.004	0.004	*b.d.*
MA-132438	Bo 06/489	97	0.141	1.36	0.172	0.156	0.009	0.406	0.177	0.209	0.017	0.063	0.052	0.021	0.005	0.004
MA-132307	Bo 06/492	80	0.033	0.275	0.027	17.46	1.87	0.459	0.113	0.038	0.002	0.010	0.025	0.001	0.001	0.002
MA-132333	Bo 06/499	98	0.208	1.29	0.138	0.083	*b.d.*	0.106	0.210	0.141	0.023	0.054	0.048	0.015	0.010	*b.d.*
MA-132389	Bo 06/500	93	0.038	5.59	0.134	0.118	0.010	0.637	0.174	0.310	0.005	0.061	0.021	0.005	0.005	*b.d.*
MA-132426	Bo 06/506	91	6.78	1.01	0.128	0.280	0.014	0.228	0.192	0.143	0.009	0.012	0.023	0.006	0.005	0.001
MA-132368	Bo 06/513	90	7.97	0.922	0.265	0.115	0.013	0.620	0.062	0.091	0.007	0.026	0.015	0.002	0.011	*b.d.*
MA-132446	Bo 06/514	92	4.97	1.64	0.499	0.202	0.001	0.292	0.075	0.129	0.014	0.049	0.022	0.005	0.007	*b.d.*
MA-132347	Bo 06/521	96	0.333	3.39	0.062	0.052	0.005	0.076	0.069	0.086	0.169	0.076	0.001	0.012	0.013	*b.d.*
MA-132413	Bo 06/532	89	9.13	1.23	0.199	0.217	0.023	0.186	0.160	0.140	0.013	0.035	0.011	0.013	0.008	*b.d.*
MA-132422	Bo 06/533	85	12.32	1.01	0.302	0.048	0.003	0.688	0.353	0.204	0.009	0.019	0.068	0.003	0.004	*b.d.*
MA-132362	Bo 06/548	91	7.98	0.526	0.062	0.044	0.001	0.125	0.113	0.040	0.010	0.006	0.020	0.005	0.004	*b.d.*
MA-132313	Bo 06/549	87	0.018	0.129	0.027	10.60	1.99	0.369	0.114	0.079	*b.d.*	0.001	0.016	0.006	0.005	0.003
MA-132374	Bo 06/555	97	0.029	1.76	0.289	0.025	0.009	0.588	0.253	0.169	0.008	0.028	0.042	0.032	*b.d.*	*b.d.*
MA-132390	Bo 06/563	97	0.047	1.75	0.421	0.048	0.002	0.246	0.034	0.086	0.019	0.042	0.019	0.006	0.004	*b.d.*
MA-132441	Bo 06/567_1	98	0.037	0.512	0.070	0.046	0.018	0.278	0.296	0.182	0.028	0.004	0.067	0.011	0.008	*b.d.*
MA-132481	Bo 06/578	96	1.71	0.776	0.105	0.038	0.006	0.633	0.519	0.341	0.002	0.008	0.072	0.009	0.010	0.009
MA-132420	Bo 06/585	97	0.050	1.40	0.134	0.068	*b.d.*	0.318	0.404	0.254	*b.d.*	0.040	0.093	0.022	0.014	0.002
MA-132412	Bo 06/608	94	4.96	0.495	0.141	0.157	0.005	0.073	0.069	0.065	0.006	0.014	0.079	0.005	0.007	*b.d.*
MA-132467	Bo 06/617	90	8.10	0.812	0.176	0.017	0.016	0.597	0.305	0.149	0.026	0.006	0.046	0.004	0.027	*b.d.*
MA-132460	Bo 06/635	98	0.881	0.881	0.079	0.127	0.005	0.107	0.105	0.118	0.018	0.047	0.034	0.007	*b.d.*	0.002
MA-132451	Bo 06/647	92	5.14	1.02	0.511	0.069	0.004	0.749	0.153	0.223	0.007	0.009	*b.d.*	0.005	0.006	*b.d.*
MA-132329	Bo 06/649	89	9.22	0.824	0.144	0.080	0.010	0.229	0.009	0.069	0.008	0.013	0.014	0.004	0.007	*b.d.*
MA-132432	Bo 06/661	97	0.052	1.93	0.153	0.069	0.002	0.187	0.042	0.172	0.042	0.059	0.008	0.007	0.006	0.001
MA-132416	Bo 06/668	96	0.602	1.03	0.369	0.040	*b.d.*	0.914	0.145	0.355	0.027	0.032	0.020	0.009	0.003	0.006
MA-132365	Bo 06/673	97	0.058	1.38	0.052	0.087	0.012	1.13	0.170	0.126	0.018	0.038	0.068	0.004	0.005	0.010
MA-132455	Bo 06/677	74	23.68	1.31	0.376	0.050	0.001	0.142	0.021	0.095	0.007	0.010	0.008	0.008	0.012	*b.d.*
MA-132353	Bo 06/680	95	3.53	0.719	0.081	0.134	0.018	0.237	0.024	0.118	0.007	0.044	0.003	0.002	0.007	0.001

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MA-132314	Bo 06/69	72	21.58	0.387	0.940	3.77	0.298	0.228	*b.d.*	0.082	0.011	0.344	*b.d.*	0.005	0.002	*b.d.*
MA-132427	Bo 06/711	98	0.120	1.15	0.241	0.037	0.004	0.172	0.133	0.144	0.034	0.058	0.026	0.007	0.002	*b.d.*
MA-132490	Bo 06/735	98	0.021	1.62	0.123	0.072	0.001	0.114	0.020	0.067	0.009	0.037	*b.d.*	0.003	0.003	*b.d.*
MA-132458	Bo 06/740	96	2.59	0.902	0.129	0.135	0.002	0.239	0.082	0.203	0.009	0.021	0.010	0.001	0.001	*b.d.*
MA-132201	Bo 06/753	87	12.00	0.176	0.063	0.024	0.004	1.07	0.002	0.034	0.003	0.016	0.001	0.008	0.002	0.002
MA-132447	Bo 06/770	98	0.068	0.757	0.112	0.511	0.001	0.129	0.013	0.037	0.013	0.028	0.023	0.007	0.018	*b.d.*
MA-132396	Bo 06/773	98	0.046	1.40	0.103	0.023	0.001	0.469	0.056	0.072	0.041	0.066	0.020	0.013	0.007	*b.d.*
MA-132360	Bo 06/78	98	0.099	1.20	0.168	0.029	0.003	0.260	0.127	0.120	0.022	0.071	0.047	0.011	0.016	*b.d.*
MA-132378	Bo 06/819	87	10.45	1.46	0.340	0.134	0.003	0.191	0.253	0.190	0.020	0.040	0.088	0.016	0.004	*b.d.*
MA-132399	Bo 06/82	99	0.111	0.465	0.190	0.033	0.005	0.583	0.028	0.041	0.001	0.005	0.011	*b.d.*	0.006	*b.d.*
MA-132424	Bo 06/83	96	1.51	0.986	0.159	0.205	0.015	0.385	0.220	0.213	0.015	0.053	0.058	0.004	0.010	0.002
MA-132436	Bo 06/861	97	0.029	1.90	0.060	0.053	*b.d.*	0.607	0.030	0.089	0.001	0.013	0.012	0.001	0.001	*b.d.*
MA-132435	Bo 06/93	91	6.55	1.53	0.278	0.103	0.009	0.662	0.042	0.105	0.018	0.027	0.006	0.005	0.008	*b.d.*
MA-132457	Bo 06/97	91	6.90	0.832	0.142	0.078	0.020	0.200	0.202	0.145	0.020	0.033	0.053	0.020	0.005	0.005
MA-136335	Bo 07/1871	77	0.018	0.079	0.023	20.75	1.16	0.688	0.339	0.041	0.003	0.004	0.079	0.004	0.007	*b.d.*
MA-136332	Bo 07/2101	86	0.002	0.874	0.014	10.51	0.322	1.83	*b.d.*	0.055	0.000	0.021	0.006	0.008	0.001	*b.d.*
MA-136331	Bo 07/2149	80	0.032	1.46	0.029	14.51	0.685	3.20	0.126	0.073	0.007	0.021	0.022	0.004	0.002	0.001
MA-136328	Bo 07/2151	80	0.019	0.449	0.021	16.04	0.589	2.91	0.132	0.051	0.001	0.009	0.013	0.000	0.001	*b.d.*
MA-136333	Bo 07/2204	83	0.020	0.488	0.020	13.74	0.530	2.05	0.024	0.036	0.008	0.013	0.015	0.004	*b.d.*	*b.d.*
MA-132197	Bo 07/29	94	4.17	0.729	0.117	0.111	0.012	0.606	0.052	0.029	0.001	0.005	0.019	*b.d.*	0.009	*b.d.*
MA-136334	Bo 07/3594	86	0.080	0.647	0.021	11.44	0.210	1.19	*b.d.*	0.094	0.003	0.037	0.007	*b.d.*	0.001	*b.d.*
MA-136325	Bo 07/3735	82	0.016	0.230	0.017	15.81	0.328	1.32	0.096	0.030	0.000	0.004	0.014	*b.d.*	0.001	*b.d.*
MA-132199	Bo 08/101	92	5.78	1.51	0.099	0.155	0.014	0.426	0.039	0.034	0.011	0.019	0.008	*b.d.*	0.002	*b.d.*
MA-132205	Bo 08/217	95	0.066	1.98	1.63	0.170	0.005	0.828	0.051	0.089	0.089	0.065	0.011	0.007	0.011	*b.d.*
MA-132198	Bo 08/227	91	5.06	2.05	0.402	0.106	0.002	1.11	0.062	0.061	0.012	0.035	0.009	0.004	0.004	0.002
MA-132206	Bo 08/229	97	0.384	1.26	0.049	0.042	0.012	0.670	0.027	0.045	0.005	0.014	0.006	0.004	0.007	*b.d.*
MA-136324	Bo 08/264	88	0.033	0.312	0.018	9.88	0.922	0.568	0.012	0.077	0.001	0.006	0.026	0.002	0.006	*b.d.*
MA-132204	Bo 08/9	82	0.193	1.28	0.072	13.68	0.164	2.02	0.440	*b.d.*	*b.d.*	0.060	0.004	0.164	*b.d.*	0.062

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MA-136328	Bo 07/576	87	0.590	0.446	0.011	9.73	1.13	1.44	*b.d.*	0.065	0.004	0.016	*b.d.*	0.009	*b.d.*	*b.d.*
MIDDLE / LATE IRON AGE																
MA-132281	Bo 11/14	73	2.74	1.04	21.90	0.048	*b.d.*	0.534	0.344	0.630	0.084	0.102	0.049	0.001	0.002	0.004
MA-132275	Bo 10/832	81	17.36	0.071	0.442	0.054	*b.d.*	0.295	0.120	0.063	0.006	0.092	0.033	0.021	*b.d.*	*b.d.*
MA-132225	Bo 10/9	86	12.83	0.263	0.239	0.025	*b.d.*	0.626	0.067	0.277	0.032	0.075	0.008	0.008	0.004	*b.d.*
MA-132194	Bo 861/t	89	10.18	0.012	0.077	0.017	0.003	0.291	0.060	0.016	*b.d.*	0.022	0.022	*b.d.*	0.018	*b.d.*
MA-132191	Bo 864/t	87	11.18	0.027	0.194	0.216	0.001	0.826	0.097	0.040	0.006	0.028	0.014	*b.d.*	0.004	0.002
MA-132393	Bo 06/1639	89	10.05	0.125	0.091	0.118	0.001	0.070	0.095	0.062	0.007	0.077	0.022	*b.d.*	*b.d.*	*b.d.*
MA-132380	Bo 06/1765	98	0.046	1.21	0.077	0.027	0.001	0.280	0.035	0.194	0.004	0.008	0.018	0.016	0.008	*b.d.*
MA-132200	Bo 06/233	97	0.697	0.348	0.211	0.755	0.033	0.290	0.110	0.078	0.008	0.052	0.031	0.005	0.001	*b.d.*
MA-132405	Bo 06/2330	98	0.048	0.464	0.048	0.448	0.013	0.508	0.183	0.085	0.021	0.023	0.117	0.003	0.004	0.001
MA-132370	Bo 06/515	89	8.74	0.598	0.906	0.100	0.010	0.134	0.024	0.078	0.005	0.005	0.016	0.002	0.003	*b.d.*
KERKENES DAĞ																
LATE IRON AGE																
MA-132591	02TR03U11met02	87	11.36	0.169	0.057	0.464	0.684	0.292	0.042	0.030	0.004	0.031	0.038	0.007	0.003	*b.d.*
MA-132600	10TR13U14met02	84	14.57	0.330	0.010	0.044	0.002	0.419	0.015	0.040	0.006	0.086	0.002	0.004	0.002	*b.d.*
MA-132620	11TR23U08met01	88	1.94	*b.d.*	9.07	0.135	*b.d.*	0.033	0.115	0.093	0.054	0.031	0.031	0.002	*b.d.*	*b.d.*
MA-132601	11TR23U11met01	68	16.99	0.032	12.31	0.065	*b.d.*	0.236	1.003	0.834	0.107	0.077	0.118	0.077	*b.d.*	0.013
MA-132607	11TR23U12met01	91	7.18	0.127	0.296	0.612	0.006	0.242	0.026	0.026	0.004	0.051	0.019	0.004	0.003	*b.d.*
MA-132597	11TR23U21met01	74	24.66	0.132	0.020	0.019	0.061	1.32	0.062	0.019	0.006	0.095	*b.d.*	0.004	*b.d.*	0.001
MA-132594	11TR23U22met01	79	17.96	0.780	0.962	0.036	0.004	0.480	0.073	0.238	0.041	0.183	0.019	*b.d.*	0.003	0.004
MA-132629	11TR24U11met01	55	37.97	0.002	5.30	0.172	0.063	1.24	0.075	0.001	0.015	0.007	*b.d.*	*b.d.*	0.001	0.002
MA-132631	11TR24U11met02	89	10.13	0.077	0.037	0.185	0.012	0.140	0.100	0.044	*b.d.*	0.003	0.024	0.010	*b.d.*	*b.d.*
MA-132626	11TR24U11met03	95	4.42	0.091	0.056	0.090	0.022	0.190	0.007	0.016	0.003	0.014	0.002	0.001	0.002	*b.d.*
MA-132615	11TR24U11met03	76	21.60	0.471	0.498	0.008	*b.d.*	0.531	0.031	0.395	0.041	0.245	0.006	0.008	0.003	*b.d.*
MA-133069	11TR24U11met04	30	63.55	0.680	5.05	0.005	*b.d.*	0.705	0.001	0.184	0.035	0.261	0.007	0.009	0.002	0.007

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%	Te wt.%	Se wt.%	Mn wt.%
MA-132593	11TR24U11met05	92	7.10	0.050	0.228	0.314	0.005	0.229	*b.d.*	0.015	0.001	0.039	0.001	0.001	0.002	*b.d.*
MA-132608	11TR24U15met01	91	8.55	0.153	0.196	0.212	0.005	0.217	0.038	0.047	0.008	0.049	0.016	0.003	0.011	*b.d.*
MA-132612	11TR24U17met01	95	3.75	0.298	0.333	0.094	0.008	0.332	0.244	0.176	0.012	0.043	0.034	0.009	*b.d.*	*b.d.*
MA-132624	11TR24U20met01	94	3.88	0.036	0.379	0.721	0.013	0.544	0.240	0.079	0.001	0.018	0.038	*b.d.*	0.008	0.001
MA-132606	11TR24U21met01	90	8.83	0.149	0.118	0.181	0.006	0.598	0.090	0.063	0.009	0.056	0.011	0.003	0.001	*b.d.*
MA-132613	11TR24U21met02	68	3.54	1.77	6.04	0.035	0.020	19.34	0.559	0.191	0.060	0.042	0.024	0.004	*b.d.*	0.152
MA-132619	11TR24U22met03	92	7.35	0.175	0.288	0.113	0.004	0.193	0.127	0.061	0.001	0.033	0.024	*b.d.*	0.006	*b.d.*
MA-132622	11TR24U22met04	91	8.19	0.043	0.104	0.057	0.102	0.204	0.212	0.054	0.005	0.025	0.043	*b.d.*	0.004	0.002
MA-132614	11TR24U22met06	82	17.02	0.115	0.829	0.023	0.008	0.064	0.073	0.059	0.011	0.039	0.006	0.006	0.005	*b.d.*
MA-132605	11TR24U22met07	82	16.68	0.204	1.17	0.036	0.001	0.138	0.063	0.049	0.020	0.057	0.009	0.005	0.004	*b.d.*
MA-132596	11TR24U22met08	73	23.82	0.128	2.41	0.027	0.006	0.153	0.147	0.080	0.020	0.100	0.032	*b.d.*	0.002	0.006
MA-132625	00CT18U17met01	89	10.37	0.088	0.220	0.103	0.001	0.046	0.089	0.100	0.007	0.036	0.012	0.004	0.007	*b.d.*
MA-132604	00CT18U17met02	88	11.07	0.090	0.133	0.067	*b.d.*	0.025	0.029	0.093	0.009	0.058	0.008	0.025	0.007	*b.d.*
MA-132630	02TR01U02met01	90	9.99	0.053	0.008	0.025	*b.d.*	0.060	0.002	0.009	0.003	0.004	0.003	0.003	0.003	*b.d.*
MA-132628	02TR01U02met02	90	9.10	0.068	0.025	0.030	*b.d.*	0.104	0.132	0.070	0.007	0.007	0.059	0.010	0.010	*b.d.*
	02TR01U07met01	63	27.16	*b.d.*	3.20	0.105	*b.d.*	1.01	5.502	0.028	0.020	0.046	0.198	*b.d.*	0.010	0.007
MA-132599	04TR11U14met01	90	9.64	0.066	0.011	0.011	0.025	0.355	*b.d.*	0.045	0.011	0.092	0.019	0.023	0.000	*b.d.*
MA-132598	04TR15U01met01	89	10.40	0.061	0.022	0.010	0.029	0.203	*b.d.*	0.005	0.014	0.094	0.018	*b.d.*	0.001	0.003
	05TR21U09met03	99	0.012	0.058	0.071	0.121	0.059	0.015	0.116	0.005	0.010	0.010	0.022	*b.d.*	0.002	*b.d.*
MA-132611	04TT25U08met01	87	12.41	0.117	0.020	0.502	*b.d.*	0.257	*b.d.*	0.006	0.009	0.044	0.021	0.037	0.006	0.006
MA-132609	04TT25U08met02	86	12.62	0.132	0.026	0.489	*b.d.*	0.258	0.007	0.019	0.009	0.047	0.009	0.019	0.001	*b.d.*
MA-132595	07TT31U04met01	84	14.25	0.297	1.57	0.045	0.000	0.012	0.002	0.069	0.022	0.105	0.013	0.032	0.001	0.004
MA-132623	11TR29U14met02	89	9.68	0.120	0.070	0.710	0.037	0.227	0.159	0.030	0.003	0.020	0.048	*b.d.*	0.008	0.001
MA-132618	11TR29U32met01	88	1.73	0.090	10.20	0.024	*b.d.*	0.024	0.090	0.143	0.029	0.034	*b.d.*	0.004	0.001	0.003
MA-132621	11TR29U34met02	87	10.33	0.023	0.034	0.397	0.014	2.38	0.067	0.012	0.003	0.025	0.014	0.002	0.004	0.007
MA-132617	11TR29U34met03	84	14.38	0.174	0.102	0.255	0.075	0.648	0.152	0.096	0.009	0.035	0.023	0.008	0.005	0.001
MA-132616	96TT15U13met05	89	10.11	0.175	0.151	0.018	0.007	0.213	*b.d.*	0.035	0.005	0.036	0.014	0.015	*b.d.*	0.009
MA-132602	97TT15U00met01	90	8.27	0.540	0.366	0.024	*b.d.*	0.480	0.003	0.063	0.004	0.050	0.001	*b.d.*	*b.d.*	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%	Te wt.%	Se wt.%	Mn wt.%
MA-132603	98TT21U01met02	89	9.17	0.803	0.442	0.016	*b.d.*	0.332	0.006	0.088	0.004	0.067	0.008	0.005	0.001	*b.d.*

