

Copper Metallurgy in Cilicia and the Amuq
in the Second Millennium BC:
Insights into Aspects of Bronze Age Technology and Trade

By

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ABSTRACT

This doctoral dissertation investigates the position and significance of the southern Anatolian coast within the exchange networks of the eastern Mediterranean and the Near East during the second millennium BC (Middle and Late Bronze Ages). To investigate this, the project employed chemical and lead isotope analysis of copper objects from the Bronze Age sites of Tarsus, Kinet, and Tell Atchana in the plains of Cilicia and Amuq in southern Turkey, to examine both the possible sources of the metal and the techniques by which this material was manufactured into finished artifacts. The observed patterns of copper technology and trade are compared to the evidence from the wider Mediterranean and the Near East, so as to identify the correlations and distinctions between the study region and the broader world of the second millennium BC.

The study assemblage consists of around one hundred metal artifacts, and includes such items as pins, small tools, arrowheads or small ornaments. The samples were selected from three different periods of the second millennium BC, the Middle Bronze Age (ca. 2000-1600 BC), the Late Bronze Age I (ca. 1600-1400 BC) and the Late Bronze Age II (ca. 1400-1200 BC), so that a comparison between these periods could be made. Both chemical and compositional analyses were performed by means of mass spectrometry, at the laboratories of Deutsches Bergbau Museum in Bochum in Germany.

The chemical analysis demonstrates a gradual shift from the arsenical-copper metallurgy to the use of tin-bronze through the second millennium BC, which correlates well with the general pattern in the Mediterranean and the Near East.

However, compared to certain other areas in the wider Mediterranean, this transition appears to have been a slower process in the plains of Amuq and Cilicia. The isotope analysis indicates that throughout the second millennium BC all three sites were supplied to a major extent by the same copper sources, the significance of which, however, fluctuated with time and locality. Possible explanations of these observed patterns in the analytical data are discussed within the frame of the socio-political and economic conditions of the period.



to my mother and father...

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Map 1. Major sites discussed in the text.

1. INTRODUCTION

This thesis investigates the role of the southern Anatolian coast in the exchange networks of the eastern Mediterranean and the Near East during the second millennium BC. Metal objects are chosen as the material of study, as their compositional and isotope analyses effectively illuminate regional aspects of technology and exchange that can be compared with the patterns from the wider Mediterranean and the Near East. To carry out this investigation, I employ geochemical and lead isotope analysis of copper artifacts from three Bronze Age sites in the region: Tarsus, Kinet Höyük, and Tell Atchana.

1.1. BRONZE AGE AND ARCHAEOLOGICAL METALLURGY

Copper industry and the circulation of copper and tin constituted a major and essential part of Bronze Age economies. Copper alloys formed the base metal, from which weapons and tools were manufactured. In addition to being the material of such strategically crucial commodities, copper alloys were also a cheaper alternative to precious metals (gold and silver) in the production of prestige and symbolic objects (Sherratt and Sherratt 1991, 361; Monroe 2009, 271). Besides copper, tin, the other constituent of bronze, appears as the second strategic metal of the period. The acquisition and circulation of this metal must have been even more crucial as it was apparently being imported from distant sources due to its scarcity in the Near East and the Mediterranean.

In addition to their intrinsic value, metals, precious or not, also had a convertible value in the economic systems of the Bronze Age, as they could be used, stored, recycled, and redistributed in a variety of forms (Sherratt 2000, 83). In this respect, metals played a crucial role in the operation of commerce, as they commonly functioned as a form of currency, or at least a standardized value system, in the pre-monetary economies of the Bronze Age. This was achieved as the prices of land and commodities were often expressed in terms of weighed amounts of metal. As far as the second millennium BC was concerned, silver was the metal most commonly used for this purpose, while copper, gold and tin are also known to have served the same function (Larsen 1976, 104; Sherratt and Sherratt 1991, 360; Knapp and Cherry 1994, 146; Snell 1995, 1491-93; Monroe 2009, 278).

Due to this significant role played by metals in antiquity, the studies of ancient metal objects and metallurgical practices, i.e., archaeometallurgy, has proven to be an invaluable means of archaeological inquiry for illuminating the exchange patterns, technology, and industrial organization of ancient societies. With particular respect to the Bronze Age, copper and its alloys appear to be the most informative as they constitute the most widely used sort of metal during this period.

1.2. CHRONOLOGICAL LIMITS OF STUDY

This thesis focuses on the timespan from 2000 to 1200 BC, which corresponds to the Middle and Late Bronze Age periods in the Near East and the Mediterranean. The Middle Bronze Age (ca. 2000-1600 BC) witnessed the emergence of certain interregional commercial networks that linked polities separated by vast distances (Larsen 1987; Sherratt and Sherratt 1991, 368-69; Van de Mieroop 94-105). Textual

evidence shed light particularly on two major trade routes of the period. The first of these linked Assur in northern Mesopotamia with Kaneš (modern Kültepe) in central Anatolia from about 1950 to 1750 BC (Larsen 1976; Larsen 1987). The second route was active in the 18th century BC, linking the Elamite polities of southwestern Iran with Mari on the Euphrates, and ultimately with the Mediterranean coast (Muhly 1995, 1509-11). Various sorts of luxury goods of metal, stone or textile were being transferred along these exchange networks. However, raw copper and tin were the most crucial commodities in circulation. Particularly significant was the import of tin from source areas east of Mesopotamia. Even though the absolute origin of tin still constitutes a matter of academic debate, textual evidence strongly implies that tin used in the Near East and the Mediterranean during the second millennium BC had its likely origins in central Asia or Afghanistan (Boroffka et al. 2002; Weeks 2003, 165-95; Cierny, Stöllner, and Weissgerber 2005; Yener 2009, 148-50; Pigott 2011). Thus, cuneiform archives from Kaneš and Mari testify that tin from eastern sources reached central Anatolia, the coastal regions of the Levant, and as far west as Crete during this period (Dossin 1970; Klengel 1992, 77-78; Knapp and Cherry 1994, 145).

Archaeometallurgical studies demonstrated that during the preceding third millennium BC, the consistent use of tin-bronze was primarily confined to certain parts of the Near East, such as Mesopotamia, southeastern Arabia, central Anatolia, and the northeastern Aegean. At the beginning of the second millennium BC, however, tin-bronze metallurgy spread to such new regions as Syria and Palestine (Moorey and Schweizer 1972, Phillip, Clogg, and Dungworth 2003), Cyprus (Balthazar 1990, 431) and the southern Aegean (Papadimitriou 2008, 280-81), parallel to the information provided by the Mari texts. In sum, the early second millennium

BC witnesses a more widespread use of tin-bronze, which was gradually replacing the copper-arsenic alloy, the other widely used copper-based metal of the Bronze Age.

The Late Bronze Age (ca. 1600-1200 BC), is characterized by the intensification of diplomatic correspondence and interregional exchange. Powerful territorial states such as the New Kingdom of Egypt, the Hittite Kingdom in Anatolia, Kassite Babylonia, and the Kingdom of Mittani in northern Mesopotamia and Syria emerge at the beginning of this period. During the second half of the period, namely in the 14th and 13th centuries BC, this league of major powers is complemented by the newly emergent Middle Assyrian Kingdom, the major trading port of Ugarit on north Syrian coast, and the kingdom of Alashiya, apparently the island of Cyprus or a part thereof (Van De Mieroop 2007, 129-42; Sherratt and Sherratt 1991, 369-73). Palace archives and royal annals recovered at the capitals of Egypt, Hatti, Assur, Kassite Babylonia, and at Ugarit shed light on intensified diplomatic correspondence and the large scale circulation of commodities, particularly after 1400 BC. Despite their absence in the realm of written correspondence, Minoan and Mycenaean polities of the Aegean appear to be also in commercial contact with the eastern Mediterranean as documented by archaeological evidence (Sherratt and Sherratt 1991, 370-73).

The intensification of interregional circulation of materials is reflected in metallurgical production, which displays not only a visible increase in the use of tin, but also in the manufacture of copper-based metals in general. In the Late Bronze Age, particularly during its second half, copper-based metals became more numerous and their typological repertoire became more diverse (Iakovidis 1982, 214; Muhly 2003, 144; Papadimitriou 2008, 282). Rich copper sources on Cyprus are now being exploited in massive scales and constituted a major part of the copper available in interregional circulation. This large scale exchange in raw metal is well documented

in textual sources, such as the Amarna archive of the mid-14th century BC, as it refers to nearly fifteen tons of copper sent from Alashiya to Egypt in a single shipment alone (Moran 1992, 107). Bulk shipment of both copper and tin is also evidenced by the discovery of a late 14th century BC shipwreck on the south Anatolian coast, the cargo of which incorporated ten tons of copper along with one ton of tin (Pulak 2000; Pulak 2005, 59-65).