APPENDIX C: pXRF RESULTS

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
BOĞAZKÖY													
EARLY BRONZE AGE													
	Bo 96/38	96	*b.d.*	1.37	0.59	*b.d.*	*b.d.*	2.08	0.14	0.06	*b.d.*	0.09	*b.d.*
	Bo 97/98	99	*b.d.*	0.04	0.01	0.02	*b.d.*	0.09	0.56	0.02	0.01	0.06	*b.d.*
	ETD 97/196	93	0.40	3.21	1.51	0.04	*b.d.*	1.45	0.05	0.04	0.02	0.04	*b.d.*
	ETD 97/206	97	*b.d.*	1.27	0.18	*b.d.*	*b.d.*	1.12	*b.d.*	0.03	0.01	0.04	*b.d.*
	ETD 97/213	98	0.02	1.20	0.07	0.04	*b.d.*	0.73	0.07	0.04	*b.d.*	0.03	*b.d.*
	ETD 97/219	96	*b.d.*	3.01	0.18	*b.d.*	*b.d.*	0.63	*b.d.*	0.04	*b.d.*	0.04	*b.d.*
	ETD 97/221	97	0.44	0.90	0.15	0.04	0.01	0.58	*b.d.*	0.02	*b.d.*	0.42	*b.d.*
	ETD 98/12	95	0.39	3.98	0.06	*b.d.*	*b.d.*	0.62	*b.d.*	0.05	*b.d.*	0.02	*b.d.*
MIDDLE BRONZE AGE													
	Bo 13/445	97	0.09	1.89	0.10	0.08	0.04	0.58	*b.d.*	0.05	0.02	0.14	*b.d.*
	Bo 13/450	99	*b.d.*	0.26	0.11	0.07	0.02	0.65	0.10	*b.d.*	*b.d.*	0.11	*b.d.*
	Bo 13/458	95	0.17	3.54	0.44	0.36	0.04	0.39	0.08	0.03	0.02	0.15	*b.d.*
	Bo 13/459	98	*b.d.*	0.68	0.16	0.07	*b.d.*	0.41	0.14	0.08	0.01	0.13	*b.d.*
	Bo 13/462	95	0.06	2.79	1.00	0.08	*b.d.*	0.54	*b.d.*	0.16	0.32	0.31	*b.d.*
	Bo 13/463	99	*b.d.*	0.36	0.06	0.05	*b.d.*	0.17	0.12	*b.d.*	*b.d.*	0.15	*b.d.*
	Bo 13/564	97	0.06	2.04	0.57	0.10	*b.d.*	0.21	0.08	0.03	*b.d.*	0.23	*b.d.*
	Bo 13/569	99	0.04	0.39	0.11	*b.d.*	*b.d.*	0.35	0.07	*b.d.*	0.04	0.15	*b.d.*
	Bo 13/631	99	*b.d.*	0.33	*b.d.*	*b.d.*	*b.d.*	0.01	0.05	0.02	*b.d.*	0.13	*b.d.*
	Bo 13/668	99	*b.d.*	0.44	0.10	0.04	*b.d.*	0.37	0.08	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 13/670	98	0.11	0.82	0.27	0.04	*b.d.*	0.41	0.05	0.01	0.01	0.03	*b.d.*
MA-132546	Bo 143/l	97	0.02	1.98	0.04	0.04	*b.d.*	0.92	0.05	0.02	*b.d.*	*b.d.*	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
MA-132557	Bo 348/h	98	0.02	0.26	0.42	0.02	*b.d.*	1.38	0.22	*b.d.*	*b.d.*	0.01	*b.d.*
MA-132556	Bo 311/s	98	0.03	1.29	0.03	0.02	0.01	0.72	0.14	*b.d.*	*b.d.*	0.02	*b.d.*
MA-132558	Bo 400/s	98	*b.d.*	1.44	0.08	0.02	*b.d.*	0.41	0.09	*b.d.*	*b.d.*	0.02	*b.d.*
LATE BRONZE AGE													
MA-136322	Boehmer 1972: Nr. 190	98	0.04	0.07	0.09	1.52	0.03	0.07	0.25	0.01	0.00	0.03	*b.d.*
	Bo 94/1	88	*b.d.*	0.24	0.01	11.1	0.40	0.74	*b.d.*	*b.d.*	0.00	*b.d.*	*b.d.*
	Bo 94/109	83	*b.d.*	1.58	0.04	12.5	0.80	1.95	*b.d.*	0.06	0.01	0.02	*b.d.*
	Bo 94/113	98	0.04	1.07	0.14	0.03	*b.d.*	0.60	0.12	0.03	*b.d.*	0.03	*b.d.*
	Bo 94/116	98	*b.d.*	1.27	0.10	0.07	*b.d.*	0.42	0.06	0.07	0.03	0.07	*b.d.*
	Bo 94/14	98	*b.d.*	1.56	0.16	0.02	*b.d.*	0.20	0.07	0.02	*b.d.*	0.02	*b.d.*
	Bo 94/141	97	0.09	0.77	0.05	0.18	*b.d.*	1.33	0.13	0.07	0.01	0.13	*b.d.*
	Bo 94/20	97	0.04	1.54	0.11	0.07	0.02	0.67	0.16	0.07	0.01	0.13	*b.d.*
	Bo 94/21	87	10.9	0.18	1.54	*b.d.*	*b.d.*	0.51	0.16	0.05	*b.d.*	0.05	*b.d.*
	Bo 94/28	73	24.2	0.12	1.05	*b.d.*	*b.d.*	0.95	0.16	0.03	*b.d.*	0.07	*b.d.*
	Bo 94/36	69	25.6	1.24	0.27	0.07	0.06	2.94	0.32	0.54	*b.d.*	0.10	*b.d.*
	Bo 94/37	73	25.1	0.64	0.40	0.12	*b.d.*	0.47	0.24	0.06	*b.d.*	0.10	*b.d.*
	Bo 94/4	98	0.06	0.58	0.03	0.25	0.02	0.72	0.05	*b.d.*	0.01	0.02	*b.d.*
	Bo 94/40	92	0.21	2.54	2.28	*b.d.*	*b.d.*	2.13	0.19	0.23	0.42	0.30	0.04
	Bo 94/57	92	6.35	0.59	0.16	0.04	0.02	0.44	0.14	0.08	*b.d.*	*b.d.*	*b.d.*
	Bo 94/76	97	0.04	2.08	0.11	0.02	*b.d.*	0.20	0.10	0.05	0.02	0.03	*b.d.*
	Bo 94/9	100	*b.d.*	0.11	*b.d.*	0.05	0.01	0.12	0.07	*b.d.*	0.00	*b.d.*	*b.d.*
	Bo 95/100	95	2.86	0.95	0.28	0.02	*b.d.*	0.69	0.12	0.09	*b.d.*	0.01	*b.d.*
	Bo 95/111	82	16.9	0.37	0.07	0.08	0.05	0.69	0.07	0.04	*b.d.*	0.02	*b.d.*
	Bo 95/113	85	0.12	0.75	0.06	9.76	0.44	3.95	*b.d.*	0.06	0.02	0.05	*b.d.*
	Bo 95/119	94	2.39	1.69	0.05	0.04	0.06	1.20	0.14	0.03	*b.d.*	0.03	*b.d.*
	Bo 95/25	86	11.6	0.96	0.12	0.02	0.01	1.03	0.17	0.02	*b.d.*	0.03	*b.d.*
	Bo 95/27	95	*b.d.*	3.19	0.28	0.97	*b.d.*	0.68	0.15	0.06	0.03	0.08	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 95/41	85	13.9	0.63	0.21	0.04	*b.d.*	0.48	0.14	0.02	*b.d.*	0.12	*b.d.*
	Bo 95/76	98	*b.d.*	0.18	0.03	0.31	0.03	0.79	*b.d.*	0.12	0.01	0.13	*b.d.*
	Bo 95/80	85	0.04	6.11	0.89	6.59	0.05	0.27	0.10	0.10	0.03	0.35	*b.d.*
	Bo 95/82	97	0.10	0.90	0.57	0.09	*b.d.*	0.75	0.08	0.04	0.05	0.07	*b.d.*
	Bo 95/95	82	15.4	0.79	0.57	0.30	0.02	0.39	0.16	0.06	*b.d.*	0.14	0.35
	Bo 96/120	95	1.68	1.65	0.39	*b.d.*	*b.d.*	1.05	0.30	0.03	*b.d.*	0.03	*b.d.*
	Bo 96/34	95	2.68	0.91	0.32	0.85	*b.d.*	0.53	*b.d.*	0.04	0.01	*b.d.*	*b.d.*
	Bo 96/36	89	8.95	0.76	0.30	0.14	0.02	1.06	0.08	0.10	*b.d.*	0.03	*b.d.*
	Bo 96/48	66	29.7	1.43	0.85	0.35	*b.d.*	1.61	0.10	0.11	0.02	0.11	*b.d.*
	Bo 97/101	94	*b.d.*	4.57	0.20	0.09	0.03	1.01	0.06	0.06	*b.d.*	0.05	*b.d.*
	Bo 97/102	87	0.23	0.97	0.10	11.1	0.10	0.12	*b.d.*	0.05	0.01	0.04	*b.d.*
	Bo 97/16	72	25.8	0.53	0.61	0.04	*b.d.*	0.62	0.15	0.05	*b.d.*	0.13	*b.d.*
	Bo 97/18	94	0.10	3.98	0.48	*b.d.*	*b.d.*	0.84	0.11	0.09	0.04	0.05	*b.d.*
	Bo 97/19	97	0.62	1.25	0.25	0.03	*b.d.*	0.33	*b.d.*	0.08	0.02	0.09	*b.d.*
	Bo 97/23	95	0.17	3.59	0.11	0.10	*b.d.*	0.51	0.08	0.20	0.01	0.04	*b.d.*
	Bo 97/24	94	*b.d.*	3.56	1.02	0.07	*b.d.*	0.77	0.11	0.06	*b.d.*	0.03	*b.d.*
	Bo 97/27	96	0.31	1.06	1.45	0.04	0.01	0.47	0.05	0.03	0.02	0.07	*b.d.*
	Bo 97/33	86	*b.d.*	0.45	0.03	8.71	0.83	3.54	*b.d.*	0.02	*b.d.*	0.02	*b.d.*
	Bo 97/37	97	0.21	*b.d.*	0.17	0.19	*b.d.*	2.48	0.11	0.02	0.01	*b.d.*	*b.d.*
	Bo 98/13	97	0.06	0.93	0.14	*b.d.*	*b.d.*	1.49	0.12	0.06	0.11	0.04	*b.d.*
	ETD 94/127	81	0.12	0.19	0.02	14.0	2.53	2.41	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 94/191	88	10.2	0.53	0.51	*b.d.*	*b.d.*	0.53	*b.d.*	0.05	0.02	0.04	*b.d.*
	ETD 94/192	100	*b.d.*	0.02	0.02	*b.d.*	*b.d.*	0.14	0.08	*b.d.*	0.02	0.03	*b.d.*
	ETD 94/198	97	0.07	1.27	0.25	0.38	*b.d.*	0.31	0.14	0.08	0.01	0.02	*b.d.*
	ETD 94/215	85	0.03	0.11	0.10	12.0	1.59	1.42	*b.d.*	*b.d.*	0.01	0.02	*b.d.*
	ETD 94/217	83	*b.d.*	0.14	0.02	15.2	0.87	0.40	*b.d.*	0.01	*b.d.*	0.02	*b.d.*
	ETD 94/234	98	0.21	1.25	0.20	0.02	*b.d.*	0.40	*b.d.*	0.09	0.02	0.19	*b.d.*
	ETD 94/246	97	0.27	1.23	0.09	0.28	0.03	0.46	0.08	0.06	0.01	*b.d.*	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	ETD 94/248	99	0.09	0.50	0.03	0.07	0.01	0.37	0.06	*b.d.*	*b.d.*	0.02	*b.d.*
	ETD 94/263	99	*b.d.*	0.24	0.34	0.03	*b.d.*	0.73	0.04	0.02	0.01	0.02	*b.d.*
	ETD 94/356	79	19.1	0.45	0.28	*b.d.*	*b.d.*	0.80	0.07	0.11	*b.d.*	*b.d.*	*b.d.*
	ETD 94/4	91	4.49	2.29	0.23	0.09	0.02	1.79	0.10	0.11	*b.d.*	0.03	*b.d.*
	ETD 94/460	68	31.1	0.59	0.15	0.07	*b.d.*	0.33	0.09	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 94/471	84	15.1	0.37	0.09	0.02	*b.d.*	0.43	0.05	0.02	*b.d.*	*b.d.*	*b.d.*
	ETD 94/479a	98	*b.d.*	1.43	0.04	*b.d.*	*b.d.*	0.84	*b.d.*	0.05	0.02	0.06	*b.d.*
	ETD 94/479b	80	17.8	0.44	0.36	0.05	*b.d.*	0.76	0.14	0.06	*b.d.*	*b.d.*	*b.d.*
	ETD 94/481	98	0.02	1.22	0.10	0.12	0.01	0.46	0.10	0.05	0.01	0.03	*b.d.*
	ETD 94/482	96	0.10	3.38	0.06	0.21	*b.d.*	0.34	0.11	0.06	0.02	0.03	*b.d.*
	ETD 94/486	98	0.04	0.74	0.04	0.18	0.06	1.06	0.17	0.01	0.00	0.04	*b.d.*
	ETD 94/6	90	8.94	0.55	0.08	0.13	*b.d.*	0.37	0.07	0.03	*b.d.*	0.05	*b.d.*
	ETD 94/7	97	0.05	1.61	0.55	*b.d.*	*b.d.*	0.73	0.06	0.04	0.01	*b.d.*	*b.d.*
	ETD 95/212a	83	14.7	1.15	0.05	0.04	0.06	0.54	0.08	0.02	*b.d.*	*b.d.*	*b.d.*
	ETD 95/212b	92	4.42	0.62	0.22	0.14	*b.d.*	2.51	0.10	0.02	*b.d.*	*b.d.*	*b.d.*
	ETD 95/228A	95	*b.d.*	1.50	1.48	0.05	0.02	1.52	0.13	0.05	0.14	0.12	*b.d.*
	ETD 95/228B	88	11.0	0.35	*b.d.*	*b.d.*	*b.d.*	0.29	0.07	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 95/228C	87	11.9	0.52	0.12	0.06	0.02	0.29	0.08	0.03	*b.d.*	0.07	*b.d.*
	ETD 95/228D	99	0.11	0.64	0.06	0.03	*b.d.*	0.17	0.08	0.04	0.10	0.06	*b.d.*
MA-136329	ETD 95/231	83	*b.d.*	0.60	0.03	12.1	0.54	3.20	*b.d.*	0.02	0.01	0.04	*b.d.*
	ETD 95/232	98	0.04	1.02	0.04	0.11	*b.d.*	0.37	0.07	0.07	*b.d.*	0.02	*b.d.*
	ETD 95/262	87	11.2	1.07	0.22	0.12	*b.d.*	0.36	0.14	0.07	*b.d.*	0.01	*b.d.*
	ETD 95/269	98	0.04	0.86	0.24	0.07	*b.d.*	0.60	0.09	0.13	0.05	0.06	*b.d.*
	ETD 95/272	91	7.21	0.47	0.97	0.04	*b.d.*	0.22	0.09	0.02	*b.d.*	0.04	*b.d.*
	ETD 95/283	95	*b.d.*	2.53	0.71	0.13	*b.d.*	1.33	0.08	0.03	0.01	0.03	*b.d.*
	ETD 95/284A	90	0.86	0.21	0.05	6.29	0.97	0.81	0.06	0.02	0.01	0.59	0.09
	ETD 95/284B	79	19.4	0.41	0.32	0.17	0.01	0.17	0.15	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 95/83	95	0.09	2.64	1.29	0.05	*b.d.*	0.37	0.05	0.13	0.02	0.05	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	ETD 96/32	96	0.33	0.06	0.05	0.03	*b.d.*	3.10	0.16	*b.d.*	*b.d.*	0.01	*b.d.*
	ETD 96/33	99	0.04	0.59	0.07	*b.d.*	*b.d.*	0.18	0.05	0.27	0.01	*b.d.*	*b.d.*
	ETD 96/34	98	0.04	0.60	0.02	0.40	0.05	0.61	*b.d.*	0.04	*b.d.*	*b.d.*	*b.d.*
	ETD 96/35	97	1.48	0.88	0.36	0.02	*b.d.*	0.66	0.05	0.04	*b.d.*	*b.d.*	*b.d.*
	ETD 96/36	98	0.09	1.20	0.12	*b.d.*	*b.d.*	0.42	0.05	0.05	0.04	0.06	*b.d.*
	ETD 96/37	99	*b.d.*	0.55	0.04	0.03	*b.d.*	0.18	0.04	0.08	0.01	0.04	*b.d.*
	ETD 96/41	99	*b.d.*	0.63	0.03	0.07	*b.d.*	0.16	0.18	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 96/42	99	0.80	0.29	0.02	*b.d.*	*b.d.*	0.21	*b.d.*	*b.d.*	0.01	*b.d.*	*b.d.*
	ETD 96/43	85	11.5	1.62	0.44	0.03	*b.d.*	0.77	*b.d.*	0.24	*b.d.*	0.05	*b.d.*
	ETD 96/45	97	0.07	1.48	0.19	0.28	*b.d.*	0.42	*b.d.*	0.18	0.01	0.03	*b.d.*
	ETD 96/54	99	0.05	0.60	0.02	0.01	*b.d.*	0.32	*b.d.*	0.04	*b.d.*	0.06	*b.d.*
	ETD 96/62	99	0.03	0.72	0.07	0.15	*b.d.*	0.26	0.08	0.04	0.01	0.01	*b.d.*
	ETD 97/212	97	0.60	1.43	0.33	0.03	*b.d.*	0.46	0.08	0.09	0.05	0.07	*b.d.*
	ETD 97/218	98	*b.d.*	1.34	0.23	0.03	*b.d.*	0.75	*b.d.*	0.01	0.01	0.04	*b.d.*
	ETD 97/229	98	*b.d.*	1.02	0.06	0.04	*b.d.*	0.37	*b.d.*	0.45	*b.d.*	0.13	*b.d.*
	ETD 97/233	97	*b.d.*	2.30	0.05	0.02	*b.d.*	0.23	0.04	0.08	0.02	0.16	*b.d.*
	ETD 97/240	95	0.08	3.61	0.44	0.03	*b.d.*	0.51	0.14	0.27	0.02	0.03	*b.d.*
	ETD 97/241	96	*b.d.*	2.52	0.43	0.91	0.09	0.21	0.08	0.03	*b.d.*	*b.d.*	*b.d.*
	ETD 97/242	82	15.8	0.73	0.97	0.05	0.01	0.13	0.10	0.11	*b.d.*	*b.d.*	*b.d.*
	ETD 97/243	98	0.07	0.81	0.16	0.03	*b.d.*	0.45	0.14	0.07	*b.d.*	0.05	*b.d.*
	ETD 97/246	98	*b.d.*	0.86	0.47	*b.d.*	*b.d.*	0.16	0.14	0.08	0.07	0.11	*b.d.*
	ETD 97/251	87	11.1	0.72	0.18	0.07	*b.d.*	0.60	0.06	0.04	*b.d.*	0.01	*b.d.*
	ETD 97/255	95	*b.d.*	2.17	0.12	0.03	0.02	2.07	0.08	0.14	0.01	0.03	*b.d.*
	ETD 97/256	98	0.10	1.49	0.08	*b.d.*	*b.d.*	0.35	*b.d.*	0.06	*b.d.*	0.06	*b.d.*
	ETD 97/257	94	0.14	4.17	0.46	0.13	*b.d.*	0.74	*b.d.*	0.02	*b.d.*	0.04	*b.d.*
	ETD 97/268	94	0.62	3.60	0.77	0.03	*b.d.*	0.72	0.08	0.06	0.01	0.05	*b.d.*
	ETD 98/06	88	10.3	0.65	0.08	*b.d.*	0.07	0.16	0.18	0.02	*b.d.*	0.14	*b.d.*
	ETD 98/07	92	3.93	0.12	0.51	3.37	0.07	0.43	*b.d.*	0.02	*b.d.*	0.03	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	ETD 98/09	97	0.02	1.83	0.16	0.04	*b.d.*	0.36	0.12	0.13	0.05	0.08	*b.d.*
	ETD 98/11	98	*b.d.*	0.90	0.49	0.04	*b.d.*	0.23	0.08	0.08	0.03	0.06	*b.d.*
	ETD 98/13	98	0.80	0.75	0.25	0.05	*b.d.*	0.13	*b.d.*	0.13	*b.d.*	0.02	*b.d.*
	ETD 98/16	98	0.06	1.16	0.14	0.05	*b.d.*	0.18	*b.d.*	0.02	*b.d.*	0.02	*b.d.*
	ETD 98/18	98	0.06	0.74	0.03	0.02	*b.d.*	0.59	*b.d.*	0.17	0.03	0.07	*b.d.*
MA-136321	ETD 98/21	77	*b.d.*	22.1	0.37	0.30	0.01	0.11	*b.d.*	0.12	0.01	0.02	*b.d.*
	ETD 98/22	98	*b.d.*	0.89	0.22	*b.d.*	*b.d.*	0.43	*b.d.*	0.03	*b.d.*	0.05	*b.d.*
	ETD 98/23	96	0.20	2.78	0.84	0.02	*b.d.*	0.42	*b.d.*	0.14	0.02	0.07	*b.d.*
	Bo 13/125	94	2.76	1.60	0.09	0.75	0.02	0.31	0.05	0.09	*b.d.*	0.17	*b.d.*
	Bo 13/655	98	0.20	0.91	0.12	0.07	*b.d.*	0.32	0.08	0.07	0.04	0.18	*b.d.*
	Bo 13/803	89	10.7	*b.d.*	0.01	*b.d.*	*b.d.*	0.47	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 09/780	96	0.73	*b.d.*	2.73	*b.d.*	*b.d.*	0.04	0.11	*b.d.*	0.29	0.15	*b.d.*
	Bo 09/1057	97	0.09	0.93	0.25	0.03	*b.d.*	1.30	0.18	0.04	*b.d.*	0.04	*b.d.*
	Bo 09/1063	99	0.05	0.30	0.03	0.11	*b.d.*	0.20	0.09	0.05	*b.d.*	*b.d.*	*b.d.*
	Bo 09/1074	99	*b.d.*	0.53	0.10	0.12	0.01	0.37	0.21	0.03	0.01	0.11	*b.d.*
MA-136336	Bo 09/1095	99	0.03	0.04	0.04	0.08	0.08	0.32	0.03	*b.d.*	0.00	0.03	*b.d.*
	Bo 09/1131	99	*b.d.*	0.33	0.07	0.02	0.02	0.45	0.06	0.06	0.01	0.05	*b.d.*
	Bo 09/1177	99	0.08	0.68	0.08	0.10	*b.d.*	0.40	*b.d.*	0.03	0.02	0.04	*b.d.*
	Bo 09/118	83	15.2	0.89	0.12	0.09	*b.d.*	0.20	0.16	0.06	*b.d.*	0.01	*b.d.*
	Bo 09/121	99	0.09	0.47	0.28	0.03	*b.d.*	0.24	0.10	*b.d.*	0.02	0.10	*b.d.*
	Bo 09/125	98	*b.d.*	1.16	0.04	0.03	*b.d.*	0.96	0.07	0.04	0.01	0.03	*b.d.*
	Bo 09/140	99	*b.d.*	0.97	0.05	0.03	0.01	0.28	0.05	0.05	*b.d.*	0.03	*b.d.*
	Bo 09/148	98	0.19	1.13	0.05	0.10	*b.d.*	0.76	*b.d.*	0.07	*b.d.*	*b.d.*	*b.d.*
	Bo 09/150	99	*b.d.*	0.35	0.02	0.04	0.04	0.12	0.04	0.03	0.01	*b.d.*	*b.d.*
	Bo 09/156	84	14.7	0.51	0.30	0.04	0.01	0.36	0.04	0.01	*b.d.*	0.03	*b.d.*
	Bo 09/194	97	0.07	1.10	0.13	0.16	*b.d.*	1.18	0.06	0.07	0.02	0.06	*b.d.*
	Bo 09/198	95	*b.d.*	2.58	0.09	0.44	0.02	1.95	0.05	0.08	*b.d.*	0.03	*b.d.*
	Bo 09/211	99	*b.d.*	0.33	*b.d.*	0.18	*b.d.*	0.17	0.04	0.02	*b.d.*	0.02	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 09/212	89	9.56	0.66	0.41	0.04	0.02	0.42	0.07	0.03	*b.d.*	*b.d.*	*b.d.*
	Bo 09/274	96	0.05	2.58	0.02	0.04	*b.d.*	1.34	0.05	0.05	0.01	0.02	0.05
	Bo 09/278	83	15.8	0.78	0.21	0.12	*b.d.*	0.27	0.06	0.09	*b.d.*	*b.d.*	*b.d.*
	Bo 09/282	79	18.8	0.92	0.48	0.13	*b.d.*	0.20	*b.d.*	0.12	*b.d.*	0.03	*b.d.*
	Bo 09/283	95	0.04	2.70	0.31	0.16	*b.d.*	1.58	0.05	0.08	*b.d.*	0.04	*b.d.*
	Bo 09/284	99	0.20	0.43	0.03	0.04	0.01	0.39	0.10	0.05	0.01	0.02	*b.d.*
	Bo 09/285	98	0.14	0.62	0.05	0.02	*b.d.*	0.89	0.10	0.11	0.05	0.07	*b.d.*
	Bo 09/293	98	0.34	0.60	0.34	0.41	0.01	0.27	*b.d.*	0.07	0.02	0.03	*b.d.*
	Bo 09/298	92	0.12	1.11	0.37	2.52	0.05	4.04	*b.d.*	0.11	0.05	0.09	*b.d.*
	Bo 09/321	98	0.39	0.77	0.15	0.06	*b.d.*	0.11	0.08	0.12	0.04	0.08	*b.d.*
	Bo 09/322	94	*b.d.*	4.00	0.41	0.11	0.04	1.05	*b.d.*	0.04	0.01	0.02	*b.d.*
	Bo 09/324	98	*b.d.*	0.93	0.64	*b.d.*	*b.d.*	0.56	*b.d.*	0.05	0.08	0.13	*b.d.*
	Bo 09/325	96	1.47	0.90	0.41	0.10	0.02	0.47	0.09	0.14	0.03	0.02	*b.d.*
	Bo 09/351	86	12.5	0.79	0.23	0.13	0.01	0.06	0.04	0.06	0.03	0.02	*b.d.*
MA-136326	Bo 09/355	91	0.05	0.58	0.02	7.12	0.23	1.01	*b.d.*	0.04	0.01	0.03	*b.d.*
	Bo 09/376	98	0.50	0.94	0.22	0.04	*b.d.*	0.17	*b.d.*	0.10	0.02	0.04	*b.d.*
	Bo 09/377	98	0.11	0.86	0.09	0.09	0.01	0.40	*b.d.*	0.04	*b.d.*	0.03	*b.d.*
	Bo 09/378	96	0.03	1.71	0.35	0.03	*b.d.*	1.06	0.05	0.77	0.01	0.04	*b.d.*
	Bo 09/398	96	0.05	1.91	0.47	*b.d.*	*b.d.*	1.69	0.06	0.03	*b.d.*	0.06	*b.d.*
	Bo 09/400	98	*b.d.*	0.81	0.16	0.34	0.03	0.51	*b.d.*	0.04	0.01	0.03	*b.d.*
	Bo 09/404	80	15.5	0.71	1.43	0.03	*b.d.*	1.98	*b.d.*	*b.d.*	*b.d.*	0.11	*b.d.*
	Bo 09/405	95	*b.d.*	1.41	0.90	0.06	*b.d.*	2.21	0.14	0.09	0.02	0.10	0.03
	Bo 09/420	98	*b.d.*	0.66	0.75	0.11	0.01	0.58	0.09	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 09/457	97	0.06	2.46	0.55	0.02	0.01	0.21	0.03	0.07	0.01	0.05	*b.d.*
	Bo 09/461	98	*b.d.*	0.82	0.37	0.10	*b.d.*	0.56	0.17	*b.d.*	*b.d.*	0.02	*b.d.*
	Bo 09/484	96	0.04	1.30	1.40	0.04	*b.d.*	0.71	0.16	0.09	0.04	0.07	*b.d.*
	Bo 09/499	84	13.9	1.12	0.51	0.03	*b.d.*	0.22	0.04	*b.d.*	*b.d.*	0.02	*b.d.*
	Bo 09/503	98	0.16	0.94	0.25	0.02	*b.d.*	0.68	*b.d.*	0.02	0.01	0.03	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 09/504	84	14.0	0.65	0.16	0.06	0.03	0.47	0.12	0.13	*b.d.*	*b.d.*	*b.d.*
	Bo 09/511	93	0.20	0.84	0.32	5.02	0.08	0.68	*b.d.*	0.09	0.07	0.06	*b.d.*
	Bo 09/53	98	0.26	0.76	0.09	0.02	*b.d.*	0.25	0.13	0.05	0.01	*b.d.*	*b.d.*
	Bo 09/583	96	0.73	1.81	0.16	0.04	*b.d.*	0.96	0.14	0.33	0.04	0.07	*b.d.*
	Bo 09/656	94	0.04	3.05	0.13	0.93	0.02	1.31	*b.d.*	0.05	0.01	0.10	*b.d.*
	Bo 09/660	97	0.22	1.27	0.71	*b.d.*	*b.d.*	0.53	0.05	0.11	0.18	0.10	*b.d.*
	Bo 09/686	98	1.43	0.35	0.04	*b.d.*	*b.d.*	0.44	0.11	0.04	*b.d.*	*b.d.*	*b.d.*
	Bo 09/687	90	5.86	1.75	0.38	0.04	*b.d.*	1.84	0.16	0.16	0.04	0.24	*b.d.*
	Bo 09/699	94	0.03	4.03	0.06	0.18	*b.d.*	1.12	*b.d.*	0.13	0.01	0.03	0.03
	Bo 09/715	81	16.1	1.74	0.51	0.23	0.03	0.10	0.12	0.03	*b.d.*	0.02	*b.d.*
	Bo 09/775	97	0.10	0.96	1.11	0.02	*b.d.*	0.39	0.10	0.16	0.04	0.07	*b.d.*
	Bo 09/797	93	0.19	0.69	0.05	4.86	0.09	1.11	*b.d.*	0.19	0.02	0.08	*b.d.*
	Bo 09/803	98	0.05	0.98	0.04	0.04	*b.d.*	0.20	0.13	0.11	0.06	0.09	*b.d.*
	Bo 09/811	93	3.52	1.69	0.25	0.07	*b.d.*	0.55	0.13	0.29	0.04	0.07	*b.d.*
	Bo 09/827	96	*b.d.*	0.60	2.12	0.82	0.02	0.64	0.11	0.03	0.02	0.01	*b.d.*
	Bo 09/835	98	*b.d.*	0.82	0.13	0.19	0.08	0.86	0.10	*b.d.*	*b.d.*	0.02	*b.d.*
	Bo 09/880	98	0.04	0.78	0.15	0.17	*b.d.*	0.44	0.11	0.03	*b.d.*	0.06	*b.d.*
MA-136338	Bo 09/972	69	0.50	0.18	0.01	20.8	2.34	7.20	*b.d.*	0.01	0.00	*b.d.*	*b.d.*
	Bo 09/991	98	0.25	0.44	0.34	*b.d.*	*b.d.*	0.38	0.10	0.02	*b.d.*	0.03	*b.d.*
	Bo 10/492	96	0.86	0.82	0.25	0.05	*b.d.*	1.50	0.32	0.11	0.05	0.01	*b.d.*
MA-132295	Bo 11/492	97	0.08	1.04	0.18	0.02	*b.d.*	1.91	0.06	0.02	0.08	0.04	*b.d.*
	Bo 11/535	98	*b.d.*	0.76	0.16	0.07	0.02	0.82	0.08	*b.d.*	0.01	0.02	*b.d.*
	Bo 12/06	74	22.8	1.10	0.80	0.18	0.04	0.44	0.43	0.16	*b.d.*	*b.d.*	*b.d.*
	Bo 13/304	92	6.52	0.99	0.29	0.21	0.03	0.23	0.06	0.04	*b.d.*	0.04	*b.d.*
	Bo 13/305	98	*b.d.*	0.69	0.09	0.08	*b.d.*	0.69	0.14	*b.d.*	*b.d.*	0.15	*b.d.*
	Bo 13/327	92	2.78	3.26	0.75	0.19	*b.d.*	1.01	0.07	0.08	0.02	0.15	*b.d.*
	Bo 13/328	97	0.37	0.57	0.67	0.05	*b.d.*	0.92	0.10	*b.d.*	0.21	0.32	*b.d.*
	Bo 13/340	94	*b.d.*	1.24	0.46	*b.d.*	*b.d.*	3.59	0.18	*b.d.*	*b.d.*	0.16	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 13/342	90	0.03	2.77	2.66	*b.d.*	*b.d.*	4.78	0.19	*b.d.*	*b.d.*	0.04	*b.d.*
	Bo 13/344	93	0.07	3.48	1.58	0.13	0.06	1.60	0.09	0.07	*b.d.*	0.15	*b.d.*
	Bo 13/346	82	15.6	0.58	0.85	0.09	*b.d.*	0.17	0.16	0.06	0.02	0.17	*b.d.*
	Bo 13/351	64	30.5	0.36	4.30	0.63	*b.d.*	0.34	0.18	*b.d.*	*b.d.*	0.12	*b.d.*
	Bo 13/363	97	0.13	1.46	0.31	0.08	*b.d.*	0.95	0.05	0.06	0.02	0.20	*b.d.*
	Bo 13/364	99	*b.d.*	0.04	0.02	0.03	*b.d.*	1.00	0.10	*b.d.*	0.01	0.08	*b.d.*
	Bo 13/377	98	*b.d.*	0.64	0.08	0.17	*b.d.*	0.70	0.06	0.06	0.09	0.14	*b.d.*
	Bo 13/381	87	11.3	0.84	0.46	0.08	0.02	0.25	0.07	*b.d.*	*b.d.*	0.17	*b.d.*
	Bo 13/382	98	*b.d.*	0.04	0.02	*b.d.*	*b.d.*	1.89	0.21	*b.d.*	*b.d.*	0.05	*b.d.*
	Bo 13/388	98	0.05	1.46	0.06	0.20	*b.d.*	0.09	*b.d.*	0.05	*b.d.*	0.16	*b.d.*
	Bo 13/392	97	0.07	1.57	0.10	0.19	*b.d.*	0.40	0.06	0.12	0.03	0.18	*b.d.*
	Bo 13/393	89	2.57	4.12	1.45	0.05	*b.d.*	2.34	0.12	0.29	0.02	0.12	*b.d.*
	Bo 13/396	97	0.12	1.75	0.18	0.24	*b.d.*	0.43	0.12	0.03	*b.d.*	0.17	*b.d.*
	Bo 13/398	96	1.08	1.53	0.32	0.08	*b.d.*	0.91	*b.d.*	0.11	0.03	0.16	*b.d.*
	Bo 13/403	79	20.0	0.29	0.27	*b.d.*	*b.d.*	0.56	0.10	*b.d.*	*b.d.*	0.13	*b.d.*
	Bo 13/413	94	*b.d.*	0.10	0.02	3.03	0.08	3.07	0.07	*b.d.*	*b.d.*	0.11	*b.d.*
	Bo 13/418	95	*b.d.*	0.11	0.27	*b.d.*	*b.d.*	4.66	0.17	*b.d.*	0.01	0.05	*b.d.*
	Bo 13/419	97	*b.d.*	1.54	0.56	0.04	*b.d.*	0.58	*b.d.*	0.04	0.12	0.25	*b.d.*
	Bo 13/421	97	0.15	1.59	0.14	0.21	*b.d.*	0.63	*b.d.*	0.05	*b.d.*	0.14	*b.d.*
	Bo 13/425	96	0.12	3.06	0.15	0.16	0.02	0.66	0.05	0.02	0.02	0.15	*b.d.*
	Bo 13/426	99	*b.d.*	0.11	0.30	*b.d.*	*b.d.*	0.85	0.07	*b.d.*	0.02	0.11	*b.d.*
	Bo 13/449	99	0.12	0.29	0.03	*b.d.*	*b.d.*	0.55	*b.d.*	*b.d.*	0.01	0.13	*b.d.*
	Bo 13/466	97	0.13	1.54	0.13	0.11	0.02	0.76	0.10	0.09	0.08	0.17	*b.d.*
	Bo 13/471	98	*b.d.*	0.82	0.11	0.14	0.11	0.58	0.05	*b.d.*	*b.d.*	0.14	*b.d.*
	Bo 13/472	97	0.08	0.83	0.48	0.08	0.02	0.50	0.12	0.03	0.36	0.15	*b.d.*
	Bo 13/473	97	*b.d.*	0.57	0.68	*b.d.*	*b.d.*	1.04	0.25	0.13	0.03	0.17	*b.d.*
	Bo 13/476	94	0.23	2.41	1.07	0.13	0.02	1.80	0.11	0.04	*b.d.*	0.12	*b.d.*
	Bo 13/479	98	*b.d.*	0.02	0.02	0.10	0.02	1.21	0.34	*b.d.*	0.01	0.04	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 13/488	93	*b.d.*	0.02	0.04	0.10	1.02	5.77	0.29	*b.d.*	0.02	0.02	*b.d.*
	Bo 13/492	96	0.43	2.30	0.13	0.10	0.02	0.68	0.10	0.10	0.03	0.12	*b.d.*
	Bo 13/499	97	0.23	1.46	0.10	0.21	0.05	0.46	0.05	0.06	0.02	0.16	*b.d.*
	Bo 13/500	98	0.06	1.15	0.45	0.07	0.04	0.21	0.07	0.14	0.02	0.16	*b.d.*
	Bo 13/520	99	*b.d.*	0.44	0.10	0.03	0.02	0.55	0.08	0.04	*b.d.*	0.08	*b.d.*
	Bo 13/527	98	0.05	0.48	0.05	0.06	*b.d.*	0.62	0.23	0.40	0.09	0.12	*b.d.*
	Bo 13/529	94	0.11	3.80	0.17	0.28	*b.d.*	1.23	*b.d.*	0.09	0.06	0.15	*b.d.*
	Bo 13/535	95	*b.d.*	1.06	0.74	*b.d.*	*b.d.*	2.53	0.19	*b.d.*	*b.d.*	0.12	*b.d.*
	Bo 13/538	98	*b.d.*	1.10	0.03	0.08	*b.d.*	0.33	0.17	0.04	*b.d.*	0.14	*b.d.*
	Bo 13/543	91	*b.d.*	0.01	0.61	*b.d.*	*b.d.*	8.39	0.25	*b.d.*	0.03	0.01	*b.d.*
	Bo 13/548	98	0.04	0.59	0.12	*b.d.*	*b.d.*	1.40	0.13	*b.d.*	*b.d.*	0.14	*b.d.*
	Bo 13/568	94	0.08	5.52	0.03	0.03	*b.d.*	0.03	0.08	*b.d.*	0.01	0.23	*b.d.*
	Bo 13/573	97	0.33	1.53	0.11	0.06	*b.d.*	0.28	0.10	0.11	0.01	0.18	*b.d.*
	Bo 13/585	97	*b.d.*	1.54	0.71	*b.d.*	*b.d.*	0.76	0.10	*b.d.*	0.01	0.18	*b.d.*
	Bo 13/586	94	0.07	2.99	0.71	0.11	0.03	1.46	*b.d.*	0.04	*b.d.*	0.15	*b.d.*
	Bo 13/587	82	14.9	1.00	1.29	*b.d.*	*b.d.*	0.57	0.17	*b.d.*	*b.d.*	0.17	*b.d.*
	Bo 13/589	96	*b.d.*	1.65	1.22	0.06	0.03	0.36	*b.d.*	0.05	0.03	0.19	*b.d.*
	Bo 13/591	96	0.05	1.48	0.24	0.18	*b.d.*	1.38	0.23	0.04	0.05	0.07	*b.d.*
	Bo 13/592	98	*b.d.*	0.66	0.05	0.03	*b.d.*	0.60	0.13	0.07	0.01	0.13	*b.d.*
	Bo 13/595	98	*b.d.*	0.13	0.24	0.04	*b.d.*	1.54	0.30	*b.d.*	*b.d.*	0.05	*b.d.*
	Bo 13/606	99	*b.d.*	0.28	0.02	*b.d.*	0.05	0.62	0.15	0.02	*b.d.*	0.16	*b.d.*
	Bo 13/610	97	0.04	1.46	1.10	*b.d.*	*b.d.*	0.37	0.16	0.09	0.06	0.06	*b.d.*
	Bo 13/618	94	2.00	1.00	1.18	*b.d.*	*b.d.*	1.49	0.20	0.05	*b.d.*	0.10	0.03
	Bo 13/620	92	0.32	4.18	2.25	0.10	0.02	1.14	0.15	0.09	0.02	0.22	*b.d.*
	Bo 13/622	79	18.0	0.75	1.21	0.06	*b.d.*	0.21	0.12	0.04	*b.d.*	0.15	*b.d.*
	Bo 13/623	80	18.8	0.58	0.30	*b.d.*	*b.d.*	0.14	0.20	*b.d.*	*b.d.*	0.14	*b.d.*
	Bo 13/624	94	0.06	2.67	0.17	0.19	*b.d.*	2.72	0.05	0.08	*b.d.*	0.15	*b.d.*
	Bo 13/625	82	12.0	1.73	2.96	0.06	*b.d.*	0.94	0.07	0.05	*b.d.*	0.19	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 13/626	98	*b.d.*	1.02	0.06	*b.d.*	*b.d.*	0.62	*b.d.*	0.03	0.01	0.14	*b.d.*
	Bo 13/628	72	26.4	0.07	0.06	0.04	*b.d.*	0.72	0.17	*b.d.*	*b.d.*	0.06	*b.d.*
	Bo 13/632	96	0.07	2.37	0.21	0.13	0.07	0.50	*b.d.*	0.04	*b.d.*	0.15	*b.d.*
	Bo 13/633	93	0.09	5.55	0.04	0.09	*b.d.*	0.44	0.16	0.26	0.01	0.17	*b.d.*
	Bo 13/639	97	0.03	1.76	0.18	0.04	*b.d.*	0.39	0.09	0.10	0.01	0.19	*b.d.*
	Bo 13/642	98	0.20	0.73	0.13	0.04	*b.d.*	0.20	0.06	0.20	0.09	0.16	*b.d.*
	Bo 13/643	97	*b.d.*	0.40	0.15	0.21	0.40	1.13	0.05	0.05	0.03	0.17	*b.d.*
	Bo 13/646	99	*b.d.*	0.29	0.10	0.03	*b.d.*	0.33	0.09	*b.d.*	*b.d.*	0.16	*b.d.*
	Bo 13/648	97	0.06	0.71	0.38	*b.d.*	*b.d.*	1.30	0.09	0.04	*b.d.*	0.08	*b.d.*
	Bo 13/659	98	0.07	0.60	0.03	0.03	*b.d.*	0.54	0.18	*b.d.*	*b.d.*	0.14	*b.d.*
	Bo 13/664	97	0.10	1.81	0.10	*b.d.*	*b.d.*	0.67	*b.d.*	0.11	0.02	0.15	*b.d.*
	Bo 13/677	83	0.06	0.47	0.01	12.0	0.67	3.47	*b.d.*	*b.d.*	0.01	0.02	*b.d.*
	Bo 13/678	99	*b.d.*	0.02	*b.d.*	*b.d.*	*b.d.*	1.02	0.07	0.02	0.01	*b.d.*	*b.d.*
	Bo 13/679	96	*b.d.*	0.16	0.04	1.73	0.09	1.97	0.20	*b.d.*	*b.d.*	0.04	*b.d.*
	Bo 13/680	98	0.07	1.57	0.18	0.05	*b.d.*	0.18	0.10	0.09	0.04	0.07	*b.d.*
	Bo 13/681	98	*b.d.*	0.37	0.02	*b.d.*	*b.d.*	0.42	0.78	*b.d.*	*b.d.*	0.03	*b.d.*
	Bo 13/588	91	0.07	3.51	2.51	0.18	0.02	2.54	0.16	0.07	*b.d.*	0.18	*b.d.*
MA-132286	Bo 11/4	96	0.03	2.25	0.16	0.05	*b.d.*	0.93	0.13	0.07	0.03	0.02	*b.d.*
MA-132293	Bo 11/42	77	20.4	1.01	0.28	0.12	*b.d.*	0.51	0.24	0.07	*b.d.*	0.09	*b.d.*
	Bo 11/8	95	*b.d.*	0.71	0.10	0.08	0.03	3.29	0.31	*b.d.*	0.02	0.08	*b.d.*
	Bo 13/101	95	0.15	3.63	0.09	0.20	*b.d.*	0.95	*b.d.*	0.11	0.01	0.10	*b.d.*
	Bo 13/116	99	*b.d.*	0.29	0.07	*b.d.*	*b.d.*	0.30	*b.d.*	*b.d.*	*b.d.*	0.17	*b.d.*
	Bo 13/122	95	0.06	2.60	0.35	*b.d.*	*b.d.*	1.32	*b.d.*	0.16	0.12	0.28	*b.d.*
	Bo 13/135	97	0.14	1.70	0.10	*b.d.*	*b.d.*	0.35	0.11	0.09	0.03	0.17	*b.d.*
	Bo 13/177	91	7.78	0.79	0.19	0.11	*b.d.*	0.31	0.04	0.08	*b.d.*	0.01	*b.d.*
	Bo 13/18	93	0.12	4.79	0.28	0.46	*b.d.*	1.31	*b.d.*	0.23	0.02	0.16	0.05
	Bo 13/204	82	16.2	0.06	0.14	0.49	*b.d.*	0.69	0.05	*b.d.*	*b.d.*	0.18	*b.d.*
	Bo 13/238	98	0.09	1.31	0.09	0.03	*b.d.*	0.23	*b.d.*	0.14	0.03	0.04	*b.d.*