The extensive political, cultural, and commercial contacts between distinct regions and polities of the second millennium BC have attracted interest from archaeologists, historians and linguists, particularly in the last two decades. Not surprisingly, the issues surrounding the sources and circulation of copper and tin constitute an important part of this interest. As a result, archaeometallurgical study programs of vast scopes have been carried out to explore these subjects¹. The rich body of data from these researches provides the backdrop, against which the results of this thesis will be evaluated to assess the significance of the studied region within the interaction spheres of the period.

Following the disruptions around 1200 BC, the large-scale interregional trading systems of the Late Bronze Age collapsed. The crisis especially affected highly centralized palatial economies, leading to the disappearance or significant attenuation of the Hittite Kingdom, the trading port of Ugarit and the Mycenaean palatial centers in the Aegean (Sherratt and Sherratt 1991, 373-75; Van de Mieroop 2007, 197-206). The 12th and 11th centuries BC constitute a period of changing settlement patterns and reorganization of trade routes in the eastern Mediterranean and the Near East. The situation of metal industries and trade during this period of

¹ These researches are outlined in Pigott 1996, Stos-Gale and Gale 2003, Kassianidou and Knapp 2005, Stos-Gale and Gale 2009.

transition would constitute a research topic in its own right. Hence, 1200 BC defines the lower chronological boundary of this research.

1.3. GEOGRAPHICAL SCOPE OF WORK

This project focuses on a specific part of the eastern Mediterranean that is constituted by the plains of Adana (Cilicia of later antiquity, modern Çukurova) and Amuq (modern Amik Ovası) in southern Turkey. During the second millennium BC, these two areas were respectively parts of Kizzuwatna and Mukiš, two countries known from textual sources. The samples studied in this research are taken from the archaeological inventories of three well excavated and studied sites: Tell Atchana in the Amuq, and Tarsus/Gözlükule and Kinet Höyük respectively situated in the western and eastern parts of the Cilician Plain. Archaeological research indicates that these settlements were the most prominent centers in this region during the period under consideration (Woolley 1955; Goldman 1956; Stein 1997; Yener 2005; Yener 2010; Yener 2013; Özyar 2005b; Gates 2000; Gates 2006).

Second millennium BC documents illuminate the political history of the region to a certain extent. Tell Atchana is identified as ancient Alalakh, which appears as the capital of the small but important kingdom of Mukiš during both the Middle Bronze (Alalakh Level VII) and the Late Bronze (Alalakh Level IV) Ages. Several hundred cuneiform tablets, which mostly contain economic accounts, were discovered in the public buildings of these two levels. During the period of Alalakh Level VII (17th century BC), Mukiš appears as a vassal of the Kingdom of Iamhad centered at Aleppo. During the period of Alalakh Level IV (15th century BC), it became the

subject of the kingdom of Mittani, the dominant political power in north Syria (Woolley 1955, 377; Yener 2005, 101-2; von Dassow 2008, 12-45).

The country of Kizzuwatna, which incorporated the plain of Cilicia, was an independent entity in the late 16th and 15th centuries BC as testified by its treaties with the Hittite kingdom (Beal 1986, 426; Bryce 1998, 111). However, for a brief period during the late 15th century BC, the kingdom of Mittani likely exercised a certain degree of hegemony over this country as well. With the demise of the Mittani kingdom in the 14th century BC, the control of both Cilicia and the Amuq fell into Hittite hands (Beal 1986, 435-40; Özyar 2005b, 4; Yener 2005, 102-3; von Dassow 2008, 61-64). Hittite involvement in the 14th and 13th centuries BC is well documented in archaeological record from all three sites. This is particularly manifested by numerous Hittite seals and sealings, and typical Hittite features observed in the architecture of large scale public buildings (Woolley 1955, 166-71; Yener 2005, 100, 110-11; Goldman 1956, 49-50; Gates 2006, 295-97). During the period of Hittite overlordship, Tarsus, which is referred to as Tarsa in texts, appears as a particularly significant administrative and cultic center in Kizzuwatna (Götze 1940, 10; Bryce 1998, 219-20, 273-74). Fourteenth and thirteenth century BC contexts of the site yielded the largest collection of Hittite administrative seals recovered outside the Hittite heartland (Gelb 1956).

The regional kingdom of Mukiš must have acted as a link to the Mediterranean Sea for its overlords to the east, namely Iamhad in the Middle and Mittani in the Late Bronze Age. Incorporating the Cilician Pass, the most important gateway between central Anatolia and the Mediterranean coast, the country of Kizzuwatna must have served the same function for the largely land-locked Hittite Kingdom. Strategically situated at the intersection of the Mediterranean with Anatolia and the Near East,

these two regions must have played pivotal roles in the circulation of materials including metals. Accordingly, this particular part of the Mediterranean carries a significant potential to provide insights into interregional exchange, as well as technological aspects of production in the second millennium BC, and was therefore chosen as the region of study in this research.

1.4. PREVIOUS ARCHAEOMETALLURGICAL RESEARCH

Previous research on the prehistoric metallurgy of Cilicia and the Amuq was predominantly concerned with the compositional analysis of copper-based artifacts (Esin 1969, Yalçın 2000 , Kuruçayırılı and Özbal 2005, and Dardeniz 2007 for Cilicia; Braidwood, Burke, and Nachtrieb 1951; Braidwood and Braidwood 1960; Moorey and Schweizer 1972; Özbal 2006; Selover 2010 for the Amuq). The outcome of these studies can be summarized as follows: In this region, tin-bronze was used infrequently during the third millennium BC, when unalloyed and arsenical copper were predominant. More consistent use of this alloy is observed during the second millennium BC, in accord with several other parts of the eastern Mediterranean.

As far as the lead isotope analysis is concerned, the small assemblage of copper artifacts studied from prehistoric Cilicia demonstrated the high degree of diversity in utilized copper sources (Gale, Stos-Gale, and Gilmore 1985, 167-71). Besides these copper objects, a few artifacts of lead and silver from the fourth and third millennium BC contexts were also subjected to isotope analysis. The results of the study indicated that the central Taurus Mountains, already known for their rich lead and silver deposits, likely supplied both Cilicia and the Amuq well before 2000 BC (Yener et al. 1991).

However, the number and scope of the archaeometallurgical study programs from the region appears quite limited when compared to those from other parts of the Mediterranean, particularly Cyprus, the Aegean, and Sardinia. This difference becomes even more visible with particular respect to the second millennium BC, as several studies from the region are entirely or predominantly concerned with periods either predating (Braidwood, Burke, and Nachtrieb 1951, Braidwood and Braidwood 1960, Esin 1969, Yalçın 2000) or postdating (Dardeniz 2007) this millennium. Thus, only a relatively small portion of the studied assemblage from the region belongs to this period.

There are also certain other issues that constitute problems and need investigation. Firstly, within the studied assemblage from the Amuq, there is no single sample that can be securely dated to the Middle Bronze Age. Furthermore, in studies focusing on the Late Bronze Age of the Amuq, a distinction between the Late Bronze I and Late Bronze II materials is not clearly evident. As a result, even if archaeometallurgical research indicates that the consistent use of tin-bronze in the Amuq was a phenomenon of the second millennium BC, we are not in a situation to tell explicitly when it started. Finally, as far as lead isotope research is concerned, the number of analysis from both Cilicia and the Amuq is confined to thirty-three samples, which constitute only a small body of data. Hence, compared to several other parts of the eastern Mediterranean, the accumulated data from this significant region appears limited for an effective characterization of the technological and commercial aspects of metal industries.

1.5. SCOPE AND METHODOLOGY

In this study, a total of 108 copper-based artifacts have been selected for sampling. In the assemblage, Tarsus, Kinet Höyük, and Tell Atchana are represented by thirty-four, thirty-one and forty-three samples respectively. These items were subjected to compositional and lead isotope analysis, both of which were performed by means of inductively-coupled plasma mass spectrometry at Deutsches Bergbau Museum in Bochum, Germany. The compositional analysis measured the concentrations of fourteen chemical elements within the copper-based matrix of each sample. The primary objective of this analysis is to delineate the aspects of alloy use, focusing particularly on two major alloy constituents, namely tin and arsenic. Within this scope, the investigation of the relative abundance of tin-bronze constitutes an especially significant part of the research. As tin was imported into the Mediterranean basin from distant sources during this period, the intensity of its usage is regarded an indicator of the degree of access to interregional exchange networks. Thus, a particular focus of the study is to determine during which phase of the second millennium BC tin started to be used consistently, an issue that has been only partially illuminated by earlier research. To achieve this, special attention was paid to sample only those artifacts that are dated precisely to one of these three major chronological phases: Middle Bronze Age (ca. 2000-1600 BC), Late Bronze Age I (ca. 1600-1400 BC) and Late Bronze Age II (ca. 1400-1200 BC).