Mannheim Number	**Object Number**	**Cu wt.%**	**Sn wt.%**	**As wt.%**	**Pb wt.%**	**Ni wt.%**	**Co wt.%**	**Fe wt.%**	**Zn wt.%**	**Sb wt.%**	**Bi wt.%**	**Ag wt.%**	**Au wt.%**
	Bo 13/39	89	0.09	1.07	0.06	4.24	0.18	5.41	0.10	0.07	0.01	0.08	*b.d.*
	Bo 13/61	95	*b.d.*	0.17	1.28	*b.d.*	*b.d.*	2.67	0.22	0.12	0.05	0.05	*b.d.*
	Bo 13/64	98	*b.d.*	0.79	0.18	0.05	*b.d.*	0.31	0.27	*b.d.*	*b.d.*	0.15	*b.d.*
	Bo 13/76	100	0.02	0.01	0.01	0.02	0.01	0.14	0.04	*b.d.*	0.00	0.13	*b.d.*
	Bo 13/82	98	*b.d.*	0.77	0.07	0.36	0.07	0.60	0.08	*b.d.*	*b.d.*	0.15	*b.d.*
	Bo 503/o	72	0.07	0.03	*b.d.*	2.68	0.23	2.82	0.61	*b.d.*	0.08	1.90	19.35
	Bo 503/o	88	0.11	0.23	*b.d.*	8.06	0.31	0.67	0.08	*b.d.*	0.10	2.45	5.45
	Bo 73/141	97	1.12	1.20	0.07	0.13	0.01	0.29	*b.d.*	0.07	0.01	0.03	0.04
	Bo 73/167	99	0.08	0.59	0.04	0.07	*b.d.*	0.38	*b.d.*	0.03	*b.d.*	0.09	*b.d.*
	Bo 74/7	97	0.43	1.57	0.14	0.14	0.01	0.41	0.08	0.07	0.02	0.06	*b.d.*
	Bo 77/146	98	0.11	0.99	0.03	0.08	*b.d.*	0.23	0.08	0.13	0.01	0.18	*b.d.*
	Bo 77/146	98	0.11	0.82	0.01	0.07	0.01	0.20	0.09	0.14	0.01	0.23	*b.d.*
	Bo 77/146	98	0.11	0.89	0.02	0.06	0.01	0.14	0.07	0.15	0.01	0.21	*b.d.*
	Bo 77/146	98	0.10	0.89	0.01	0.07	*b.d.*	0.21	0.06	0.13	0.01	0.18	*b.d.*
	Bo 77/146	98	0.12	0.96	*b.d.*	0.06	0.01	0.17	*b.d.*	0.13	*b.d.*	0.19	*b.d.*
MA-132283	Bo 11/1205	98	*b.d.*	0.34	0.01	0.02	*b.d.*	0.99	0.13	*b.d.*	*b.d.*	0.07	*b.d.*
MA-132282	Bo 11/1215	98	0.76	1.14	0.09	0.03	*b.d.*	0.15	0.12	0.11	0.01	0.07	*b.d.*
	ETD 99/54	85	0.04	0.24	0.02	14.1	0.16	0.27	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 99/55	98	*b.d.*	0.97	0.08	0.13	0.02	0.58	0.07	0.06	0.02	0.04	*b.d.*
	ETD 99/57	88	*b.d.*	0.97	0.08	8.62	0.25	2.26	*b.d.*	0.06	0.01	0.12	*b.d.*
	ETD 99/58	99	0.03	0.89	0.04	0.02	*b.d.*	0.38	*b.d.*	0.02	0.01	0.03	*b.d.*
	ETD 99/59	89	10.1	0.70	0.14	0.03	*b.d.*	0.36	0.06	0.07	*b.d.*	0.02	*b.d.*
	ETD 99/60	99	*b.d.*	0.86	0.02	0.06	0.02	0.31	*b.d.*	0.03	0.01	0.03	*b.d.*
	ETD 99/67	97	0.09	1.07	0.27	0.28	0.01	0.77	0.08	0.07	0.02	*b.d.*	*b.d.*
	ETD 99/68	98	0.08	0.80	0.05	0.02	*b.d.*	0.65	*b.d.*	0.01	0.01	0.02	*b.d.*
	ETD 99/69	98	0.04	0.72	0.11	0.11	*b.d.*	0.83	0.08	0.03	*b.d.*	0.03	*b.d.*
	ETD 99/70	96	0.07	1.32	0.54	0.07	0.01	1.14	0.06	0.36	0.03	0.03	*b.d.*
	ETD 99/71	98	*b.d.*	1.33	0.13	0.12	*b.d.*	0.26	*b.d.*	0.15	0.01	0.04	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	ETD 99/73	89	6.71	2.43	0.41	0.10	0.02	1.37	0.04	0.10	0.03	0.09	*b.d.*
	ETD 99/75	97	*b.d.*	0.66	0.11	1.40	*b.d.*	1.05	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 99/76	97	*b.d.*	1.16	0.13	0.90	0.03	0.81	*b.d.*	0.02	*b.d.*	*b.d.*	*b.d.*
	ETD 99/80	92	4.57	2.40	0.24	0.10	*b.d.*	0.39	0.05	0.14	0.01	0.05	0.03
	ETD 99/81	83	14.3	1.64	0.12	*b.d.*	*b.d.*	0.29	0.19	0.35	*b.d.*	0.08	*b.d.*
	ETD 99/82	96	0.13	2.61	0.82	0.06	*b.d.*	0.49	0.14	0.04	*b.d.*	0.06	*b.d.*
	ETD 99/83	92	4.51	1.47	0.44	*b.d.*	*b.d.*	1.33	0.26	*b.d.*	*b.d.*	0.04	*b.d.*
	ETD 99/85	87	10.9	0.51	0.22	*b.d.*	*b.d.*	0.55	0.09	0.57	*b.d.*	0.06	*b.d.*
	ETD 99/86	97	1.00	1.51	0.11	0.08	0.02	0.64	*b.d.*	0.09	*b.d.*	0.05	*b.d.*
	ETD 99/87	97	0.31	1.65	0.11	0.09	0.02	0.51	*b.d.*	0.10	0.01	0.03	*b.d.*
	ETD 99/88	82	14.6	0.46	2.28	*b.d.*	*b.d.*	0.72	*b.d.*	0.12	0.07	0.05	*b.d.*
	ETD 99/89	99	0.17	0.66	0.04	*b.d.*	*b.d.*	0.25	0.05	0.07	*b.d.*	*b.d.*	*b.d.*
	ETD 99/90	87	12.2	0.42	0.36	0.07	0.03	0.14	0.10	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 99/92	98	0.14	0.65	0.14	0.05	*b.d.*	0.34	0.06	0.06	0.10	0.06	*b.d.*
	ETD 99/93	96	0.46	1.76	0.28	0.02	*b.d.*	1.00	*b.d.*	0.21	0.03	0.14	*b.d.*
	ETD 99/94	98	0.64	0.89	0.05	0.14	0.04	0.22	*b.d.*	0.04	*b.d.*	0.10	*b.d.*
	ETD 99/95	83	0.04	0.25	0.03	14.4	0.29	1.39	*b.d.*	0.05	*b.d.*	0.02	*b.d.*
	ETD 99/96	80	17.2	1.51	*b.d.*	0.07	*b.d.*	1.12	*b.d.*	0.14	*b.d.*	*b.d.*	*b.d.*
	Bo 07/2742	89	0.62	3.99	4.86	0.04	0.02	1.24	*b.d.*	0.07	*b.d.*	0.07	*b.d.*
	Bo 92/225	85	13.7	0.55	0.26	*b.d.*	*b.d.*	0.32	0.19	0.08	0.02	0.16	*b.d.*
	ETD 96/39	99	0.02	0.24	0.01	*b.d.*	*b.d.*	0.22	*b.d.*	0.02	*b.d.*	0.01	*b.d.*
	ETD 96/44	99	0.31	0.60	0.06	*b.d.*	*b.d.*	0.23	*b.d.*	0.02	0.01	0.04	*b.d.*
	ETD 96/47	98	0.23	1.27	0.07	0.10	*b.d.*	0.27	*b.d.*	0.07	0.01	0.04	*b.d.*
	ETD 96/50	84	15.0	0.56	0.01	*b.d.*	*b.d.*	0.28	*b.d.*	0.06	*b.d.*	*b.d.*	*b.d.*
	ETD 96/51	90	6.29	2.07	0.43	0.11	0.01	0.45	*b.d.*	0.17	0.04	0.06	*b.d.*
	ETD 96/53	87	0.32	0.17	0.14	11.7	0.44	0.24	*b.d.*	*b.d.*	*b.d.*	0.02	*b.d.*
	ETD 96/59	98	0.06	0.66	0.10	*b.d.*	*b.d.*	1.11	0.10	0.04	0.01	0.02	*b.d.*
	ETD 96/61	81	16.0	1.10	0.63	0.14	*b.d.*	0.43	0.11	0.07	0.02	0.04	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
MA-136337	Dowel_1	97	*b.d.*	2.01	0.35	0.12	0.01	0.46	*b.d.*	*b.d.*	0.05	*b.d.*	*b.d.*
	10-1-92	72	23.6	0.50	0.67	*b.d.*	0.05	2.37	0.43	*b.d.*	*b.d.*	0.10	*b.d.*
	10-1-92	75	21.3	0.53	0.54	*b.d.*	*b.d.*	2.68	0.35	*b.d.*	*b.d.*	0.10	*b.d.*
	10-1-92	76	21.8	0.52	0.20	0.02	0.02	0.85	0.14	*b.d.*	*b.d.*	0.10	*b.d.*
	10-1-92	77	19.5	0.54	0.77	*b.d.*	*b.d.*	1.70	0.39	*b.d.*	*b.d.*	0.10	*b.d.*
	10-1-92	78	21.0	0.44	0.01	*b.d.*	*b.d.*	*b.d.*	0.88	0.03	*b.d.*	0.11	*b.d.*
	10-1-92	80	16.5	0.35	0.26	*b.d.*	0.04	2.28	0.31	*b.d.*	*b.d.*	0.12	*b.d.*
	10-1-92	81	16.0	0.28	0.04	*b.d.*	*b.d.*	2.42	0.18	*b.d.*	*b.d.*	0.11	*b.d.*
	10-1-92	82	15.1	0.33	0.37	*b.d.*	0.04	1.40	0.32	*b.d.*	*b.d.*	0.10	*b.d.*
	10-1-92	82	16.2	0.32	0.02	*b.d.*	*b.d.*	0.68	0.27	*b.d.*	*b.d.*	0.12	*b.d.*
	ETD 00/10	90	7.93	1.24	0.21	0.14	*b.d.*	0.20	0.06	0.09	*b.d.*	*b.d.*	*b.d.*
	ETD 00/11	93	*b.d.*	3.04	1.85	0.07	0.10	1.55	*b.d.*	0.08	*b.d.*	0.04	*b.d.*
	ETD 00/16	91	8.16	0.51	0.02	0.04	0.09	0.26	*b.d.*	0.02	*b.d.*	*b.d.*	*b.d.*
	ETD 00/17	74	24.0	0.23	0.01	0.05	*b.d.*	1.23	0.10	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 00/6	92	6.19	0.75	0.18	0.05	0.03	0.41	0.05	0.05	*b.d.*	*b.d.*	*b.d.*
	ETD 00/7	98	0.35	1.04	0.05	*b.d.*	*b.d.*	0.69	*b.d.*	0.07	*b.d.*	0.01	*b.d.*
	ETD 00/8	86	*b.d.*	1.10	0.01	7.05	0.33	5.36	*b.d.*	0.08	0.01	*b.d.*	*b.d.*
	ETD 00/9	93	5.16	1.01	0.19	0.06	*b.d.*	0.33	*b.d.*	0.07	*b.d.*	*b.d.*	*b.d.*
	ETD 98/15	79	*b.d.*	0.44	0.02	16.5	0.68	3.44	*b.d.*	0.08	0.01	*b.d.*	*b.d.*
	Bo 89/41	73	3.18	0.85	21.97	0.02	*b.d.*	0.08	*b.d.*	0.30	0.05	0.50	*b.d.*
	Bo 78/113	89	9.64	0.61	0.05	0.04	*b.d.*	0.17	0.06	0.04	*b.d.*	0.13	*b.d.*
	Bo 81/8	92	5.77	0.30	0.13	0.23	*b.d.*	1.60	0.10	0.07	*b.d.*	*b.d.*	*b.d.*
MA-132563	Bo 82/102	95	4.41	0.04	0.01	*b.d.*	*b.d.*	0.46	*b.d.*	*b.d.*	*b.d.*	0.01	*b.d.*
MA-132562	Bo 82/103	92	4.29	0.22	0.08	*b.d.*	*b.d.*	2.77	0.09	0.06	*b.d.*	*b.d.*	*b.d.*
MA-132301	Bo 82/109a	100	*b.d.*	0.21	*b.d.*	0.03	0.01	0.18	*b.d.*	*b.d.*	*b.d.*	0.02	*b.d.*
MA-132176	Bo 82/112	90	8.46	0.51	0.06	0.02	*b.d.*	1.04	0.16	0.12	*b.d.*	*b.d.*	*b.d.*
MA-132175	Bo 82/140	87	11.6	0.07	*b.d.*	*b.d.*	*b.d.*	0.72	0.22	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 82/148	98	0.71	0.32	0.01	0.02	0.01	0.98	0.10	*b.d.*	0.01	0.10	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 83/220	89	9.63	0.46	0.17	0.05	*b.d.*	0.08	0.13	0.09	*b.d.*	0.01	*b.d.*
	Bo 83/310	90	8.38	0.74	0.15	0.15	0.01	0.06	0.13	0.05	*b.d.*	0.01	*b.d.*
	Bo 83/442	97	0.08	1.14	1.04	0.18	0.01	0.26	0.06	0.10	0.05	0.05	*b.d.*
	Bo 83/444	98	0.03	1.33	0.03	*b.d.*	*b.d.*	0.48	0.08	0.08	0.01	0.06	*b.d.*
	Bo 83/450	99	0.03	0.71	0.09	0.05	0.01	0.24	0.06	0.07	0.02	0.04	*b.d.*
MA-132578	Bo 83/580	82	16.4	0.78	0.13	0.03	*b.d.*	0.29	*b.d.*	0.05	*b.d.*	0.02	*b.d.*
MA-132582	Bo 83/712	84	14.7	0.53	0.20	*b.d.*	*b.d.*	0.51	0.06	0.04	*b.d.*	*b.d.*	*b.d.*
MA-136323	Bo 83/819	98	0.14	0.01	*b.d.*	0.06	0.03	1.64	0.13	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 83/889	97	2.30	0.53	0.01	0.02	*b.d.*	0.14	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 84/22	94	5.23	0.17	0.07	*b.d.*	*b.d.*	0.24	0.10	0.03	*b.d.*	0.10	*b.d.*
	Bo 84/341	93	5.23	0.75	0.45	0.28	*b.d.*	0.31	0.14	0.05	*b.d.*	0.07	*b.d.*
	Bo 84/531	82	16.5	0.89	0.09	0.32	0.01	0.23	0.13	0.03	*b.d.*	*b.d.*	*b.d.*
	Bo 84/563	83	14.9	0.90	0.65	0.07	*b.d.*	0.41	0.20	0.05	*b.d.*	0.11	*b.d.*
	Bo 85/117	91	0.15	0.56	0.01	6.34	0.09	2.08	*b.d.*	0.08	0.01	0.04	*b.d.*
	Bo 85/144	83	16.2	0.17	0.01	*b.d.*	*b.d.*	0.19	0.09	*b.d.*	*b.d.*	0.09	*b.d.*
	Bo 85/153	89	10.3	0.30	0.12	*b.d.*	*b.d.*	0.20	*b.d.*	0.09	*b.d.*	0.09	*b.d.*
	Bo 85/515	99	0.16	0.37	0.17	*b.d.*	*b.d.*	0.26	0.05	0.16	0.03	0.06	*b.d.*
MA-132587	Bo 86/101	94	1.24	2.90	0.36	0.04	*b.d.*	1.08	0.06	0.06	0.10	0.06	*b.d.*
	Bo 86/168	87	12.1	0.29	0.04	*b.d.*	0.03	0.49	0.19	0.05	*b.d.*	*b.d.*	*b.d.*
	Bo 86/282	91	7.02	1.02	0.38	0.09	*b.d.*	0.12	0.08	0.11	*b.d.*	0.02	*b.d.*
MA-132586	Bo 86/321	98	*b.d.*	0.65	0.66	0.03	*b.d.*	0.70	*b.d.*	0.13	0.11	*b.d.*	*b.d.*
	Bo 86/411	86	12.0	0.73	0.25	0.09	*b.d.*	0.39	0.14	0.05	*b.d.*	0.01	*b.d.*
	Bo 86/427	82	16.6	0.28	0.03	*b.d.*	*b.d.*	0.77	0.23	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 86/431	97	0.45	1.40	0.18	0.08	*b.d.*	0.29	0.09	0.09	0.04	0.07	*b.d.*
	Bo 91/2414	84	15.2	0.55	0.12	*b.d.*	0.04	0.22	0.12	0.02	*b.d.*	0.13	*b.d.*
	Herbordt Kat Ify-39 (12); Bo 82-214b	84	11.9	0.86	0.32	0.24	0.06	1.70	0.39	0.06	*b.d.*	0.02	*b.d.*
	Herbordt Kat Ify-39 (14); Bo 82-314a	88	10.9	0.16	0.08	0.07	0.06	0.76	0.27	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (15); Bo 82-314a	86	11.7	0.97	0.98	0.16	0.03	0.36	0.19	0.06	*b.d.*	*b.d.*	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Herbordt Kat Ify-39 (16); Bo 82-214a	85	11.1	1.35	0.43	0.66	0.02	1.39	0.30	0.13	*b.d.*	0.01	*b.d.*
	Herbordt Kat Ify-39 (2); Bo 82-214b	85	13.1	0.73	0.27	0.14	*b.d.*	0.32	0.26	0.06	*b.d.*	0.02	*b.d.*
	Herbordt Kat Ify-39 (20); Bo 82-314a	88	0.12	0.18	*b.d.*	10.7	1.15	0.33	*b.d.*	0.02	*b.d.*	0.02	*b.d.*
	Herbordt Kat Ify-39 (22); Bo 82-314a	86	12.6	0.08	0.04	*b.d.*	*b.d.*	1.22	0.08	0.10	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (23); Bo 82-214b	86	12.3	0.39	0.21	0.06	0.04	0.81	0.29	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (24); Bo 82-314a	88	9.89	0.16	0.01	*b.d.*	*b.d.*	1.51	0.25	*b.d.*	*b.d.*	0.01	*b.d.*
	Herbordt Kat Ify-39 (25); Bo 82-314a	86	12.3	0.30	0.15	0.07	*b.d.*	0.55	0.11	*b.d.*	*b.d.*	0.02	*b.d.*
	Herbordt Kat Ify-39 (26); Bo 82-314a	85	13.2	0.13	0.65	0.11	0.08	1.03	0.31	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (27); Bo 82-314a	83	13.8	0.49	0.17	0.04	*b.d.*	1.86	0.26	0.05	*b.d.*	0.01	*b.d.*
	Herbordt Kat Ify-39 (28); Bo 82-314a	86	12.0	1.33	0.22	0.09	*b.d.*	0.53	0.08	0.06	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (29); Bo 82-314a	83	14.0	0.11	0.13	*b.d.*	*b.d.*	2.47	0.19	0.14	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (3); Bo 82-314a	81	15.9	0.71	0.12	0.14	*b.d.*	1.29	0.37	0.06	*b.d.*	0.02	*b.d.*
	Herbordt Kat Ify-39 (32); Bo 82-314a	83	15.6	0.16	0.12	*b.d.*	*b.d.*	1.29	0.13	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (35); Bo 82-214b	85	14.3	0.65	0.04	0.03	*b.d.*	0.28	0.06	0.02	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (36); Bo 82-314a	90	8.33	0.54	0.28	*b.d.*	*b.d.*	0.54	0.32	0.15	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (39); Bo 82-314a	76	20.6	0.65	0.71	*b.d.*	*b.d.*	1.17	0.34	0.27	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (4); Bo 82-314a	82	15.0	0.28	0.03	0.38	0.37	1.74	0.34	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (41); Bo 82-314a	85	13.5	0.43	0.10	*b.d.*	*b.d.*	0.30	0.13	0.04	*b.d.*	0.01	*b.d.*
	Herbordt Kat Ify-39 (42); Bo 82-314a	80	18.3	0.48	0.12	0.04	*b.d.*	0.62	0.18	0.20	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (43); Bo 82-314a	86	12.4	0.48	0.14	*b.d.*	*b.d.*	0.61	0.23	*b.d.*	*b.d.*	0.01	*b.d.*
	Herbordt Kat Ify-39 (44); Bo 82-314a	85	14.3	0.23	*b.d.*	*b.d.*	*b.d.*	0.17	0.10	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (45); Bo 82-314a	89	8.83	0.11	0.03	*b.d.*	*b.d.*	1.72	0.18	0.04	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (51); Bo 82-314a	85	12.7	0.85	0.61	0.13	0.02	0.81	0.22	0.05	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (6); Bo 82-314a	81	16.1	0.31	0.04	*b.d.*	*b.d.*	2.17	0.30	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Herbordt Kat Ify-39 (7); Bo 82-314a	88	10.0	1.13	0.34	0.13	*b.d.*	0.34	0.14	0.06	*b.d.*	0.01	*b.d.*
	Herbordt Kat Ify-39 (8); Bo 82-314a	91	6.32	0.02	0.01	*b.d.*	*b.d.*	2.04	0.23	*b.d.*	*b.d.*	0.02	*b.d.*
	scale 9	79	18.7	0.15	0.05	*b.d.*	*b.d.*	1.41	0.15	0.13	*b.d.*	*b.d.*	*b.d.*
	Bo 82/19	83	14.6	0.56	0.12	*b.d.*	*b.d.*	0.98	0.53	*b.d.*	*b.d.*	*b.d.*	*b.d.*