Besides the determination of alloy constituents, the basic statistical parameters, namely median and variance are computed for each chemical element. Inter-element relationships are investigated in detail by means of more complex statistical techniques, namely binary correlation and principal component analyses. The goal of

these analyses is to examine whether the samples can be grouped into certain clusters with respect to their geochemical compositions. This information will be combined with the results of the lead isotope analysis so as to delineate the degree of diversity of copper sources and their variation between sites and periods. Finally, inferences about the possible origins of copper, which are provided by the lead isotope analysis, will be discussed and evaluated. It is, however, to note that commenting on the absolute provenance of copper is not a straightforward process due to certain inherent limitations of the method as I will discuss in detail in Chapter 5.

Subjecting an adequate number of samples to analysis from both Cilicia and the Amuq, this thesis will enrich the currently limited compositional and isotope data from the second millennium BC south Anatolia and significantly broaden our understanding of the position of this region within the interaction networks of the Middle and Late Bronze Ages. To achieve these aims, the thesis is broken into the following parts: Chapter 2 reviews the second millennium BC history of the studied region. The proceeding Chapter 3 addresses the patterns of exchange and production of copper-based metals during this millennium in the broader context of the Mediterranean and the Near East. These two chapters together constitute the background information, against which the outcome of this study will be assessed and interpreted. Chapters 4 and 5 respectively present the results of the compositional and isotope analysis. In each chapter, the presented information will be digested in a concise summary and conclusion section at the end.

2. CILICIA AND AMUQ IN THE SECOND MILLENNIUM BC

2.1 INTRODUCTION

This chapter presents the second millennium BC history of Cilicia and the Amuq, as far as it could be reconstructed from the combined textual and archaeological evidence. The primary aim of this overview is to delineate the historical events and circumstances, which might have conditioned the aspects of metal production and trade. In this respect, the similarities and differences between different sites and time periods may be the results of particular historical conditions in operation. Besides, the discussion also aims at illuminating the patterns of interaction of the study region with the outside world, which is expected to be complemented by the outcome of this research.

To explore these subjects effectively, this discussion is divided into two parts. The first of these, Section 2.2, presents the history and outcome of the archaeological work at each site under study. A primary focus is the absolute chronology, which, however, is most of the times far from being certain and constitutes a matter of scholarly debate. In the subsequent Section 2.3, the political history of Cilicia and the Amuq will be addressed in more detail.

2.2 ARCHAEOLOGY AND CHRONOLOGY

2.2.1. Tell Atchana/Alalakh

Archaeological Work

Tell Atchana, Alalakh of the Bronze Age, is situated in the Amuq plain, within the Hatay province of Turkey (classical Antioch). The site had originally been excavated by Sir Leonard Woolley under the sponsorship of the British Museum and the University of Oxford, with hopes to discover a site that exposes cultural links between the ancient civilizations of the Near East and the Aegean. Among many prehistoric mounds identified in the Amuq Plain in earlier surveys, Tell Atchana was chosen as a potential site to reveal such connections. This decision was primarily influenced by the strategic location of this site on the Orontes River, which forms a natural gateway between the Mediterranean coast and inland Syria (Stein 1997; Yener 2005, 99-100). Following the exploratory soundings in 1936, excavations were carried out between 1937 and 1939 until their interruption by the Second World War. The work resumed after the war and continued for four successive seasons from 1946 to 1949.

The mound has horizontal dimensions of 750 x 325 meters, occupying an area of 22 hectares, and is 9 meters high at its peak (Yener 2005, 99). Woolley's excavations identified eighteen habitation levels spanning the period roughly from 2000 to 1200 BC, and thus, covering the entirety of the Middle and Late Bronze Ages. In the excavation report, these levels are designated and numerated from the earliest Alalakh XVII to the latest Alalakh 0. Among these strata, Level VII (17th-16th century

BC), and Level IV (15th century BC) appeared to be the most impressive and significant, as both exposed a palace with associated cuneiform archives. Through the preliminary investigation of textual material, the site has been immediately and undoubtedly identified as ancient Alalakh, the capital of the regional kingdom of Mukiš.

Epigraphical studies of the archives were published by S. Smith in 1940 and by J. Wiseman in 1953, which were followed by the final publication of the excavation results by Woolley in 1955. The finds from Woolley's first series of excavations between 1936 and 1939 are distributed between the local archaeological museum in Hatay, the British Museum, University College, the Ashmolean Museum, Nicholson Museum, and Cyprus. The material from the second, postwar stage of excavations is kept in Hatay Archaeological Museum and the storage facilities of the current field project.

Survey work at the site was resumed in the year 2000 under the directorship of Prof. K. A. Yener as part of the Amuq Valley Regional Project of Chicago University. Since 2003, the same director carries out excavations, first as part of the Amuq Valley Regional Project and currently under the auspices of Koç University. The new series of excavations heretofore unearthed primarily Late Bronze Age contexts, and recently started to expose Middle Bronze Age strata. The results of the 2003-2004 excavation seasons and material studies were published in 2010 (Yener 2010), while a new volume focusing exclusively on Late Bronze Age II levels is forthcoming.

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The earliest strata, namely Levels XVII-VIII, were designated by Woolley as “archaic levels”, and were encountered only in two deep soundings. Hence, these early phases of occupation were not well represented in terms of finds. The most noticeable outcome from these soundings was the discovery of a temple in the earliest stratum, which marks the foundation of the settlement at the beginning of the second millennium BC. Evidence from later strata demonstrated that the temple continued to be rebuilt at the same spot until the final phase of the settlement (Woolley 1955, 10-32). The pottery of these early levels is characterized by the Syro-Cilician Painted Ware, a hallmark of Cilicia, the Amuq, and the Aleppo area during the early second millennium BC (Stein 1997, 57-58).

It was in Level VII that Alalakh first appears as a fortified urban town and more importantly, a palatial center with textual archives. A total of 175 cuneiform tablets have been found in the archive rooms of the palace and the temple. The documents were written in Akkadian and primarily contain inventories, ration lists, and lists of people with their occupations. These texts provide sufficient evidence to identify this town as Alalakh, the capital of the kingdom of Mukīš; and bear the names of two rulers: Iarim-Lim and his son and successor Ammitaqum. This relatively small but important local kingdom appears as a vassal to the greater, regional kingdom of Iamhad. With its capital at Aleppo, Iamhad controlled most of north Syria; and was one of the most powerful political entities in the Near East during the early centuries of the second millennium BC (Wiseman 1953, 2-4; Stein 1997, 55; Yener 2005, 101; von Dassow 2008, 12-16). The contacts of this palatial center with the outside world are well reflected in the international character of its elite art. This is especially

manifested by the palace frescoes that echo Minoan designs (Niemeier and Niemeier 1998, 82-85), and the local cylinder seals and seal impressions that feature Babylonian, Egyptian and Cappadocian motifs (Collon 1975, 198).

Alalakh Level VII ends with a destruction, after which the palace went out of use. The subsequent Levels VI and V, each of which were divided into subphases A and B by Woolley, continued to be well fortified settlements. The architecture of these strata, however, was not well understood, due to the disturbance by later building activities. The period spanned by these two levels were designated by Woolley as the “Dark Age”, due to the paucity of textual material. Nevertheless, a large public building in Level VB appears to have an administrative function and could be identified as a palace (Yener 2005, 107, fig. 4.28, 4.29).

As far as ceramic record is concerned, Level VI witnessed an abundance of Syro-Palestine wares, which continues into the succeeding Level V. Cypriot imports first appear at Level VIA in the form of Bichrome, Red-on-Black and Monochrome Wares. These are followed by White Slip I and Base Ring I wares in Level VIB. In Level V, White Slip I continues to be imported, while White Slip II and Base Ring II Wares start to occur (Stein 1997, 58).

Alalakh Level IV is architecturally well documented with its administrative and residential buildings. A new and large scale palace was built during this period, which incorporates the earlier Level VB palace as its southern wing (Woolley 1955, plate XXII, Yener 2005, fig. 4.30). In terms of pottery imports, it was in Level IV that Nuzi Ware was introduced into Alalakh. Cypriot White Slip I, White Slip II, and Base Ring II Wares continued to be imported, whereas Bichrome Ware now disappears (Stein 1997, 58).

The archive of Level IV, which consists of nearly 300 tablets, to a large extent contains census lists and inventories like the earlier Level VII documents. Idrimi, Niqmepa, and Ilmilimma are referred to as the three rulers of Alalakh corresponding to this level (von Dassow 2008, 27). Besides the archival material, invaluable insight into the events of this period is also provided by the statue inscription of Idrimi, as it delivers the deeds of this ruler before and after his ascent to the throne (Oppenheim 1969).

Sometime after the Level IV Palace had been destroyed by fire, a massive mudbrick structure, designated as the “Fortress” by Woolley, was built over its remains (Woolley 1955, fig. 59; Yener 2005, 110-11, fig. 4.31, 4.32). With its courtyard flanked by storage compartments and faced by buttresses, this building clearly echoes the characteristics of Hittite royal and sacred architecture. These typical features are well known from the major Hittite centers in central Anatolia, as well as the large Late Bronze Age II building at Tarsus in neighboring Cilicia (Yener 2005, 110-11). The construction of this building and its later renovation were respectively attributed by Woolley to Levels III and II, while its abandonment in the early 13th century BC was considered to mark the beginning of Level I. The settlement corresponding to Level I also involved the final phase of the temple and a cluster of houses aligned along the city wall (Yener 2005, 112, fig. 4.33).

However, a recent re-analysis of Woolley’s records of stratigraphy resulted in an entirely different interpretation of Levels III-I (Fink 2010). According to this new re-assessment of archaeological evidence, Alalakh seems to have ceased to exist as a city late in the 14th century (1320/1313 BC), while only small patches of the site continued to be occupied, possibly as a Hittite stronghold (Fink 2010, 120-44). Interestingly, the recent fieldwork strongly supports this possibility. A major

undertaking of the new excavations was a section cut through Woolley's Levels IV-0 in the area of the Level IV palace and the so-called Fortress of Levels III-II. The new examination of stratigraphical sequence identified no evidence for the Fortress in Level III, and thus, the structure seems to have occupied one single building phase, which corresponds to Woolley's Level II only (Yener 2013, 14-17). Even more significant was the fact that the evidence for habitation in the 13th century BC (corresponding to Woolley's Level I) was found only at the temple. This led the excavators to propose an abandonment of the settlement at the end of the 14th century BC, parallel to Fink's re-analysis of Woolley's records, while only the temple continued into the 13th century BC (Yener 2013, 17-20).

In any case, occupation strata datable to the 14th or 13th centuries BC correspond to the period of Hittite involvement at Alalakh, which manifests itself in both material and textual evidence. A limestone stela, which was reused as a step in the temple of Level I, depicts a royal figure and his wife rendered in typical Hittite royal iconographic tradition (Woolley 1955, plate XLVII). The accompanying inscription in Hittite hieroglyphs identifies the figure as Tudhaliya, apparently a Hittite administrator of Alalakh, and perhaps a relative of the Hittite king (Yener 2005, 112; Yener 2013, 18). Another Hittite ruler of Alalakh was a man named Paluwe, two seals of whom were recovered at the site. These seals are typical Hittite hieroglyphic seals and entitle their owner as "king's son, ruler of the land" (von Dassow 2008, 78). Numerous such Hittite seals found in these Levels testify the full-fledged imposition of Hittite administration at Alalakh. Moreover, some of the few cuneiform tablets recovered from these levels were written in Hittite language, which further signifies the extent of Hittite involvement at the site (von Dassow 2008, 63).

There is also sufficient evidence to testify that the Hittite influence at Alalakh went beyond administrative matters and was also felt in cultic and religious affairs. This is quite well documented by the recovery of miniature votive vessels and pointed juglets, the counterparts of which are found in ritual pools at the Hittite capital (Yener 2013, 18). Likewise, a ceremonial bronze axe, which has its parallels in Hittite royal iconography, was discovered in the recent excavations (Yener 2011).

As far as the ceramic imports in Levels III-I are concerned, typical Cypriot wares already attested in Level IV continued to be imported and were now accompanied by Mycenaean pottery (Stein 1997, 58). Mycenaean imports at Alalakh comprise less than 0.5 percent of the total ceramic assemblage and about 20 percent of Cypriot imports. These numbers correlate with the typical relative abundance of Mycenaean ceramics in other towns of the Levant (Koehl 2010, 81). The Mycenaean repertoire at Alalakh was first interpreted by Woolley to encompass both LH IIIA and LH IIIB phases (Woolley 1955, 372-76; Stein 1997, 58). However, more recent analysis of the assemblage assigns it exclusively to the LH IIIA phase, with the latest examples dating to the LH IIIA:2 Late subphase of the late 14th century BC (Koehl 2010, 82). Accordingly, the new dating of Mycenaean pottery supports the recent re-interpretation of stratigraphy, which proposes that the settlement was largely abandoned around 1300 BC (Yener 2013, 17).

Level 0, the last habitation stratum identified by Woolley, was interpreted as a short-lived settlement. Its only notable architectural feature is a large, stone-built, circular structure, which was argued to have been a tower (Woolley 1955, fig. 69; Yener 2005, 103, fig. 4.34). However, the architectural remains, as well as the pottery record of this stratum are pretty scanty and could not be clearly characterized (Yener 2005, 112). On the other hand, the recent excavations discovered several Iron Age

levels corresponding to the timespan between the 12th and 8th centuries BC, testifying that the site continued to be habituated after the Bronze Age (Yener 2013, 20-21).

Chronology

Due to its uninterrupted sequence of occupation through the second millennium BC, and its history that can be linked to Syro-Mesopotamian and Hittite histories at certain points, Alalakh has always been a hot spot of debates on Bronze Age chronology. Unfortunately, the major problems associated with the second millennium BC chronology of the Near East and the eastern Mediterranean are far from being solved and the debates still continue.

The ten earliest levels (Levels XVII-VIII), which are defined as the “archaic levels” by Woolley, were originally dated to the period 3400-1780 BC (Woolley 1955, 377-78). However, the inaccuracy of this dating has been made clear by Mellink when she pointed out the erroneous interpretation by Woolley of certain pottery types. The pottery of these early levels is characterized by the Syro-Cilician Painted Ware of the early second millennium BC, whereas the earlier pottery of the Amuq region is entirely absent. Moreover, in collaboration with Porada, Mellink ascertained that the iconography of the cylinder seals from levels XIII-X have their parallels in Neo-Sumerian seals (end of the third, beginning of the second millennium BC), rather than the glyptic of the third millennium BC as Woolley had believed. Accordingly, the earliest level of the site (Level XVII), and thus, the foundation of the settlement, has been dated to the turn of the third millennium BC, partially overlapping with the end of the Early Bronze III in Cilicia (Mellink 1957, 395-97).

The most heated discussion and debate about chronology revolved around Level VII as its archive links Alalakh to Mari and thus, indirectly to the first dynasty

of Babylon. A linkage can also be made to the Hittite Old Kingdom since the destruction of Level VII is commonly attributed to Hattušili I, who claims to have demolished Alalakh².

The first attempt to absolutely date Level VII and establish a general chronology for the proceeding levels was made by Smith in 1940 through a preliminary analysis of the ceramic and glyptic record. Smith's chronological scheme was then followed by Woolley in the final publication of the excavations. The occurrence of some egyptianizing motifs in the glyptic of Level VII was considered by Smith and Woolley to indicate egyptian influence during Level VII. They also argued that the preceding Level VIII might have been under the political dominance of the Twelfth Dynasty of Egypt (2055-1773 BC), which would imply that the date of Level VII cannot be separated from this dynasty by a long margin (Woolley 1955, 384-91). However, this proposition was not based on solid grounds as the Egyptian influence on the glyptic of Alalakh is scanty at best, not to mention the total lack of archaeological or literary evidence to support any Egyptian hegemony (von Dassow 2008, 8)³. Also, Iarim-Lim, the first king of Alalakh associated with Level VII, was mistaken by Smith to be a contemporary of Hammurabi of Babylon. As a result of these erroneous synchronisms, Smith and Woolley dated Level VII to 1780-1750 BC (Woolley 1955, 384-86).

The necessity to lower the date of Level VII emerged following the comprehensive study of Alalakh's textual records by Wiseman. Level VII archives refer to two rulers of Alalakh: Iarim-Lim, to whom the foundation of the Level VII palace is attributed and his son and successor Ammitaqum, during whose reign the

² Studies on this subject that have been published before 1989 are reviewed in detail in McCellan 1989, 182-86.