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	Bo 06/1115	97	1.39	0.20	0.03	*b.d.*	*b.d.*	1.64	0.06	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 06/1133	83	15.8	0.18	0.22	0.08	*b.d.*	0.72	0.12	0.04	*b.d.*	0.06	*b.d.*
	Bo 07/2668	97	0.04	0.87	0.09	*b.d.*	*b.d.*	1.49	0.05	0.03	0.11	0.10	*b.d.*
	Bo 07/2685	88	10.1	0.75	0.30	0.06	*b.d.*	0.16	0.08	0.08	*b.d.*	0.03	*b.d.*
	Bo 07/2690	77	21.6	0.27	0.37	0.11	*b.d.*	0.50	0.12	0.05	*b.d.*	0.06	*b.d.*
	Bo 07/2691	96	*b.d.*	3.10	*b.d.*	*b.d.*	*b.d.*	0.46	0.08	0.11	0.18	0.01	*b.d.*
	Bo 07/2748	87	9.99	1.05	0.73	0.06	*b.d.*	0.43	*b.d.*	0.24	0.19	0.08	*b.d.*
	Bo 07/2819	97	0.10	0.75	0.12	0.10	*b.d.*	1.69	0.04	0.17	0.09	0.05	*b.d.*
	Bo 08/1510	86	*b.d.*	0.46	0.02	11.2	0.47	2.18	*b.d.*	0.02	*b.d.*	0.03	*b.d.*
	Bo 08/1544	97	0.06	0.44	1.35	0.02	*b.d.*	0.63	0.21	*b.d.*	*b.d.*	0.16	*b.d.*
	Bo 08/358	99	0.05	0.39	0.01	*b.d.*	*b.d.*	0.15	*b.d.*	0.05	*b.d.*	0.24	*b.d.*
	Bo 08/359	86	12.2	1.10	0.14	0.06	*b.d.*	0.33	0.17	0.27	*b.d.*	0.01	*b.d.*
	Bo 08/393	95	3.12	0.80	0.14	0.03	*b.d.*	0.42	0.16	0.07	*b.d.*	*b.d.*	*b.d.*
	Bo 08/403	89	9.32	0.58	0.08	*b.d.*	0.07	0.48	0.14	0.03	*b.d.*	*b.d.*	*b.d.*
	Bo 08/415	98	0.09	1.20	0.50	0.03	*b.d.*	0.22	*b.d.*	0.13	0.04	0.11	*b.d.*
	Bo 08/826	98	0.09	0.82	0.21	0.06	*b.d.*	0.12	0.08	0.07	0.03	0.05	*b.d.*
	Bo 08/892	97	*b.d.*	0.94	1.06	0.03	*b.d.*	0.29	0.09	0.08	0.03	0.04	*b.d.*
	Bo 08/914	95	*b.d.*	4.06	0.01	0.02	*b.d.*	0.84	0.20	*b.d.*	*b.d.*	0.04	*b.d.*
	Bo 08/931	99	0.07	0.62	0.10	0.03	*b.d.*	0.31	0.04	0.08	0.02	0.19	*b.d.*
	Bo 08/934	98	0.90	0.58	0.10	0.04	*b.d.*	0.38	0.08	0.07	0.02	0.05	*b.d.*
	Bo 08/952	94	0.29	4.05	0.30	0.08	0.02	0.58	0.07	0.22	0.01	0.04	*b.d.*
	Bo 09/54	97	0.10	1.69	0.81	0.06	0.01	0.29	0.12	0.07	0.01	0.06	*b.d.*
	Bo 09/64	91	7.44	0.75	0.16	0.12	0.02	0.40	0.20	0.17	*b.d.*	0.02	*b.d.*
	Bo 09/73	67	31.3	1.26	0.20	0.10	*b.d.*	0.21	0.08	0.11	*b.d.*	0.05	*b.d.*
	Bo 02/39	98	1.21	0.52	0.18	*b.d.*	*b.d.*	0.13	0.09	0.14	0.05	0.06	*b.d.*
	Bo 02/41	98	0.10	0.57	0.73	*b.d.*	*b.d.*	0.73	0.08	0.09	0.07	0.06	*b.d.*
	Bo 02/45	89	8.49	1.22	0.13	0.13	*b.d.*	0.50	*b.d.*	0.05	0.01	0.03	*b.d.*
	Bo 02/49	99	0.06	0.23	0.38	*b.d.*	*b.d.*	0.20	0.09	0.10	0.06	0.09	*b.d.*

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	Bo 02/50	98	0.03	0.31	0.07	0.32	*b.d.*	1.14	0.08	0.03	0.01	0.01	*b.d.*
	Bo 02/55	97	0.60	0.98	0.65	0.04	*b.d.*	0.72	0.07	0.13	0.13	0.08	*b.d.*
	Bo 03/21	98	0.12	0.59	0.02	*b.d.*	*b.d.*	0.82	0.09	0.07	0.05	0.11	*b.d.*
	Bo 03/41	79	20.6	0.13	0.02	0.06	*b.d.*	0.44	0.14	*b.d.*	*b.d.*	0.03	*b.d.*
	Bo 04/30	58	38.3	1.42	0.19	0.52	*b.d.*	1.23	0.19	0.06	*b.d.*	0.04	*b.d.*
	Bo 04/32	97	0.99	0.49	0.29	*b.d.*	*b.d.*	1.15	0.10	0.06	0.04	0.05	*b.d.*
	Bo 04/34	96	*b.d.*	2.53	0.75	*b.d.*	*b.d.*	1.06	*b.d.*	0.09	0.01	*b.d.*	*b.d.*
	Bo 05/13	87	0.16	1.12	0.17	0.04	*b.d.*	0.94	0.11	0.04	0.02	10.86	0.15
	Bo 05/13	96	*b.d.*	0.12	0.02	1.90	0.25	0.77	0.18	*b.d.*	*b.d.*	0.37	0.12
	Bo 05/13	97	*b.d.*	0.04	*b.d.*	2.37	0.29	0.38	0.05	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 05/13	99	*b.d.*	0.20	0.08	0.04	*b.d.*	0.78	0.19	*b.d.*	*b.d.*	0.02	*b.d.*
	Bo 05/13	99	*b.d.*	0.11	0.09	0.03	*b.d.*	0.88	0.13	*b.d.*	*b.d.*	0.02	*b.d.*
	Bo 05/21	99	0.04	0.43	0.12	0.03	*b.d.*	0.35	0.17	0.02	*b.d.*	0.03	*b.d.*
	Bo 05/23	98	0.06	0.84	0.06	*b.d.*	*b.d.*	1.03	0.13	*b.d.*	0.01	0.01	*b.d.*
	Bo 05/25	97	0.02	1.57	0.33	*b.d.*	*b.d.*	0.59	0.13	0.06	0.02	0.04	*b.d.*
	Bo 05/29	70	29.0	0.17	0.04	0.04	*b.d.*	0.17	0.19	*b.d.*	*b.d.*	0.02	*b.d.*
	Bo 05/30	86	2.55	3.36	0.47	0.32	*b.d.*	6.88	0.21	0.31	0.03	0.07	*b.d.*
	Bo 05/31	78	21.0	0.75	0.04	*b.d.*	*b.d.*	0.18	0.16	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 05/33	88	8.23	1.86	0.50	0.07	*b.d.*	0.76	0.18	0.22	*b.d.*	0.03	*b.d.*
	Bo 05/34	94	0.44	1.65	1.07	0.04	*b.d.*	2.24	0.19	0.13	0.17	0.11	*b.d.*
	Bo 05/36	75	15.6	4.50	0.42	0.25	0.08	3.54	0.16	0.09	0.01	0.04	*b.d.*
	Bo 05/38	95	0.53	1.12	0.93	*b.d.*	*b.d.*	1.79	0.17	0.08	0.22	0.07	*b.d.*
	Bo 05/51	86	9.34	2.03	1.39	0.08	*b.d.*	0.60	0.16	0.08	0.03	0.04	*b.d.*
	Bo 06/1039	79	20.4	0.16	0.05	0.10	*b.d.*	0.10	0.15	*b.d.*	*b.d.*	0.10	*b.d.*
MA-132533	Bo 06/1359	97	0.03	0.61	0.01	0.10	*b.d.*	1.73	0.13	0.02	*b.d.*	0.05	0.01
MA-132529	Bo 06/137	97	0.29	1.43	0.30	0.04	0.01	0.82	0.06	0.01	*b.d.*	0.02	*b.d.*
MA-132532	Bo 06/1378	97	0.02	1.64	0.04	0.08	*b.d.*	0.91	0.06	0.13	0.01	0.04	*b.d.*
	Bo 06/1387	93	0.33	4.46	0.18	0.68	*b.d.*	1.43	0.09	0.14	*b.d.*	0.05	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
MA-132522	Bo 06/1465	96	*b.d.*	1.70	0.19	0.05	0.02	1.45	0.05	0.32	0.01	0.03	*b.d.*
MA-132505	Bo 06/166	98	*b.d.*	0.60	0.04	0.21	*b.d.*	0.88	0.14	0.02	*b.d.*	0.02	*b.d.*
	Bo 06/1874	77	19.1	0.86	0.37	0.07	*b.d.*	2.18	0.22	0.07	*b.d.*	0.01	*b.d.*
MA-132525	Bo 06/2094	97	0.12	1.47	0.23	0.07	*b.d.*	0.38	*b.d.*	0.39	0.02	0.08	*b.d.*
	Bo 06/2251	98	0.11	0.75	0.50	0.02	*b.d.*	0.20	0.06	0.05	0.58	0.05	*b.d.*
	Bo 06/2269	99	*b.d.*	0.54	0.12	*b.d.*	0.01	0.22	0.08	0.08	*b.d.*	0.06	*b.d.*
	Bo 06/2350	92	5.24	1.38	0.38	0.04	*b.d.*	0.46	0.13	0.19	0.02	0.05	*b.d.*
MA-132346	Bo 06/2428	90	0.05	0.17	0.01	7.93	1.05	0.88	*b.d.*	*b.d.*	0.01	*b.d.*	*b.d.*
MA-132409	Bo 06/259	79	20.7	0.38	0.03	*b.d.*	*b.d.*	0.13	0.15	0.05	*b.d.*	0.02	*b.d.*
MA-132506	Bo 06/353	83	16.6	0.24	*b.d.*	*b.d.*	*b.d.*	0.31	0.11	*b.d.*	*b.d.*	*b.d.*	*b.d.*
MA-132507	Bo 06/417	97	0.04	0.66	1.38	*b.d.*	*b.d.*	0.33	*b.d.*	0.08	0.05	0.07	*b.d.*
MA-132518	Bo 06/486	92	5.11	1.58	0.36	0.07	*b.d.*	0.58	*b.d.*	0.13	*b.d.*	0.04	*b.d.*
MA-132307	Bo 06/492	81	0.04	0.24	*b.d.*	16.5	1.94	0.37	*b.d.*	*b.d.*	*b.d.*	0.01	*b.d.*
	Bo 07/1225	75	0.06	1.32	0.04	16.2	0.66	7.03	*b.d.*	0.04	0.01	0.03	*b.d.*
	Bo 07/1288	99	0.05	0.79	0.06	0.03	*b.d.*	0.22	*b.d.*	0.11	0.01	0.03	*b.d.*
	Bo 07/1301	98	0.67	1.04	0.17	0.04	*b.d.*	0.31	*b.d.*	0.13	0.03	0.07	*b.d.*
	Bo 07/1720	84	15.2	0.14	*b.d.*	*b.d.*	*b.d.*	0.43	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 07/1745	80	17.4	0.94	0.97	0.42	*b.d.*	0.21	*b.d.*	0.14	0.03	0.06	*b.d.*
	Bo 07/1755	97	0.11	0.75	0.04	0.35	*b.d.*	1.28	*b.d.*	0.03	*b.d.*	*b.d.*	*b.d.*
	Bo 07/1802	94	0.08	4.04	0.23	0.11	*b.d.*	1.39	*b.d.*	0.13	0.01	0.01	*b.d.*
	Bo 07/1810	88	6.69	2.50	1.57	0.07	0.02	0.78	*b.d.*	0.09	0.06	0.06	*b.d.*
	Bo 07/1818	98	0.04	0.06	0.01	1.12	0.12	0.81	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 07/1821	98	0.04	0.50	*b.d.*	1.17	0.10	*b.d.*	*b.d.*	*b.d.*	*b.d.*	0.02	*b.d.*
	Bo 07/1860	94	2.53	1.57	0.10	*b.d.*	*b.d.*	2.09	0.11	0.07	*b.d.*	0.02	*b.d.*
MA-136335	Bo 07/1871	86	*b.d.*	0.05	0.32	11.5	0.70	1.13	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 07/1874	97	0.07	1.27	0.78	*b.d.*	*b.d.*	0.50	0.11	0.12	0.25	0.08	*b.d.*
	Bo 07/1920	90	2.91	1.17	0.39	0.11	*b.d.*	3.71	0.12	1.08	0.02	0.08	0.05
	Bo 07/1921	97	*b.d.*	1.77	0.42	0.02	*b.d.*	1.04	*b.d.*	0.01	*b.d.*	0.02	0.04

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 07/1936	87	3.91	4.70	1.32	0.17	*b.d.*	2.04	0.07	0.28	0.16	0.12	*b.d.*
	Bo 07/2045	98	0.05	0.49	0.14	*b.d.*	*b.d.*	1.26	0.15	0.06	0.03	0.03	*b.d.*
	Bo 07/2054	81	17.6	0.81	0.13	0.03	*b.d.*	0.32	0.06	0.10	*b.d.*	*b.d.*	*b.d.*
	Bo 07/2055	99	*b.d.*	0.18	0.03	0.27	*b.d.*	0.05	0.05	*b.d.*	0.02	0.06	*b.d.*
	Bo 07/2079	91	0.40	3.72	0.81	1.82	0.03	1.88	*b.d.*	0.31	0.03	0.09	*b.d.*
	Bo 07/2087	88	0.14	5.10	2.45	0.05	*b.d.*	3.55	0.11	0.06	0.16	0.20	0.10
	Bo 07/2089	96	2.45	0.62	0.07	0.06	*b.d.*	0.30	0.10	0.08	*b.d.*	0.02	*b.d.*
	Bo 07/2093	95	0.49	1.05	0.39	0.03	*b.d.*	1.96	0.08	0.12	0.46	0.23	*b.d.*
MA-136332	Bo 07/2101	89	*b.d.*	0.90	0.05	6.52	0.24	3.04	*b.d.*	0.03	*b.d.*	0.02	*b.d.*
	Bo 07/2104	96	*b.d.*	1.40	0.08	*b.d.*	0.02	1.24	*b.d.*	1.01	*b.d.*	0.06	*b.d.*
	Bo 07/2121	98	0.05	0.43	0.06	*b.d.*	*b.d.*	1.60	0.04	*b.d.*	0.01	0.02	*b.d.*
	Bo 07/2129	85	12.3	0.87	0.41	0.06	*b.d.*	1.37	0.15	0.13	*b.d.*	0.01	*b.d.*
	Bo 07/2130	97	0.45	0.48	0.18	0.04	*b.d.*	1.66	0.09	0.17	0.02	0.03	*b.d.*
	Bo 07/2143	98	0.17	0.83	0.12	*b.d.*	*b.d.*	0.59	*b.d.*	0.07	0.02	0.05	*b.d.*
MA-136331	Bo 07/2149	68	0.05	2.70	0.07	16.4	1.03	11.7	*b.d.*	0.03	0.01	0.04	0.05
MA-136328	Bo 07/2151	80	*b.d.*	0.52	0.01	14.0	0.60	5.08	*b.d.*	*b.d.*	*b.d.*	0.01	*b.d.*
	Bo 07/2154	99	*b.d.*	1.04	0.02	0.07	0.01	0.23	*b.d.*	0.02	*b.d.*	*b.d.*	*b.d.*
	Bo 07/2200	83	16.2	0.37	0.08	*b.d.*	*b.d.*	0.46	0.07	*b.d.*	*b.d.*	*b.d.*	*b.d.*
MA-136333	Bo 07/2204	84	*b.d.*	0.51	0.01	10.4	0.41	4.64	*b.d.*	*b.d.*	*b.d.*	0.01	*b.d.*
	Bo 07/2211	99	0.37	0.10	0.08	*b.d.*	*b.d.*	0.63	0.09	*b.d.*	*b.d.*	0.02	*b.d.*
	Bo 07/2215	97	*b.d.*	0.26	0.18	*b.d.*	0.05	2.39	0.21	*b.d.*	*b.d.*	0.03	*b.d.*
	Bo 07/2221	95	0.06	1.00	1.12	0.13	*b.d.*	1.78	0.12	0.33	0.31	0.09	*b.d.*
	Bo 07/2224	96	0.05	2.13	0.55	0.04	*b.d.*	1.21	0.08	0.11	0.01	0.03	*b.d.*
	Bo 07/2227	97	0.20	1.58	0.18	0.06	*b.d.*	0.26	0.11	0.11	0.01	0.05	*b.d.*
	Bo 07/2228	91	0.05	0.59	0.14	3.37	0.07	4.60	0.07	0.13	0.03	0.07	*b.d.*
	Bo 07/2235	97	*b.d.*	1.54	0.69	*b.d.*	*b.d.*	0.80	*b.d.*	0.08	0.02	0.03	*b.d.*
	Bo 07/2239	76	21.9	0.55	0.30	0.06	*b.d.*	1.26	0.17	0.09	*b.d.*	*b.d.*	*b.d.*
	Bo 07/2240	99	0.03	0.74	0.01	*b.d.*	*b.d.*	0.21	0.13	*b.d.*	*b.d.*	0.03	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 07/2252	98	*b.d.*	*b.d.*	0.23	*b.d.*	*b.d.*	1.30	0.21	0.15	0.03	*b.d.*	*b.d.*
	Bo 07/2256	94	1.20	3.11	0.72	0.08	*b.d.*	0.50	0.19	0.19	0.04	0.05	*b.d.*
	Bo 07/2258	98	0.07	0.85	0.04	0.03	*b.d.*	0.48	0.05	0.05	0.01	0.03	*b.d.*
	Bo 07/2260	97	*b.d.*	0.85	0.86	*b.d.*	*b.d.*	0.30	0.23	0.31	0.22	0.30	*b.d.*
	Bo 07/2269	91	7.11	1.04	0.38	0.05	*b.d.*	0.29	*b.d.*	0.09	*b.d.*	0.02	*b.d.*
	Bo 07/2272	98	0.09	0.53	1.01	0.05	0.11	0.30	*b.d.*	0.04	0.01	0.04	*b.d.*
	Bo 07/2305	76	20.4	1.40	0.45	1.06	0.02	0.36	0.16	0.07	*b.d.*	0.07	*b.d.*
	Bo 07/2354	76	22.3	0.71	0.16	0.04	*b.d.*	0.30	0.15	0.06	*b.d.*	*b.d.*	*b.d.*
	Bo 07/2397	97	0.21	1.26	0.57	0.04	*b.d.*	0.38	*b.d.*	0.10	0.14	0.09	*b.d.*
	Bo 07/2422	89	8.01	1.23	0.35	*b.d.*	*b.d.*	0.80	0.12	0.27	0.13	0.09	*b.d.*
	Bo 07/2445	99	*b.d.*	0.35	0.22	*b.d.*	*b.d.*	0.42	0.05	0.02	0.02	*b.d.*	*b.d.*
	Bo 07/2456	98	0.07	0.46	0.20	*b.d.*	*b.d.*	0.57	0.10	0.17	0.38	0.11	*b.d.*
	Bo 07/2458	96	0.09	0.85	1.29	*b.d.*	*b.d.*	1.25	0.13	0.03	0.03	0.05	*b.d.*
	Bo 07/2460	97	0.12	1.05	0.56	0.02	0.01	0.52	0.08	0.25	*b.d.*	0.12	*b.d.*
	Bo 07/2470	98	0.14	1.13	0.14	0.06	*b.d.*	0.22	0.16	0.07	0.02	0.12	*b.d.*
	Bo 07/2471	78	14.7	3.59	1.36	0.14	*b.d.*	1.58	0.22	0.29	0.11	0.07	*b.d.*
	Bo 07/2483	98	0.07	0.89	0.37	0.05	*b.d.*	0.62	0.15	0.12	0.03	0.05	*b.d.*
	Bo 07/2484	79	18.8	1.44	0.26	0.15	*b.d.*	0.26	0.11	0.11	0.02	0.09	*b.d.*
	Bo 07/2637	97	0.22	0.31	0.82	0.09	*b.d.*	1.32	0.19	0.10	0.02	0.06	*b.d.*
	Bo 07/2707	95	0.02	0.04	*b.d.*	3.47	0.17	1.29	0.08	*b.d.*	*b.d.*	0.01	*b.d.*
MA-132197	Bo 07/29	83	15.1	0.67	0.15	0.09	*b.d.*	0.93	0.13	0.04	*b.d.*	0.03	*b.d.*
	Bo 07/3402	99	0.37	0.41	0.22	*b.d.*	0.02	0.25	*b.d.*	0.04	*b.d.*	0.02	*b.d.*
	Bo 07/3431	81	16.6	1.32	0.25	0.15	*b.d.*	0.39	0.11	0.10	*b.d.*	*b.d.*	*b.d.*
	Bo 07/3440	98	0.03	0.83	0.01	0.03	*b.d.*	1.06	*b.d.*	*b.d.*	*b.d.*	0.10	*b.d.*
	Bo 07/3441	96	0.17	2.44	0.18	*b.d.*	*b.d.*	0.77	0.11	0.08	*b.d.*	*b.d.*	*b.d.*
	Bo 07/3444	98	0.14	1.31	0.16	*b.d.*	*b.d.*	0.38	*b.d.*	0.11	0.04	0.07	*b.d.*
	Bo 07/3457	97	*b.d.*	1.14	0.06	*b.d.*	*b.d.*	1.41	0.05	0.04	*b.d.*	0.04	*b.d.*
	Bo 07/3460	96	0.14	2.03	0.13	0.12	0.01	1.20	*b.d.*	0.06	0.01	0.03	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 07/3481	98	0.05	0.87	0.44	*b.d.*	*b.d.*	0.80	*b.d.*	0.11	0.08	0.10	*b.d.*
	Bo 07/3484	67	28.9	2.32	0.64	0.25	*b.d.*	0.92	0.11	0.16	0.02	0.09	*b.d.*
	Bo 07/3490	95	0.02	1.22	1.14	0.07	*b.d.*	1.97	0.06	*b.d.*	*b.d.*	0.03	*b.d.*
	Bo 07/3509	96	0.14	1.90	0.22	*b.d.*	*b.d.*	1.10	*b.d.*	0.05	0.05	0.09	*b.d.*
	Bo 07/3571	79	19.2	0.52	0.27	*b.d.*	*b.d.*	0.43	0.05	0.04	*b.d.*	*b.d.*	*b.d.*
MA-136334	Bo 07/3594	92	0.09	0.55	0.03	5.58	0.09	1.57	*b.d.*	0.01	0.01	0.03	*b.d.*
	Bo 07/3606	99	0.10	0.46	0.19	0.03	*b.d.*	0.19	0.06	0.07	0.06	0.03	*b.d.*
	Bo 07/3693	79	19.2	0.98	0.28	0.15	*b.d.*	0.17	0.10	0.06	*b.d.*	0.03	*b.d.*
	Bo 07/3694	77	21.1	0.93	0.10	0.32	0.02	0.72	0.11	0.08	*b.d.*	*b.d.*	*b.d.*
	Bo 07/3723	79	18.9	0.71	0.16	0.03	0.04	0.95	0.11	0.09	*b.d.*	0.02	*b.d.*
MA-136325	Bo 07/3735	88	*b.d.*	0.19	*b.d.*	9.10	0.21	2.25	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 07/3739	81	15.9	2.04	0.66	0.18	*b.d.*	0.37	0.19	0.12	*b.d.*	0.04	*b.d.*
	Bo 07/3798	91	0.52	4.82	1.88	0.03	*b.d.*	1.05	0.13	0.09	0.28	0.17	0.07
	Bo 07/3803	94	4.43	0.88	0.11	0.03	*b.d.*	0.57	0.14	0.13	*b.d.*	0.04	*b.d.*
	Bo 07/3811	97	0.06	1.81	0.09	0.04	*b.d.*	0.80	0.10	0.13	0.03	0.06	*b.d.*
	Bo 07/3816	98	0.04	1.26	0.04	0.03	*b.d.*	0.47	0.13	0.04	*b.d.*	0.01	*b.d.*
	Bo 08/100	97	*b.d.*	2.11	0.01	0.07	*b.d.*	0.25	0.07	0.05	0.01	0.03	*b.d.*
	Bo 08/102	97	0.04	0.85	0.03	0.13	*b.d.*	1.44	0.09	0.02	0.01	0.04	*b.d.*
	Bo 08/105	92	1.05	2.01	1.29	0.02	*b.d.*	3.24	0.26	0.06	0.02	0.08	0.03
	Bo 08/132	88	10.3	0.32	0.37	0.11	*b.d.*	0.58	0.12	0.19	*b.d.*	0.03	*b.d.*
	Bo 08/134	80	19.1	0.43	0.14	*b.d.*	*b.d.*	0.49	0.20	0.06	*b.d.*	*b.d.*	*b.d.*
	Bo 08/140	89	2.67	2.71	0.43	*b.d.*	*b.d.*	5.03	0.13	0.17	0.06	0.15	*b.d.*
	Bo 08/143	95	0.18	0.18	0.01	3.48	0.11	0.49	*b.d.*	0.03	0.02	0.06	*b.d.*
	Bo 08/1511	89	9.23	0.99	0.55	0.06	*b.d.*	0.15	0.05	0.12	*b.d.*	0.29	*b.d.*
	Bo 08/156	97	0.70	1.48	0.29	0.06	*b.d.*	0.21	0.04	0.13	0.03	0.07	*b.d.*
MA-132549	Bo 08/16	98	*b.d.*	0.36	0.13	*b.d.*	*b.d.*	1.49	0.22	0.12	0.02	0.01	*b.d.*
	Bo 08/160	77	17.9	2.47	0.29	*b.d.*	*b.d.*	1.50	0.08	0.21	0.03	0.10	*b.d.*
	Bo 08/197	98	0.07	0.59	0.10	*b.d.*	0.01	0.80	0.08	0.05	0.02	0.05	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 08/212	95	0.17	1.10	0.39	*b.d.*	0.04	2.79	0.07	0.02	0.02	0.01	*b.d.*
MA-132205	Bo 08/217	94	0.14	2.03	2.44	*b.d.*	*b.d.*	1.41	0.12	0.20	0.07	0.05	0.03
MA-132198	Bo 08/227	83	13.6	1.90	0.75	0.11	*b.d.*	0.80	0.11	0.13	*b.d.*	0.04	*b.d.*
MA-132206	Bo 08/229	96	1.24	1.39	0.10	*b.d.*	0.02	1.46	0.07	0.06	0.02	0.04	*b.d.*
	Bo 08/236	92	0.34	3.25	1.66	0.03	*b.d.*	1.96	0.11	0.18	0.10	0.13	*b.d.*
	Bo 08/25	98	*b.d.*	0.53	0.04	0.45	*b.d.*	0.74	*b.d.*	0.05	0.01	0.01	*b.d.*
	Bo 08/255	79	16.6	2.19	0.32	0.14	*b.d.*	1.25	0.07	0.30	0.09	0.07	*b.d.*
	Bo 08/258	95	0.04	2.30	1.20	0.02	*b.d.*	0.75	*b.d.*	0.13	0.19	0.06	*b.d.*
MA-136324	Bo 08/264	91	*b.d.*	0.33	0.01	7.66	0.79	0.69	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 08/27	95	1.30	1.14	1.77	0.04	*b.d.*	0.41	*b.d.*	0.21	0.03	0.07	*b.d.*
	Bo 08/28	93	5.88	0.56	0.08	*b.d.*	0.04	0.48	0.06	0.06	*b.d.*	0.01	*b.d.*
	Bo 08/300	98	0.06	1.11	0.17	0.06	*b.d.*	0.30	0.05	0.18	0.05	0.09	*b.d.*
	Bo 08/36	97	0.06	1.97	0.08	*b.d.*	*b.d.*	0.60	0.18	0.15	0.04	0.14	*b.d.*
	Bo 08/37	96	0.78	0.89	0.30	0.05	*b.d.*	1.53	0.22	0.14	0.05	0.07	*b.d.*
	Bo 08/42	93	0.72	1.91	2.93	0.04	*b.d.*	1.09	0.12	0.08	0.14	0.14	*b.d.*
	Bo 08/43	77	20.7	1.68	0.30	0.03	*b.d.*	0.38	0.12	0.20	*b.d.*	*b.d.*	*b.d.*
	Bo 08/44	95	0.11	3.81	0.09	*b.d.*	*b.d.*	0.73	0.08	0.10	0.01	0.05	*b.d.*
	Bo 08/53	94	1.11	2.82	0.27	0.09	*b.d.*	1.56	0.13	0.15	0.02	0.08	*b.d.*
	Bo 08/57	99	0.04	0.28	0.03	0.04	0.06	0.40	0.09	0.02	0.01	*b.d.*	*b.d.*
	Bo 08/66	90	7.79	1.29	0.19	0.07	*b.d.*	0.24	0.05	0.20	0.02	0.03	*b.d.*
	Bo 08/69	88	10.8	0.72	0.15	0.04	*b.d.*	0.31	0.07	0.15	*b.d.*	*b.d.*	*b.d.*
	Bo 08/73	91	0.12	7.20	0.24	0.13	*b.d.*	1.27	0.04	0.13	*b.d.*	0.06	*b.d.*
	Bo 08/77	97	*b.d.*	1.68	0.42	*b.d.*	*b.d.*	0.32	0.08	0.18	0.13	0.11	*b.d.*
	Bo 08/841	98	*b.d.*	0.68	0.02	*b.d.*	*b.d.*	0.85	0.11	*b.d.*	*b.d.*	0.10	*b.d.*
	Bo 08/859	97	0.31	0.69	0.38	*b.d.*	*b.d.*	1.17	0.42	*b.d.*	*b.d.*	0.09	*b.d.*
	Bo 08/87	97	0.24	1.62	0.29	0.05	*b.d.*	0.69	0.06	0.06	0.09	0.05	*b.d.*
	Bo 08/884	98	0.03	0.76	0.39	0.04	*b.d.*	0.87	0.17	*b.d.*	0.08	0.05	*b.d.*
	Bo 08/966	99	0.24	0.29	0.03	*b.d.*	*b.d.*	0.12	0.10	0.03	0.01	*b.d.*	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 07/519	98	0.02	0.31	1.35	0.02	*b.d.*	0.13	*b.d.*	0.02	0.02	0.06	0.03
	Bo 07/523	99	0.02	0.11	0.50	*b.d.*	*b.d.*	0.20	*b.d.*	0.17	0.08	0.08	*b.d.*
MA-136328	Bo 07/576	89	0.02	0.26	*b.d.*	6.56	0.74	3.39	*b.d.*	*b.d.*	0.01	*b.d.*	*b.d.*
	Bo 07/578	99	0.04	0.17	0.61	*b.d.*	*b.d.*	0.05	*b.d.*	0.08	0.01	0.08	*b.d.*
	Bo 07/591	75	11.2	2.62	9.79	0.04	*b.d.*	1.47	0.05	0.15	0.05	0.03	*b.d.*
EARLY IRON AGE													
	Bo 96/31	84	5.82	1.97	6.14	0.07	*b.d.*	1.24	0.17	0.06	0.03	0.27	*b.d.*
	Bo 96/45	75	21.5	0.73	0.35	0.08	0.03	1.57	0.18	0.05	*b.d.*	0.08	*b.d.*
	Bo 96/85	94	4.05	0.03	0.02	*b.d.*	*b.d.*	1.41	0.25	*b.d.*	*b.d.*	0.01	*b.d.*
	Bo 97/25	44	26.6	1.26	25.91	0.62	0.12	1.38	0.12	0.06	*b.d.*	0.15	*b.d.*
	Bo 97/26	88	11.0	0.44	0.05	*b.d.*	0.01	0.35	0.09	0.02	*b.d.*	*b.d.*	*b.d.*
	Bo 97/31	92	6.51	0.87	0.22	0.07	*b.d.*	0.32	*b.d.*	0.06	*b.d.*	0.02	*b.d.*
	Bo 97/35	90	0.18	1.11	0.32	2.61	0.12	5.63	*b.d.*	0.08	0.02	0.11	*b.d.*
	Bo 97/38	77	19.2	1.73	0.95	0.12	0.04	1.19	0.15	0.09	*b.d.*	0.01	*b.d.*
	Bo 97/87	90	8.46	0.65	0.11	0.05	0.03	0.31	0.16	0.04	*b.d.*	0.01	*b.d.*
	Bo 97/90	87	11.5	0.32	0.22	0.04	*b.d.*	0.88	0.17	0.03	*b.d.*	0.10	*b.d.*
	Bo 97/93	96	0.16	1.00	0.28	0.06	*b.d.*	2.15	0.04	0.07	0.03	0.08	0.04
	Bo 97/94	89	9.10	0.79	0.18	0.05	0.07	0.55	0.18	0.03	*b.d.*	*b.d.*	*b.d.*
	Bo 97/97	99	0.02	0.24	0.18	0.11	*b.d.*	0.46	0.12	*b.d.*	*b.d.*	0.09	*b.d.*
	Bo 97/99	92	7.22	0.64	0.12	0.10	0.01	0.13	0.05	0.06	*b.d.*	0.04	*b.d.*
	ETD 96/31	97	0.28	1.74	0.19	0.13	*b.d.*	0.81	*b.d.*	0.13	*b.d.*	0.04	*b.d.*
	ETD 96/38	96	2.76	0.52	0.25	0.03	*b.d.*	0.66	0.05	0.05	*b.d.*	0.01	*b.d.*
	ETD 96/46	98	*b.d.*	0.53	0.03	*b.d.*	*b.d.*	0.59	0.38	0.03	*b.d.*	0.03	*b.d.*
	ETD 97/197	73	23.7	0.26	0.47	*b.d.*	*b.d.*	1.52	0.06	0.06	*b.d.*	0.88	*b.d.*
	ETD 97/198	80	17.8	0.84	0.62	0.17	0.02	0.40	0.26	0.02	*b.d.*	0.04	*b.d.*
	ETD 97/203	88	10.4	0.44	0.26	0.09	0.02	0.87	0.05	0.04	*b.d.*	0.02	*b.d.*
	ETD 97/215	97	0.40	0.13	0.47	0.08	0.01	1.14	0.16	0.22	0.09	0.07	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	ETD 97/225	70	27.4	0.32	0.53	0.03	*b.d.*	1.16	*b.d.*	0.09	*b.d.*	0.05	*b.d.*
	ETD 97/235	98	0.96	0.37	0.04	0.22	0.02	0.04	*b.d.*	*b.d.*	0.01	0.01	*b.d.*
	ETD 97/236	80	16.7	0.24	0.02	*b.d.*	*b.d.*	1.05	0.09	*b.d.*	*b.d.*	1.37	*b.d.*
	ETD 97/239	76	19.2	0.76	0.92	0.08	*b.d.*	2.46	0.09	0.06	*b.d.*	0.14	0.18
	ETD 97/245	99	0.02	0.54	0.05	*b.d.*	*b.d.*	0.23	0.09	0.03	0.01	0.03	*b.d.*
	ETD 97/253	97	0.55	1.64	0.36	*b.d.*	*b.d.*	0.15	*b.d.*	0.17	*b.d.*	0.05	*b.d.*
	ETD 97/261	90	8.77	0.16	0.66	*b.d.*	*b.d.*	0.40	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 97/265	93	6.57	0.55	0.14	0.03	0.05	0.08	*b.d.*	0.03	*b.d.*	*b.d.*	*b.d.*
	ETD 97/273	80	18.1	0.50	0.20	0.07	*b.d.*	1.39	0.06	0.02	*b.d.*	*b.d.*	*b.d.*
	ETD 97/340A	88	9.48	0.98	0.09	0.04	*b.d.*	0.85	*b.d.*	0.07	*b.d.*	0.01	*b.d.*
	ETD 97/340B	92	7.32	0.54	0.08	*b.d.*	*b.d.*	0.20	*b.d.*	0.04	*b.d.*	0.03	*b.d.*
	ETD 97/340C	98	0.10	1.46	0.09	0.04	*b.d.*	0.39	*b.d.*	0.09	0.12	0.05	*b.d.*
	ETD 97/340D	100	*b.d.*	0.15	0.02	0.09	0.03	0.12	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 98/04	93	5.69	0.61	0.14	0.07	0.05	0.11	0.14	0.03	*b.d.*	0.02	*b.d.*
MIDDLE / LATE IRON AGE													
MA-132554	Bo 307/n	91	8.22	0.30	0.31	0.01	*b.d.*	0.13	0.08	0.21	*b.d.*	0.11	*b.d.*
MA-132559	Bo 443/i/3	90	8.88	0.21	0.71	0.13	*b.d.*	0.11	0.06	0.03	*b.d.*	0.02	*b.d.*
	Bo 94/122	97	*b.d.*	0.78	0.04	0.17	0.19	1.86	0.06	*b.d.*	0.01	0.02	*b.d.*
	Bo 94/32	78	17.3	1.05	0.81	0.08	*b.d.*	1.95	0.29	0.10	*b.d.*	0.06	*b.d.*
	Bo 94/35	97	0.74	0.93	0.11	0.08	*b.d.*	0.44	0.18	0.09	0.02	0.08	*b.d.*
	Bo 95/12	85	12.2	0.48	1.90	0.04	*b.d.*	0.17	0.16	0.02	*b.d.*	*b.d.*	*b.d.*
	Bo 95/126	79	19.0	0.19	0.63	*b.d.*	*b.d.*	0.65	0.25	0.09	*b.d.*	0.17	*b.d.*
	Bo 95/13	80	15.6	1.25	1.82	0.03	*b.d.*	0.41	0.19	0.49	0.07	0.24	*b.d.*
	Bo 95/69	72	23.5	0.59	2.87	0.04	0.05	0.45	0.24	0.12	*b.d.*	0.09	*b.d.*
	Bo 96/67	87	12.3	0.44	0.40	0.08	*b.d.*	0.05	0.09	0.02	*b.d.*	0.03	*b.d.*
	Bo 97/30	66	32.8	0.33	0.10	0.04	0.02	0.70	*b.d.*	0.03	*b.d.*	*b.d.*	*b.d.*
	ETD 94/125	88	11.6	0.14	0.17	*b.d.*	*b.d.*	0.27	0.09	0.09	*b.d.*	0.04	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	ETD 94/126	96	3.56	0.33	0.03	0.02	*b.d.*	0.34	0.05	0.02	*b.d.*	0.05	*b.d.*
	ETD 94/178	89	8.78	0.66	1.48	0.03	*b.d.*	0.12	0.19	0.09	*b.d.*	0.08	*b.d.*
	ETD 94/19	98	0.67	*b.d.*	0.64	*b.d.*	*b.d.*	0.24	0.11	*b.d.*	*b.d.*	0.02	*b.d.*
	ETD 94/211	94	0.93	0.27	0.02	4.66	0.12	0.04	*b.d.*	0.02	0.01	*b.d.*	*b.d.*
	ETD 94/212	99	*b.d.*	0.32	0.03	0.04	*b.d.*	0.43	0.09	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 94/241	91	5.52	0.64	2.03	0.30	0.03	0.15	0.13	0.06	0.01	0.49	0.10
	ETD 94/261	99	0.04	0.43	0.18	*b.d.*	*b.d.*	0.54	0.12	0.09	*b.d.*	*b.d.*	*b.d.*
	ETD 94/284	87	12.0	0.50	0.06	0.08	*b.d.*	0.15	0.05	0.03	*b.d.*	*b.d.*	*b.d.*
	ETD 94/330	84	13.9	0.08	1.20	*b.d.*	*b.d.*	0.79	0.18	0.14	*b.d.*	*b.d.*	*b.d.*
	ETD 94/390	86	12.2	0.76	0.37	0.06	0.01	0.49	0.09	0.24	*b.d.*	0.04	*b.d.*
	ETD 94/463	86	3.07	0.29	0.02	4.34	0.52	0.77	*b.d.*	*b.d.*	*b.d.*	4.72	*b.d.*
	ETD 94/470	93	5.99	0.48	0.14	*b.d.*	*b.d.*	0.43	0.06	0.15	*b.d.*	0.01	*b.d.*
	ETD 94/475	87	10.2	1.69	0.28	0.08	*b.d.*	0.79	0.04	0.09	0.01	0.04	*b.d.*
	ETD 94/483	91	7.81	0.83	0.13	0.03	0.01	0.09	0.10	0.06	*b.d.*	0.02	*b.d.*
	ETD 94/5	97	1.13	0.62	0.16	0.35	0.01	0.26	0.06	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 95/268	91	8.18	0.44	0.38	0.18	0.01	0.10	0.09	0.03	*b.d.*	0.02	*b.d.*
	ETD 96/25	82	17.0	0.24	0.36	0.04	*b.d.*	0.12	0.20	0.07	*b.d.*	0.08	*b.d.*
	ETD 96/26	88	7.52	0.74	2.11	0.03	*b.d.*	1.19	0.08	0.09	*b.d.*	*b.d.*	*b.d.*
	ETD 96/48	98	0.42	1.06	0.14	*b.d.*	*b.d.*	0.46	*b.d.*	0.01	*b.d.*	0.06	*b.d.*
	ETD 96/49	85	12.8	0.09	0.25	*b.d.*	*b.d.*	1.15	0.15	0.13	*b.d.*	0.06	*b.d.*
	ETD 96/52	98	0.03	0.70	0.55	0.15	0.05	0.58	0.05	0.05	*b.d.*	0.03	*b.d.*
	ETD 96/56	99	*b.d.*	0.53	0.02	*b.d.*	*b.d.*	0.47	0.08	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 97/195	95	3.12	0.74	0.04	0.04	*b.d.*	0.43	0.06	0.17	*b.d.*	0.07	*b.d.*
	ETD 97/202A	99	*b.d.*	0.53	0.58	0.08	*b.d.*	0.19	*b.d.*	0.02	*b.d.*	0.06	*b.d.*
	ETD 97/202B	86	11.5	0.55	0.60	0.12	0.03	0.78	0.05	0.02	*b.d.*	0.02	*b.d.*
	ETD 97/209	92	6.29	0.80	0.12	0.15	*b.d.*	0.50	0.11	0.05	*b.d.*	0.10	*b.d.*
	ETD 97/211	98	0.09	0.91	0.03	*b.d.*	*b.d.*	0.54	*b.d.*	0.03	0.23	0.05	*b.d.*
	ETD 97/227	96	0.05	2.21	0.34	0.39	0.04	0.46	*b.d.*	0.02	0.01	0.04	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	ETD 97/231	85	11.2	0.08	1.93	*b.d.*	*b.d.*	1.25	0.38	0.02	0.01	0.07	*b.d.*
	ETD 97/232	86	12.4	0.52	0.81	0.07	*b.d.*	0.35	0.11	0.11	*b.d.*	0.03	*b.d.*
	ETD 97/234	97	0.68	1.53	0.12	0.09	*b.d.*	0.67	*b.d.*	0.08	0.02	0.07	*b.d.*
	ETD 97/238	90	8.67	0.79	0.32	*b.d.*	0.02	0.30	0.11	0.09	*b.d.*	*b.d.*	*b.d.*
	ETD 97/259	90	8.22	0.95	0.15	0.04	0.01	0.52	*b.d.*	0.09	*b.d.*	*b.d.*	*b.d.*
	ETD 97/262	89	9.53	0.59	0.38	*b.d.*	0.02	0.14	*b.d.*	0.10	*b.d.*	0.01	*b.d.*
	ETD 97/269	85	13.2	0.08	0.23	*b.d.*	*b.d.*	0.93	0.16	0.12	*b.d.*	0.07	*b.d.*
	ETD 97/271	89	8.95	0.64	0.83	0.06	*b.d.*	0.30	0.08	0.06	*b.d.*	0.11	*b.d.*
	ETD 97/272	97	0.13	0.04	1.13	*b.d.*	*b.d.*	1.06	0.08	*b.d.*	*b.d.*	0.53	*b.d.*
	ETD 97/341	89	8.49	0.14	1.90	0.02	*b.d.*	0.11	0.27	0.10	0.03	0.12	*b.d.*
	ETD 98/08	85	13.5	0.37	0.74	0.06	*b.d.*	0.19	0.16	0.13	*b.d.*	0.08	*b.d.*
	ETD 98/10	97	0.05	1.22	0.05	0.72	0.02	0.38	0.04	0.12	0.01	0.05	*b.d.*
	ETD 98/20	84	14.4	0.60	0.82	0.08	*b.d.*	0.15	*b.d.*	0.12	*b.d.*	*b.d.*	*b.d.*
	ETD 98/26	99	0.08	0.08	0.02	*b.d.*	*b.d.*	0.92	0.18	0.02	0.01	0.06	*b.d.*
	Bo 12/08	82	16.7	0.05	*b.d.*	0.03	*b.d.*	1.18	0.16	*b.d.*	*b.d.*	0.02	*b.d.*
	Bo 13/103	83	16.0	*b.d.*	*b.d.*	0.30	*b.d.*	0.39	0.07	*b.d.*	*b.d.*	0.15	*b.d.*
	Bo 13/29	81	17.6	0.27	0.05	0.57	*b.d.*	0.26	0.12	*b.d.*	*b.d.*	0.13	*b.d.*
	Bo 13/6	87	12.4	*b.d.*	*b.d.*	0.31	*b.d.*	0.53	*b.d.*	*b.d.*	*b.d.*	0.12	*b.d.*
	Bo 09/1064	79	18.3	0.53	0.68	0.38	0.01	0.39	0.21	0.03	*b.d.*	0.04	*b.d.*
	Bo 09/1712	80	16.0	0.22	2.94	0.09	*b.d.*	0.66	0.22	0.03	0.15	0.04	*b.d.*
	Bo 11/35	79	19.3	0.22	0.36	0.03	*b.d.*	0.22	0.26	0.24	0.01	0.19	*b.d.*
	Bo 13/10	84	14.6	0.10	0.09	0.06	*b.d.*	0.64	0.25	*b.d.*	*b.d.*	0.17	*b.d.*
	Bo 13/113	79	19.2	0.28	0.66	*b.d.*	*b.d.*	0.36	0.28	0.12	*b.d.*	0.21	*b.d.*
	Bo 13/119	92	6.64	0.86	0.04	0.09	*b.d.*	0.17	0.11	0.03	*b.d.*	0.15	*b.d.*
	Bo 13/130	87	10.9	0.03	0.07	0.10	*b.d.*	1.19	0.55	*b.d.*	*b.d.*	0.06	*b.d.*
	Bo 13/198	96	2.93	0.07	0.04	*b.d.*	*b.d.*	0.33	0.14	*b.d.*	0.01	0.16	*b.d.*
	Bo 13/42	75	23.8	0.08	0.74	*b.d.*	*b.d.*	0.19	0.22	0.07	*b.d.*	0.21	*b.d.*
	Bo 13/65	96	0.04	0.54	0.22	0.05	*b.d.*	2.91	0.29	0.03	0.02	0.06	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 13/97	88	10.0	0.36	0.28	*b.d.*	*b.d.*	0.39	0.93	0.06	*b.d.*	0.11	*b.d.*
MA-132561	Bo 554/p	88	10.3	0.23	0.38	*b.d.*	*b.d.*	0.26	0.10	0.20	*b.d.*	0.06	*b.d.*
	Bo 73/57b	86	13.4	0.05	0.21	0.12	0.01	0.16	0.26	*b.d.*	*b.d.*	0.06	*b.d.*
	Bo 73/57c	90	8.94	0.17	0.69	0.05	*b.d.*	0.10	0.13	0.12	*b.d.*	0.05	*b.d.*
	Bo 73/59b	84	12.1	0.03	*b.d.*	3.32	0.42	0.52	0.14	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 73/59c	84	11.1	0.06	*b.d.*	3.36	0.50	0.61	0.05	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 73/59d	89	10.3	0.46	*b.d.*	0.09	*b.d.*	0.11	0.10	*b.d.*	*b.d.*	0.03	*b.d.*
	Bo 73/77	89	10.1	0.18	0.01	0.24	*b.d.*	0.13	0.15	0.05	*b.d.*	0.05	*b.d.*
	Bo 99/17	64	27.6	0.32	5.48	0.64	*b.d.*	1.85	0.31	0.12	0.04	0.03	*b.d.*
	Bo 99/18	92	4.64	*b.d.*	2.05	*b.d.*	*b.d.*	0.70	0.11	*b.d.*	0.11	0.05	*b.d.*
	Bo 99/19	90	6.19	*b.d.*	2.14	0.75	0.03	0.66	0.09	*b.d.*	*b.d.*	0.02	*b.d.*
	ETD 99/61	88	11.1	0.10	0.02	*b.d.*	*b.d.*	0.89	0.06	*b.d.*	0.02	0.02	*b.d.*
	ETD 99/62	84	14.5	*b.d.*	0.01	0.54	0.03	0.45	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 99/63	82	15.8	0.23	0.19	0.07	*b.d.*	1.20	0.11	*b.d.*	*b.d.*	0.02	*b.d.*
	ETD 99/64	92	5.59	0.13	0.83	*b.d.*	*b.d.*	1.07	0.09	*b.d.*	0.08	*b.d.*	*b.d.*
	ETD 99/65	84	13.5	*b.d.*	2.09	0.03	*b.d.*	0.03	*b.d.*	*b.d.*	*b.d.*	0.03	*b.d.*
	ETD 99/66	88	11.2	0.22	0.56	0.02	*b.d.*	0.19	0.05	0.10	*b.d.*	0.05	*b.d.*
	ETD 99/77	85	14.1	0.02	*b.d.*	0.40	*b.d.*	0.36	0.10	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	ETD 99/91	89	8.90	0.05	0.04	1.11	0.12	0.29	0.06	*b.d.*	*b.d.*	0.02	*b.d.*
	Bo 07/566	55	36.3	*b.d.*	7.45	0.05	*b.d.*	0.50	0.60	0.49	*b.d.*	0.05	*b.d.*
	ETD 96/11	84	13.0	0.08	2.39	*b.d.*	*b.d.*	0.34	0.07	0.07	*b.d.*	0.04	*b.d.*
	ETD 96/55	83	2.34	0.61	12.25	*b.d.*	*b.d.*	0.96	*b.d.*	0.24	0.22	0.06	*b.d.*
	Bo 88/37	55	40.6	0.38	1.93	0.30	*b.d.*	0.93	0.22	*b.d.*	*b.d.*	0.14	*b.d.*
	1-3-88	84	12.3	0.28	2.48	0.82	*b.d.*	0.14	0.14	0.03	*b.d.*	0.03	*b.d.*
	1-2430-91	61	30.0	0.14	1.38	0.24	*b.d.*	2.38	4.41	*b.d.*	0.02	0.17	*b.d.*
	Bo 89/128	76	18.5	0.39	4.50	*b.d.*	*b.d.*	0.15	0.05	0.02	0.03	*b.d.*	*b.d.*
	Bo 89/29	89	10.3	0.05	0.04	0.06	0.01	0.08	0.10	0.03	*b.d.*	0.17	*b.d.*
	Bo 89/29	99	0.44	0.05	0.02	*b.d.*	0.02	0.16	*b.d.*	*b.d.*	*b.d.*	0.15	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	Bo 89/31	90	8.96	0.39	0.12	0.08	*b.d.*	0.33	*b.d.*	0.06	*b.d.*	0.32	*b.d.*
	Bo 89/99	99	0.03	0.62	0.04	0.07	0.01	0.42	*b.d.*	0.03	*b.d.*	0.14	*b.d.*
	1-106-85	56	20.4	1.07	19.45	0.76	*b.d.*	1.56	0.24	0.20	0.04	*b.d.*	*b.d.*
	1-42-88	95	0.09	1.06	3.44	0.04	*b.d.*	0.09	*b.d.*	0.04	*b.d.*	0.04	0.03
	1-85-89	88	5.86	0.66	2.47	0.10	0.05	2.35	0.10	*b.d.*	0.02	0.02	*b.d.*
	1-1990-81	84	14.8	0.89	0.09	0.09	*b.d.*	0.17	0.07	0.18	*b.d.*	0.23	*b.d.*
	Bo 05/28	90	6.98	0.43	0.86	0.12	*b.d.*	1.21	0.23	0.11	0.03	*b.d.*	*b.d.*
MA-132512	Bo 06/561	71	27.2	0.52	0.26	0.23	*b.d.*	0.78	0.26	0.08	*b.d.*	0.06	*b.d.*
	Bo 07/1325	84	15.4	0.17	0.01	0.14	*b.d.*	0.21	0.04	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	Bo 07/508	70	28.9	*b.d.*	0.20	*b.d.*	0.18	0.74	0.13	0.05	*b.d.*	0.04	*b.d.*
KERKENES DAĞ													
LATE IRON AGE													
	00CT11U01met01	92	6.60	0.33	0.42	0.36	*b.d.*	0.28	*b.d.*	*b.d.*	*b.d.*	0.03	*b.d.*
	00CT50U02met01	89	9.40	0.16	0.45	0.18	*b.d.*	0.83	*b.d.*	*b.d.*	*b.d.*	0.04	*b.d.*
	00CT51U01met01	88	10.1	0.13	1.04	0.33	*b.d.*	0.20	*b.d.*	*b.d.*	*b.d.*	0.03	*b.d.*
	02TR04U04met03	90	8.35	0.05	0.30	1.06	*b.d.*	0.24	*b.d.*	*b.d.*	*b.d.*	0.04	*b.d.*
	09CAPPU00met01	92	6.50	0.10	0.19	0.65	*b.d.*	0.47	*b.d.*	*b.d.*	*b.d.*	0.02	*b.d.*
	10TR13U16met01	79	14.5	*b.d.*	6.03	0.29	*b.d.*	0.24	*b.d.*	*b.d.*	*b.d.*	0.04	*b.d.*
	11TR23U36met01	86	13.2	0.05	0.25	0.13	*b.d.*	0.07	*b.d.*	*b.d.*	*b.d.*	0.03	*b.d.*
	11TR24U06met01	76	19.1	0.07	3.50	0.25	*b.d.*	0.19	*b.d.*	0.43	*b.d.*	0.03	*b.d.*
	11TR30U10met01	69	23.9	0.06	6.49	0.19	*b.d.*	0.16	*b.d.*	*b.d.*	*b.d.*	0.10	*b.d.*
	03TR06U12met01	82	3.97	*b.d.*	14.05	0.22	*b.d.*	0.09	*b.d.*	*b.d.*	0.07	0.04	*b.d.*
	02TR01U02met04	84	15.5	0.03	0.19	0.31	0.03	0.25	*b.d.*	*b.d.*	*b.d.*	0.03	*b.d.*
	02TR01U07met01	81	9.90	0.04	0.37	0.20	*b.d.*	1.46	7.27	*b.d.*	*b.d.*	0.05	*b.d.*
	02TR01U07met02	76	13.3	0.04	0.37	0.17	*b.d.*	1.89	8.00	*b.d.*	*b.d.*	0.06	*b.d.*
	02TR02U04met01	98	1.32	0.05	0.39	0.05	0.01	0.11	*b.d.*	*b.d.*	*b.d.*	0.06	*b.d.*
	02TR02U10met08	88	9.86	0.06	0.13	1.10	0.12	0.28	*b.d.*	*b.d.*	*b.d.*	0.03	*b.d.*