³ Smith and Woolley's dating of iconography in the glyptic of Level VII has later been falsified also by Kantor 1956; Albright 1957, 29-30; and Collon 1975, 185-86.

settlement was possibly destroyed. Iarim-Lim was the younger brother of Abban, the king of Iamhad. Their father, Hammurabi I of Iamhad, is known to have been a younger contemporary of Zimri-Lim of Mari and Hammurabi of Babylon (Gates 1987, 72-73). Accordingly, the correlations between the archives of Alalakh and Mari leave no doubt that the end of Level VII must have postdated Hammurabi of Babylon by a couple of generations (Landsberger 1954, 49-54).

Previously, the destruction of Alalakh Level VII had been credited to Muršili I, the Hittite king, who is known to have sacked Babylon and put an end to Hammurabi's dynasty. However, a tablet discovered at Hattuša in 1957 rendered Hattušili I, grandfather and immediate predecessor of Muršili, a more likely candidate. This tablet bears an annalistic account of this Hittite king, in which he explicitly claims to have destroyed Alalakh (Otten 1958).

This synchronism between Alalakh Level VII and Hattušili I is strengthened by the Hittite accounts of Hattušili's campaigns, as they refer to a Iarim-Lim, and his son Hammurabi, presumably the last two kings of Iamhad also attested in the Alalakh archives. Another Hittite text from around this date also mentions a Hammurabi, who could also be Hammurabi of Iamhad, or perhaps, Hammurabi of Alalakh, who ruled after the Level VII destruction (Astour 1989, 11; Klengel 1992, 64; von Dassow 2008, 15). A further personal name that occurs in both Hattušili's accounts and Alalakh texts is Zukraši, who appears in Hittite records as a military commander in service of the king of Iamhad. The same name had commonly been considered to occur with the same title in Alalakh texts (Na'aman 1974, 273-74; Astour 1989, 11; Wilhelm 1989, 21; Klengel 1992, 81). However, the title attested in Alalakh tablets has more recently been reinterpreted to have a religious rather than a military affiliation, which would render the two Zukrašis not to be the same person (von Dassow 2008, 16n36).

If we turn to archaeological evidence, early studies on the ceramic and glyptic records from Level VII and their comparisons with the southern Levant lead to a late 17th century BC date for the Level VII destruction (Kantor 1956; Albright 1957; Na'aman 1976, Collon 1982, 3). As opposed to these researchers, who intentionally focused on Level VII so as to draw correlations between material and textual evidence, M. H. Gates worked on the ceramic assemblages of Levels VI and V, which yielded almost no written documents. Gates' crossdating of this material with the Levant, Cyprus and Tell el Dab'a in the Nile Delta lead her to the conclusion that the end of Level VII should be lowered to around 1575 BC. The result of her work was the following chronological sequence for Levels VII-V (Gates 1981, 33-36; Gates 1987, 75-79):

Level VII: 1650/30-1580/1575 BC

Level VIA: 1575-1550 BC

Level VIB: 1550-1525 BC

Level VA: 1525-1500 BC

Level VB: 1500-1460 BC

Especially crucial for Gates' analysis were the ceramic correlations with Megiddo and the occurrence of Cypriot Bichrome pottery at Alalakh Levels VI and V. However, the uncertainties in the Megiddo sequence have been pointed out by McCellan, even though he accepted Gates' dates to a major extent (McCellan 1989, 190-92). Gates' dating was also later supported by Heinz, who examined the previously unstudied pottery from levels XVII-VII in comparison with more recent finds from Syria, the Levant and Tell el Dab'a (Heinz 1992, 203-5). However, the yet-to-be-published carbon dates from the current fieldwork dates the Level VII

destruction to around 1625 BC, and thus, agrees with a late 17th century BC dating (Yener, 2013, personal communication).

Level IV is the second level of Alalakh to yield substantial textual material to become another hot spot of the chronology debate. Idrimi appears as the first of the three rulers of Alalakh referred to by Level IV documents. Besides, in his statue inscription, he claims to have built a royal house at Alalakh in a grandiose scale. Therefore, he is commonly credited with the building of the Level IV palace (Na'aman 1974, 267; Collon 1975, 167; von Dassow 2008, 36). However, only three tablets from Level IV belong to his reign and this paucity of textual records lead some scholars to entertain the possibility that he might have ruled during the preceding Level V⁴. If this was the case, the foundation of the Level IV palace should be attributed to his son Niqmepa (Gates 1981, 8; Bergoffen 2005, 61).

Textual evidence synchronizes Idrimi with the Mittanian king Parattarna and the Hittite king Zidanta II⁵. However, because the absolute dates of either king are uncertain, dating Idrimi on textual grounds becomes equally problematic. As far as the final destruction of this level is concerned, the presumed attribution of this event to two different Hittite kings also led to conflicting dates. Hence, the association of this destruction with Tudhaliya I/II and Šuppiluliuma would respectively indicate a date around 1400 BC and the middle of the 14th century BC (von Dassow 2008, 42, 62-64; Yener 2005, 102)⁶.

⁴ This attribution actually has first been argued by Woolley, however on the basis of the erroneous reconstruction of the dynastic sequence as Niqmepa-Ilmilimma-Idrimi (Woolley 1955, 387-95).

⁵ Possible dates for the Hittite king Zidanta II vary from the early to the mid-15th century BC (Dinçol 2006).

⁶ Two Tudhaliyas, who were once thought to have ruled around that time, could be the same person. Thus, many Hittitologists opt for the designation Tudhaliya I/II (Bryce 1998, 131-33). His reign is commonly dated towards or just after 1400 BC, even though some scholars place him into the third quarter of the 15th century BC (Dinçol 2006).

A link between Idrimi and Egypt has also been argued by some scholars. In his statue inscription Idrimi claims to have spent seven years in the land of Canaan before becoming the king of Alalakh. Also, Tuthmosis III claims to have received tributes from Alalakh in his thirty-eighth regnal year (1441 BC). Accordingly, it has been assumed that Idrimi might have been backed by this pharaoh during his stay in Canaan and during his ascent to the throne at Alalakh (Zeeb 2004, 87-90)⁷. However, just as the earlier texts from Alalakh, neither the statue inscription nor the Level IV archive hand in any reference to Egypt or its pharaohs. Likewise, no reference to Idrimi can be found in Egyptian accounts. Thus, the attempts to link Idrimi to Tuthmosis III do not lead to any strong argument.

With respect to ceramic evidence, the beginning of Level IV is commonly dated around the middle of the 15th century BC (Gates 1981, Heinz 1992, Fink 2010). A somewhat later date has been proposed by Bergoffen, who places this level into the timespan of 1415-1380/75 BC according to her analysis of Cypriot ceramic imports. (Bergoffen 2005, 65, 71-73)⁸. The dating of the end of Level IV appears more problematic. The analysis of Cypriot and Mycenaean imports indicate a date after 1425 BC for the termination of Level IV, but there are uncertainties about how long after this date the event took place. Stein's study of the ceramic parallels between Alalakh Level IV and Nuzi Stratum II lead her to the conclusion that the destruction of Alalakh IV must have happened sometime within the lengthy timespan of 1425-1375 BC (Stein 1989, 59-60)⁹. This proposed dating is also supported by the current

⁷ However, the same terminology was used to refer to Alalakh's tribute as the Hittite and Babylonian gifts to Tuthmose III. Moreover, there is no strong evidence to suggest that Egypt actually controlled north Syria during this period. Thus, copper, timber and slaves that Tuthmose received from Alalakh were more likely interpalatial gifts rather than tributes from a vassal. (von Dassow 2008, 22n53, cf. Astour 1989, 57)

⁸ von Dassow (2008, 40n95) criticizes Bergoffen for being premised by textual evidence, which she mostly derives from secondary literature.

⁹ The analysis of Nuzi Ware and faience cylinder seals constitute the basis of her argument.

excavator (Yener 2013, 14-15). McCellan, on the other hand, dates the end of Level IV to the mid-14th century BC, based on the frequency patterns of Cypriot wares and their comparison with those from Cyprus and Megiddo (McCellan 1989, 211-12). As an alternative, some scholars are inclined to consider the destruction of the Level IV palace and that of the associated town as two distinct events. The basis of this argument was the possible time lag between the destruction of the Level IV palace and the emergence of the Level III Fortress (Woolley 1955, 399). According to this view, the demolition of the palace was tentatively dated towards 1400 BC, followed by the ultimate destruction of the settlement in the early or mid-14th century BC (Stein 1997, 35; von Dassow 2008, 40, 63). The proposed dates for major events in the history of the site between Levels VII and IV are summed up in table 2.1.

Table 2.1. Proposed dates for three major events in Alalakh's history.