Mannheim Number	Object Number	Cu wt.%	Sn wt.%	As wt.%	Pb wt.%	Ni wt.%	Co wt.%	Fe wt.%	Zn wt.%	Sb wt.%	Bi wt.%	Ag wt.%	Au wt.%
	02TR02U10met09	88	10.9	0.10	0.39	0.22	*b.d.*	0.47	*b.d.*	*b.d.*	*b.d.*	0.04	*b.d.*
	02TR02U10met11	81	9.16	0.03	0.25	0.21	*b.d.*	1.37	7.79	*b.d.*	*b.d.*	0.04	*b.d.*
	02TR05U13met01	63	*b.d.*	*b.d.*	0.41	0.45	*b.d.*	0.46	*b.d.*	*b.d.*	0.34	35.18	0.16
	03TR05U02met03	91	8.06	0.22	0.49	0.35	*b.d.*	0.42	*b.d.*	*b.d.*	*b.d.*	0.03	*b.d.*
	04TR16U15met03	83	14.7	0.23	1.14	0.06	*b.d.*	0.09	0.72	0.06	0.01	0.08	*b.d.*
	05TR15U09met01	83	*b.d.*	*b.d.*	0.20	0.57	*b.d.*	1.15	*b.d.*	*b.d.*	0.12	14.50	0.09
	05TR15U14met02	81	18.1	0.07	0.23	0.17	*b.d.*	0.21	*b.d.*	*b.d.*	*b.d.*	0.03	*b.d.*
	05TR16U17met02	98	1.41	0.12	0.24	0.13	*b.d.*	0.09	*b.d.*	0.04	*b.d.*	0.02	*b.d.*
	05TR16U17met03	85	13.7	0.28	0.98	0.11	*b.d.*	0.15	0.05	0.17	*b.d.*	0.15	*b.d.*
	05TR17U12met01	84	7.55	0.09	0.32	0.32	*b.d.*	1.88	5.86	*b.d.*	0.02	0.02	*b.d.*
	05TR17U14met01	81	11.5	0.35	0.38	0.08	*b.d.*	0.56	5.74	0.11	0.02	0.07	*b.d.*
	05TR17U14met01	83	13.4	0.15	0.92	0.29	*b.d.*	0.96	1.37	*b.d.*	*b.d.*	0.03	*b.d.*
MA-132627	05TR17U14met02	87	12.1	0.03	0.05	0.26	0.05	0.35	*b.d.*	*b.d.*	*b.d.*	0.03	*b.d.*
	05TR17U14met06	87	11.7	0.01	0.09	0.31	0.05	0.39	*b.d.*	*b.d.*	*b.d.*	0.03	*b.d.*
	05TR21U12met01	87	12.6	0.03	0.13	0.23	0.02	0.17	*b.d.*	*b.d.*	*b.d.*	0.02	*b.d.*
	05TR21U17met01	86	12.7	0.02	0.26	0.17	*b.d.*	0.56	*b.d.*	*b.d.*	*b.d.*	0.02	*b.d.*
	96TT17U05met01	87	12.9	0.22	0.10	0.20	*b.d.*	0.16	*b.d.*	*b.d.*	*b.d.*	*b.d.*	*b.d.*
	96ST05U07met02	92	7.43	0.40	0.19	0.14	*b.d.*	0.35	*b.d.*	0.03	*b.d.*	0.02	*b.d.*