Event	Proposed date	Proposed or accepted by
End of Level VII	ca. 1750 BC	Smith 1940, Woolley 1955
	ca. 1640-1600 BC	Kantor 1956, Albright 1957, Na'aman 1976, Collon 1982
	ca. 1580/1575 BC	Gates 1981, McCellan 1989
Beginning of Level IV	ca. 1460/1450 BC	Gates 1981, Heinz 1992, Fink 2010
	ca. 1415 BC	Bergoffen 2005
End of Level IV	ca. 1425-1375 BC	Stein 1989, Bergoffen 2005, von Dassow 2008, Yener 2013
	Mid-14 th century BC	McCellan 1989, Fink 2010

As far as Alalakh Levels III-I are concerned, these were placed into the 14th and 13th centuries BC, based on Hittite affinities, as well as Cypriot and Mycenaean ceramic imports. The beginnings of Levels III and II were respectively dated by Woolley to 1370 and 1350/1340 BC, primarily based on Mycenaean pictorial kraters

found in the temples of these two levels (Woolley 1955, 396; Yener 2005, 103). Level I, on the other hand, was dated to the period between 1275-1190 BC as inferred from the early examination of Mycenaean ceramic imports (Yener 2005, 103).

However, as discussed above, the recent assessment of stratigraphy, as well as the new dating of Mycenaean pottery suggest an entirely different interpretation of these latest Bronze Age strata. Recent evidence from the current fieldwork indicates that none of the uppermost Bronze Age contexts, with the exception of the temple, could be dated later than very early 13th century BC. This argument is based on carbon dating, the presence of Nuzi Ware in the uppermost deposits, and the new analysis of Mycenaean sherds, which assigns them exclusively to the LH III A2 Late phase (Koehl 2010, Yener 2013, 17-18). As noted above, this evidence is also supported by Fink's re-analysis of Woolley's records on stratigraphy (Fink 2010, 120-44).

The ill-defined Level 0 was dated by means of a scarab found in a grave, which was associated by Woolley with this level. As the scarab was originally attributed to Ramesses VI, Woolley proposed a mid-12th century BC date for Level 0. However, a recent study of the scarab identified it as belonging to Amenhotep III, and thus, dated it to the 14th century BC instead (Yener 2013, 21). As for the recently discovered Iron Age levels, the earliest one could be dated to the 12th century BC with the help of LH IIIC Middle "Developed" Mycenaean imports, while the latest stratum is tentatively attributed to the period 950-750 BC (Yener 2013, 20-21).

At this point it is worth noting that many of the chronological schemes proposed for Alalakh are the outcomes of attempts to provide supportive evidence for either of the Mesopotamian Middle or Low chronologies. These chronologies propose the following dates for two major events in Babylonian history, namely the ascent of

Hammurabi of Babylon to throne, and the sack of Babylon by the Hittite king Muršili (table 2.2).

Table 2.2. Two major events in Babylonian history according to the Middle and Low Mesopotamian Chronologies.

Chronology	Hammurabi's ascent to Babylon's throne	Muršili's sack of Babylon
Middle	1792 BC	1595 or 1587 BC
Low	1728 BC	1539 or 1531 BC

In general terms, any chronological scheme, which places the end of Alalakh Level VII into the late 17th century BC or earlier, fits better into the Mesopotamian Middle Chronology. Others, dating the end of Level VII, and hence, the Hittite king Hattušili I, Muršili's immediate predecessor, to around 1575 BC, are compatible with the Mesopotamian Low Chronology.

2.2.2. Tarsus/Gözlükule

The mound of Gözlükule¹⁰ is situated in the center of the township of Tarsus (Hittite Tarsa, classical Tarsos) in Mersin province, on the western fringes of Çukurova Plain (classical Cilicia Pedias). The site was excavated by Hetty Goldman from 1934 to 1938 and from 1946 to 1949. The mound has horizontal dimensions of 350 x 150 meters and had a height of 32 meters at the time of Goldman's excavations, which render it the most imposing mound in the western part of the Cilician Plain. The fieldwork demonstrated an uninterrupted occupational sequence from the Neolithic into the Islamic Period. Throughout this lengthy timespan, Tarsus evidently enjoyed its highly strategic location near the southern entrance of the Cilician Gates,

¹⁰ Henceforth 'Tarsus'.

the most important gateway between central Anatolia and the Mediterranean coast (Özyar 2005b, 1-3). The outcome of the excavations has been published in three volumes in 1950, 1956, and 1963, respectively presenting Hellenistic-Roman, Neolithic thru Bronze Age, and Iron Age levels (Goldman 1950, Goldman 1956, Goldman 1963). The finds from these excavations are distributed between the local museums at Adana and Tarsus, the storerooms of the current field project, and Bryn Mawr College.

Fieldwork at the site was re-initiated in 2001 by Prof. A. Özyar of Boğaziçi University, in cooperation with Bryn Mawr College. The results from the preliminary surveys and study seasons between 2001 and 2003 were published in an edited volume in 2005 (Özyar 2005a). The excavations, which started in 2007 and continued to the present day, uncovered mostly medieval contexts, below which Bronze Age strata recently started to be exposed.

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Excavations by Goldman identified four Middle Bronze Age strata. In the earliest of these, the characteristic Middle Bronze Age ceramics start to appear in small quantities and co-exist with the Early Bronze Age III assemblage, which displayed strong central Anatolian affinities. Accordingly, this earliest level of the Middle Bronze Age is defined as the “Middle Bronze Transitional” phase by the excavator (Goldman 1956, 40-43). In the three later strata, which Goldman designates as the “Middle Bronze Floruit”, typical Middle Bronze Age pottery, particularly the Syro-Cilician Painted Ware, replaces the Early Bronze Age repertoire (Goldman 1956, 164). Thus, the Middle Bronze Age at Tarsus represents a break with central

Anatolia in favor of extensive links with northern Syria. As far as ceramic imports are concerned, only a handful examples of Cypriot Black-on-black and Red-on-red wares were found in the Middle Bronze Age contexts of Tarsus (Goldman 1956, 164; Kozal 2005, 135).

In the succeeding Late Bronze Age I period, a large building is unearthed, which the excavator designated as the “Late Bronze I House”. A Hittite hieroglyphic seal and the bulla of the Kizzuwatnean king Išputahšu were found in a deposit associated with this structure, which likely indicates the administrative function of the building. This king of Kizzuwatna is known from Hittite sources to have signed a treaty with the Hittite king Telipinu (late 16th or early 15th century BC) (Goldman 1956, 44-48, 281, plan 21).

The ceramic assemblage of the Late Bronze Age I represents a turn towards central Anatolia, succeeding the Syrian affinities of the Middle Bronze Age. This affiliation with central Anatolia is well reflected in the popularity of the Monochrome Ware with typical early Hittite fabric, technique and shapes. Some characteristic Syrian types such as the Tell el Ajul ware occur as sporadic imports (Goldman 1956, 183). As for Cypriot imports, few sherds of the Red-on-red Ware may belong to the beginning of the Late Bronze I period, if not to the end of the Middle Bronze Age. Typical Late Cypriot wares of that period, such as the White Slip I or Base Ring I are absent at Tarsus as these are very rare overall in Cilicia (Kozal 2005, 135-36).

The succeeding Late Bronze IIa Level represents the period of Hittite involvement at Tarsus. The hallmark of this settlement is the massive structure that consists of a large courtyard and rectangular compartments aligned around it (Goldman 1956, 49-50, plan 22). With these features and the use of cyclopean blocks for exterior walls, the building clearly resembles typical Hittite public buildings,

particularly temples. Goldman, however, admits the lack of secure evidence to ascribe a sacral function to this structure. As a result of the later disturbances in the Iron Age and Roman times, not all activities associated with this building could be ascertained. However, at least two adjacent rooms of the building could be identified to constitute a metal workshop.

Definitive evidence for an administrative function is provided by another large scale building from this period, which was designated by the excavator as the “East House” (Goldman 1956, 51-56, plan 23). In a sealed pit associated with this building, numerous broken Hittite Hieroglyphic bullae are found. Based on this evidence, Goldman interprets the structure as the possible office of a local governor. The walls of the building consist of piers and rubble interstices, once again echoing Hittite architectural traits.

Late Bronze IIa level of Tarsus yielded the largest group of Hittite Hieroglyphic seals and seal impressions known outside of the Hittite heartland (Gelb 1956). Aside from seven biconvex seals, a total of fifty-four impressions were found, half of which was recovered from the above-mentioned pit by the East House, while some others have been found in the vicinity of the large Late Bronze IIa building. The presence of Hittite Hieroglyphic seals in such a significant quantity unmistakably points to the importance of this town as an administrative center in the southern territories of the Hittite kingdom. The most noticeable seal impression belongs to Puduhepa, the Hittite Queen and wife of Hattušili III (early 13th century BC), who was herself a native of Kizzuwatna (Gelb 1956, 245, 248). The fragment of a Hittite land grant document has also been found in the pit by the East House, which interestingly dates to the Old Kingdom period and predates other finds from the pit (Gelb 1956, 246, 253-54). Unfortunately, the author of the text remains undetermined.