APPENDIX D: LEAD ISOTOPE ANALYSIS RESULTS

Lead isotope analysis is an accepted method in archaeology to determine the provenance of several classes of materials, including many metals (Pernicka 2014: 247). The element lead (Pb) has four stable isotopes ^{208}Pb, ^{207}Pb, ^{206}Pb, and ^{204}Pb. Of these four isotopes, only ^{204}Pb is non-radiogenic where ^{208}Pb, ^{207}Pb and ^{206}Pb are formed by the regular decay of ^{232}Th, ^{235}U and ^{238}U respectively (Allègre 2008: 294-312). The unique relationship among these four isotopes of lead, which are often expressed in ratios, theoretically allow for the calculation of geological age based on principles of radiometric geochronology (ex. U-Pb and Pb-Pb dating). The specificity of lead isotope ratios coupled with the fact that ultra-trace amounts of lead occur in many materials, including most if not all archaeological metals, allows for a robust and relatively straightforward way to ascertain material alteration, transport and provenience (Aggarwal, et al. 2008: 2662). There exist three important conditions concerning the study of lead isotopes to characterize sources and artifacts:

1.) The relative concentrations of these four isotopes are assumed to have been uniform throughout the earth at the time it was formed;

2.) Isotopes ^{208}Pb, ^{207}Pb, and ^{206}Pb have continued to be formed on earth from the radioactive decay of uranium and thorium. Therefore, naturally occurring lead is composed of a diagnostic mixture of radiogenic and original terrestrial lead

3.) Ratios of lead isotopes vary depending on the geological age of the ore body and the conditions under which it mineralizes, the proportions of which vary among geological formations (Guilbert and Park 2007: 286-290).

Additionally, because different ore sources often have unique lead isotope ratios according to a specific geological origin, *variation among different sources can in some cases be greater than variation within sources* (Weigand, et al. 1977). Under these conditions, the isotopic analyses of metal objects and metal-rich residues, which often contain measurable amounts of lead, can be compared to lead isotopes from known ore sources (Brill and Wampler 1967; Gale and Stos-Gale 1982; Grögler, et al. 1966). Strong similarities among artifacts and ore sources can be used as evidence for their provenance.

While much debate and contention surrounds the nature of artifact-ore relationships and how one ascertains these relationships (Budd, et al. 1996; Budd, et al. 1993; Gale 2001; Knapp 2000) for the purposes of this study, I will judge artifact-ore relationships in terms of source discrimination. Since geographically distinct ore sources can have very similar lead isotope ratios, similarity in isotope ratios does not necessarily equate to congruity in artifact-ore relationships (Pollard, et al. 2007: 17). For this reason, this study aims to eliminate as many conceivably utilized sources as possible based on their isotopic signatures.

Artifact samples were carefully selected and prepared in the laboratory to avoid cross contamination. For non-drilling samples, all surfaces were mechanically abraded using clean, lead-free silica polish and set aside. Samples were further prepared for chemical separation and lead purification for analysis by MC-ICPMS using methods described in Höppner et al. (2005: 303) and Niederschlag et al. (2003).

Comparative lead isotope data for ores used in this study are previously published. These data were generated by decades of research by the Oxford group (Gale, et al. 1997; Gale, et al. 1985; Rohl 1996; Stos-Gale and Gale 2009; Stos-Gale, et al. 1996; Stos-Gale, et al. 1998; Stos-Gale, et al. 1995; Stos-Gale, et al. 1984), the Heidelberg group (Lutz, et al. 1994; Pernicka, et al. 1984; Seeliger, et al. 1985; Wagner, et al. 1986, 1989; Wagner, et al. 2003; Wagner and Öztunalı 2000; Wagner, et al. 1985), research at the Smithsonian Institute (Sayre, et al. 2001; Sayre, et al. 1992; Yener, et al. 1991), the Deutsches Bergbau-Museum (Yalçın and Maass 2013), and select analyses by the Tokyo group (Hirao, et al. 1995).

Mannheim Number	Find Number	Site	^{208}Pb/^{206}Pb mean	^{207}Pb/^{206}Pb mean	^{206}Pb/^{204}Pb mean	^{208}Pb/^{204}Pb calc mean	^{207}Pb/^{204}Pb calc mean
MA-132200	Bo 06/253	Boğazköy	2.0783	0.83986	38.663	15.624	18.603
MA-132303	Bo 11/590	Boğazköy	2.0652	0.83282	38.813	15.652	18.794
MA-132443	Bo 06/1837	Boğazköy	2.0648	0.83068	38.837	15.624	18.809
MA-132185	B0 170/h	Boğazköy	2.0717	0.83543	38.878	15.678	18.766
MA-132306	Bo 06/1397	Boğazköy	2.0746	0.83682	38.762	15.635	18.684
MA-132389	Bo 06/500	Boğazköy	2.0758	0.83782	38.674	15.609	18.631
MA-132439	Bo 06/1751	Boğazköy	2.0729	0.83589	38.765	15.632	18.701
MA-132188	Bo 284/e	Boğazköy	2.0566	0.82708	39.051	15.705	18.988
MA-132204	Bo 08/9	Boğazköy	2.0714	0.83522	38.746	15.623	18.705
MA-132190	B0 216/p	Boğazköy	2.0714	0.83523	38.741	15.621	18.703
MA-132198	Bo 08/24	Boğazköy	2.0706	0.83530	38.822	15.661	18.749
MA-132199	Bo 08/101	Boğazköy	2.0714	0.83636	38.820	15.674	18.741
MA-132307	Bo 06/492	Boğazköy	2.0607	0.83129	38.819	15.660	18.838
MA-132309	Bo 06/189	Boğazköy	2.0722	0.83955	38.485	15.592	18.572
MA-132178	Bo 84/551	Boğazköy	2.0580	0.82847	38.962	15.685	18.932
MA-132182	Bo 82/138	Boğazköy	2.0568	0.82763	38.989	15.689	18.956
MA-132183	Bo 171/h	Boğazköy	2.0715	0.83753	38.660	15.631	18.663
MA-132191	Bo 864/t	Boğazköy	2.0761	0.83916	38.659	15.626	18.621
MA-132194	Bo 861/t	Boğazköy	2.0706	0.83448	38.954	15.699	18.813
MA-132444	Bo 06/1601	Boğazköy	2.0557	0.82711	39.001	15.692	18.972
MA-132476	Bo 06/1742	Boğazköy	2.0671	0.83352	38.851	15.666	18.795
MA-132180	Bo 477/d	Boğazköy	2.0582	0.82735	39.036	15.692	18.966
MA-132591	02TR03U11met02	Kerkenes Dağ	2.0475	0.82848	38.591	15.615	18.848
MA-132594	11TR23U22met01	Kerkenes Dağ	2.0774	0.83848	38.766	15.647	18.661
MA-132596	11TR24U22met08	Kerkenes Dağ	2.0630	0.83272	38.867	15.688	18.840
MA-132604	00CT18U17met02	Kerkenes Dağ	2.0738	0.83673	38.801	15.655	18.710
MA-132605	11TR24U22met07	Kerkenes Dağ	2.0633	0.83313	38.819	15.675	18.814
MA-132606	11TR24U21met01	Kerkenes Dağ	2.0861	0.84550	38.497	15.603	18.454

Mannheim Number	**Find Number**	**Site**	**^{208}Pb/^{206}Pb mean**	**^{207}Pb/^{206}Pb mean**	**^{206}Pb/^{204}Pb mean**	**^{208}Pb/^{204}Pb calc mean**	**^{207}Pb/^{204}Pb calc mean**
MA-132608	11TR24U15met01	Kerkenes Dağ	2.0793	0.83976	38.721	15.638	18.622
MA-132614	11TR24U22met06	Kerkenes Dağ	2.0655	0.83387	38.802	15.665	18.786
MA-132619	11TR24U22met03	Kerkenes Dağ	2.0789	0.84021	38.720	15.649	18.625
MA-132621	11TR29U34met02	Kerkenes Dağ	2.0822	0.84304	38.481	15.580	18.481
MA-132622	11TR24U22met04	Kerkenes Dağ	2.0782	0.84669	38.116	15.529	18.341
MA-132623	11TR29U14met02	Kerkenes Dağ	2.1100	0.85855	38.016	15.468	18.017
MA-132624	11TR24U20met01	Kerkenes Dağ	2.0722	0.83670	38.870	15.695	18.758
MA-132626	11TR24U11met03(tack)	Kerkenes Dağ	2.0926	0.85090	38.447	15.634	18.373
MA-132615	11TR24U11met03(sheet)	Kerkenes Dağ	2.0838	0.84779	38.398	15.622	18.427
MA-132631	11TR24U11met02	Kerkenes Dağ	2.0485	0.82551	38.809	15.639	18.945

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