Typical Hittite New Kingdom shapes are the hallmark of the pottery assemblage of Late Bronze Age IIa Tarsus. Imports from Cyprus and Syria are present but relatively few. Cypriot pottery, now found in the form of White Slip II and Base Ring II Wares, is however more numerous than the preceding Middle Bronze and Late Bronze I periods (Goldman 1956, 203-5; Kozal 2005). Likewise, possible Cilician imports on Cyprus are confined to only two bowls from Myrtou-Stephania; and even these could be Levantine rather than Cilician products (Kozal 2005, 137).

At the end of the Late Bronze Age IIa period, the settlement was destroyed by fire. The succeeding occupation level, Late Bronze IIb, is recognized as a “squatter settlement” by the excavator due to haphazardly built houses. Based on the influx of Mycenaean LH IIIC pottery, this level was dated to the 12th century BC (Goldman 1956, 58-59).

Chronology

In her discussion of chronology, Goldman presents only a rough and tentative scheme of dates for individual occupational levels (Goldman 1956, 62-64). The “Middle Bronze Age Transitional” and “Middle Bronze Age Floruit” phases are respectively dated to 2100-1900/1850 BC and 1900/1850-1650 BC. As for the proceeding Late Bronze Age I, D. Slane, the second researcher to study the second millennium BC chronology of Tarsus, breaks this period into five subphases, which she numerates from the earliest A IV to the latest A VIII (Slane 1987, 467-69). She observes a gradual increase in central Anatolian ceramic influence in levels A IV and A V, which leads to the full-fledged Old Hittite corpus of Level A VI. As she assigns Level A VI to the 16th century BC, the preceding Levels A IV and A V are dated prior

to 1600 BC. Finally, the later phase of the Late Bronze I period, which correspond to Levels VII and VIII, are assigned to the 15th century BC, and hence, to the era when the kings of Kizzuwatna were corresponding with Hittite kings in equal terms (Slane 1987, 469).

Late Bronze Age IIa level, the period of Hittite occupation, was tentatively dated by Goldman to 1450-1225 BC, terminating with the influx of the Mycenaean LH IIIC pottery in Late Bronze Age IIb. On the other hand, Slane prefers an early 14th century BC date for the foundation of the large Late Bronze Age IIa building, the hallmark of the Hittite period at Tarsus (Slane 1987, 469). The current field project at the site is expected to fine-tune the second millennium BC chronology of Tarsus and provide absolute dates for each chronological phase.

2.2.3. Kinet Höyük

The mound of Kinet Höyük¹¹ is situated near Dörtyol in the Hatay province of Turkey and lies on the eastern shore of the Gulf of Iskenderun (classical Alexandria). With its area of 3.3 hectares, it is the largest mound in the eastern sector of Cilician Plain. The excavations at the site had been conducted between 1992 and 2007 under Prof. M. H. Gates of Bilkent University. The twenty-six meters high soil deposition of the mound revealed an uninterrupted occupational history from the Neolithic until the Hellenistic period. After a hiatus following the Hellenistic Age, the site was resettled in medieval times (Gates 2000, 79). As inferred from the situation of the site in a narrow coastal plain bordered by mountains, the settlement must have been primarily oriented towards maritime affairs throughout its history. This proposition is supported

¹¹ Henceforth 'Kinet'.

by geomorphological research as it determined that the site incorporated two harbors in antiquity (Gates 2000, 79).

The outcome of the fieldwork is yet to be presented in a final publication following the study seasons currently underway¹². The finds from the excavations are kept in Hatay Archaeology Museum and the storage of the excavation house. As far as the ancient name of the site is concerned, this could not be securely identified. Nonetheless, Issos of classical periods, and on inference, Iron Age Sissu (known from Assyrian annals) and Late Bronze Age Zise (known from Idrimi's statue inscription) have been proposed as likely candidates (Gates 2000, 79).

The Middle Bronze Age exposure in Kinet (Kinet Period 16) unearthed a two hundred-square meter portion of a large building. Two consecutive occupational phases were identified in this structure, both of which yielded the characteristic Syro-Cilician Painted Ware of the period. The later phase (Phase 2) is better defined with two sectors serving distinct functions. One sector was evidently utilized for processing cereal, whereas the other one was a metal workshop (Gates 2000, 80-82, fig. 3, 4). This phase of the building also contains a large collection of storage jars, and an assortment of Cypriot ceramics. The latter group consists of two juglets from the 18th or early 17th century BC, and about 15 sherds of the White Painted VI, Base Ring, and Monochrome Wares of the 16th and early 15th centuries BC. While not attested in this assemblage, Cypriot Bichrome Ware is present in other Middle Bronze Age deposits of the site (Gates 2000, 83-88; Gates 2006, 298).

Similar to the Middle Bronze Age level, the Late Bronze Age I town (Kinet Period 15) revealed part of a large public building (Gates 2006, 295-99). With rectangular compartments and walls without any doorways, the spatial organization of

¹² The annual reports of each field season have been published by M. A. Gates in *Kazı Sonuçları Toplantısı (Annual Meetings of Excavation Results)* from 1992 onwards.

the building displays definite Hittite characteristics and resembles the public buildings in central Anatolia, the so-called Fortress of Alalakh, and the Late Bronze Age IIA building of Tarsus. At least part of the structure has been identified as a metal workshop by the discovery of a copper bun ingot, crucible fragments, a mold, and scrap metal. Typical Hittite shapes of the Old Kingdom period define the pottery of Kinet Period 15 (Gates 2006, 297, fig. 4). Cypriot imports include few examples of Bichrome and White Slip I Wares (Gates 2006, 298-99).

Kinet Periods 14, 13.1, and 13.2 represent the Late Bronze Age II occupation at the site. The architectural evidence from these levels revealed exclusively domestic buildings, but no large scale structure comparable to those of Periods 16 and 15 (Gates 2006, 300-302). Just as the Late Bronze Age IIA phase at Tarsus, the ceramic repertoire of periods 14 and 13.1 was dominated by typical Hittite New Kingdom shapes and wares, the mass production of which was highly standardized (Gates 2006, 306).

Period 13.2 is the final stage of the Late Bronze Age at Kinet and was characterized by Gates as a “sub-Hittite” phase. The architectural layout displays a major break from the preceding period with its differently oriented buildings (Gates 2006, 302-4). Most of the typical Hittite pottery shapes of the preceding era continue into this period; but local potters seem to have abandoned the rigid standardization in favor of more random combinations of formal and decorative features. As a result, the pottery of this phase differs from those of contemporary Hittite assemblages attested elsewhere. It was also during Period 13.2 that Cypriot and Syrian pottery imports appear in more remarkable quantities (Gates 2006, 304). Level 12, which proceeds the destruction of Level 13.2, witnesses the influx of Mycenaean LH IIIC pottery.

Chronology

The two phases identified in the large Middle Bronze Age (Period 16) building are respectively dated by the excavator to the 17th and late 16th centuries BC based on ceramic and radiocarbon evidence (Gates 2000, 83-89). The final destruction of the building is considered to mark the termination of the Middle Bronze Age at Kinet. The beginning and the end of the Late Bronze Age I (Period 15) are assigned to the mid-16th and mid-14th centuries BC respectively. (Gates 2006, 298). Accordingly, the proceeding Late Bronze Age II period, represented by Levels 14, 13.1 and 13.2, spans the period from the mid-14th century BC until the destruction of Level 13.2 around 1200 BC.

2.3. OUTLINE OF POLITICAL HISTORY

As the upcoming discussion will demonstrate, the study region remained under the political hegemony of certain outside powers through most of the second millennium BC. Obviously, the incorporation of a region into a powerful territorial political entity would have significant effects on its economic conditions.

Archaeological and textual evidence commonly implies that the major political powers of the Bronze and Iron Ages tended to exercise a certain degree of control over the industries of their dependents, which commonly manifests itself in a high degree of standardization and uniformity of production. This phenomenon is primarily observed in the production of common pottery types, as demonstrated within the territories of the Hittite and Middle Assyrian kingdoms (Gates 2001, 141; Postgate 2007; Glatz 2009, 129-31). However, it is significant to notice that in certain

other cases, such as the Neo-Assyrian Empire of the Iron Age, a firm state control of local production is not evident (Postgate 2007, 149).

Major centralized powers may also dictate and limit the types and quantities of commodities in circulation within their territories, which could lead to the attenuation of trade (Kozal 2005, 137). Conversely, the involvement of such a centralized power in a region may impose a higher security of trade routes and lead to the growth of commercial activity. Our discussion now turns to the overview of the political history of Cilicia and the Amuq so as to examine which political and economic parameters might have conditioned the production and exchange patterns of metals.

2.3.1. Before Mittanian Hegemony

The early second millennium BC in the Near East witnessed the emergence of several territorial states, among which the kingdom of Iamhad stands out as the dominant political entity in northwest Syria. Centered at its capital Aleppo, this kingdom appears to have exercised hegemony over such major centers as Emar and Ebla, and likely had some control over others like Carchemish and Ugarit (Klengel 1992, 61, 70-78). The tablets from the Mari archive (second quarter of the 18th century BC) refer to a city named Alahtum, which appears as a property of Iamhad. If this Alahtum was an alternative form of the toponym Alalakh, as some researchers believe, the evidence demonstrates Iamhad's superior position over Alalakh as early as the 18th century BC (von Dassow 2008, 13n26).

At the time of Alalakh Level VII, the association between Alalakh and Iamhad is more clearly demonstrated by textual records as they testify that it was the king of Iamhad, who established Alalakh as the capital of a small, regional kingdom. When

king Abban¹³ was the ruler of Iamhad, his brother Iarim-Lim was in charge of the territory of Irride on the eastern frontier of the kingdom. After this territory had been largely destroyed by Abban to suppress a local uprising, Iarim-Lim was given the new territory of Alalakh and some other towns in its proximity. Accordingly, the foundation of the Level VII palace, which is commonly dated to the 17th century BC, is attributed to Iarim-Lim (von Dassow 2008, 13). Iarim-Lim was succeeded by his son Ammitaqum, during whose reign the city appears to have been destroyed together with its palace. The position of Alalakh's kingdom as a vassal of Iamhad is clearly evident, as both kings of Level VII refer to themselves as "servants to the kings of Aleppo" (von Dassow 2008, 13). The destruction of Alalakh Level VII, which took place in the late 17th or early 16th century BC, is commonly attributed to the Hittite king Hattušili I, who narrates in his annals to have demolished this town as his first target on his march towards the Euphrates¹⁴ (Klengel 1992, 81; von Dassow 2008, 15).

The scanty textual evidence from the proceeding Levels VI and V is not sufficient to reconstruct the events between the end of Level VII and the reign of Idrimi of Level IV in the mid-15th century BC¹⁵. It was during this period that the Hittite king Muršili, grandson and immediate successor of Hattušili I, put an end to the dynasties of Babylon¹⁶ and Iamhad. It is quite possible that Alalakh remained an independent entity after the demise of Iamhad until the Mittanian supremacy, namely during the period corresponding to Levels VI and V (von Dassow 2008, 17-18). One

¹³ Klengel (1992) prefers a transliteration as Abba-el. However, according to von Dassow (2008, 13n26), the rendering as Abban should be favored since an optional -n ending on names ending with vowels is a common feature in Alalakh documents.

¹⁴ The source of this information is the bilingual annalistic account of Hattušili I. (Otten 1958). The name of the town appears as Alalha, which is generally accepted to be another form of Alalakh. (Klengel 1992, 80-81).

¹⁵ Only five tablets were recovered from these occupation levels.

¹⁶ 1539 or 1531 BC according to the Mesopotamian Low Chronology. 1595 or 1587 BC according to the Mesopotamian Middle Chronology (Heinz 1992, 200).

of the few tablets from Level VI refers to a Hammurabi as the ruler of Alalakh, whose name was already mentioned in a Level VII tablet as the crown prince to his father Ammitaqum. This piece of evidence is significant as it testimonies the continuity of the regal family and palatial administration after the Level VII destruction (von Dassow 2008, 15). Also, Idrimi and his son Niqmepa, who ruled Alalakh during Level IV, used a dynastic seal, which bears the name of an Abban, Son of Šarran. It is very likely that Abban and Šarran were two rulers associated with Alalakh Levels VI or V (von Dassow 2008, 18n40).

If we turn to Cilicia, textual references to this region are not evident until the 16th and 15th centuries BC, which coincide with the period of the Hittite Old Kingdom in Anatolia. Second millennium BC documents account the land of Kizzuwatna, the territory of which is understood to incorporate the area of classical Cilicia. In Hittite ritual texts pertaining to the religious festivals in Kizzuwatna, Adaniya and Tarsa are mentioned as two cities in close connection, and hence can be identified as modern Adana and Tarsus respectively (Garstang and Gurney 1959, 58-62). On the other hand, in certain cases the toponym Adaniya could also refer to a larger territory and was a term more or less synonymous with Kizzuwatna (Beal 1986, 424n2; Bryce 1998, 111). However, the boundaries of this land could not be confidently reconstructed.

As discussed above, the fragment of a land grant document sealed with an Old Hittite royal seal has been found at Tarsus (Gelb 1956, 246, 253-54, fig. 404, 408). Unfortunately the seal impression only bears the generic Old Hittite royal title Tabarna, and hence, its owner remains undetermined¹⁷. Nevertheless, the seal demonstrates the capacity of an Old Hittite king to make land grants in Kizzuwatna,

¹⁷ Beal (1986, 424-25n3) favors Zidanta I and Amunna as likely candidates, whereas Easton (1981, 16, 24) attributes the seal to Huzziya. At least one of the personal names in this document could be identified as a Hurrian name.

which could only be possible if the region was under some degree of Hittite control, if not completely annexed. The Hittite domination of the region could have started in the wake of Hattušili's attack on Alalakh (Beal 1986, 425-26). During the reign of the Hittite King Amunna, possibly four generations after Hattušili I, Adaniya was listed among the hostile countries, against which this Hittite king unsuccessfully campaigned¹⁸. It was probably after this event that Kizzuwatna emerged as an autonomous political entity (Beal 1986, 426; Bryce 1998, 111).

Išputahšu, the first recorded king of Kizzuwatna, is well known from his bulla found at Tarsus. In the inscription of this seal he presents himself as "Išputahšu, Great King, Son of Pariyawatri" (Gelb 1956, 246-47, fig. 401, 405)¹⁹. He is also known to have concluded a treaty with the Hittite king Telipinu²⁰, which hands in the earliest reference to the country of Kizzuwatna (Bryce 1998, 111). Due to the fragmentary state of the tablet, the content of the treaty cannot be deciphered; but the text implies that the correspondence between the two kings was in equal terms. Telipinu, who is known to have campaigned against such other countries of southern Anatolia as Lawazantiya and Hassuwa, probably intended to secure peace with at least one of the major countries of the region (Beal 1986, 427; Bryce 1998, 111)²¹.

The policy of Telipinu was apparently followed by Tahurwaili, the first or second Hittite king after Telipinu, who drew up a parity contract with Eheya of Kizzuwatna. This document concerns the mutual return of future fugitives and safety of future delegates, who could be either a son or an official of the kings in question. Once again, the equal positions of the two sides were implied (Otten, 1971, 65-67;

¹⁸ Dates of Amunna vary from the early 16th century BC to shortly after 1500 BC (Dinçol 2006).

¹⁹ Beal (1986, 426) thinks that Pariyawatri might have been the ruler of Adaniya, against whom Amunna had fought one generation before Išputahšu.

²⁰ Telipinu is the second king to rule after Amunna. His dates vary between the mid-16th and mid-15th century BC. (Dinçol 2006)

²¹ This treaty is also the earliest documented diplomatic correspondence of the Hittite kingdom.

Beal 1986, 428; Bryce 1998, 120). Another treaty with almost the same formulation is known to have been concluded between Padatiššu of Kizzuwatna and a Hittite king, whose name has not been preserved. However, the striking similarity of the language to that of the Eheya treaty indicates that the date of Padatiššu could not be separated from Eheya and Tahurwaili by a long time (Beckman 1999, 11-13; Otten 1971, 67)²². The content of the treaty between Zidanta II of Hatti and Pilliya of Kizzuwatna is better known and deals with the mutual return of cities each side had taken from the other during some military hostility (Beal 1986, 428-31; Bryce 1998, 122)²³.

2.3.2. Mittanian Hegemony

It was in Level IV that Alalakh reappears as a palatial center with an extensive archive of cuneiform tablets, which account Idrimi, Niqmepa, and Ilmilimma as the three subsequent rulers associated with this level (Wiseman 1953, 5-8)²⁴. Textual information, however, is not sufficient to securely reconstruct the extent of the territory ruled from Alalakh. As Niqmepa used the titles “King of Alalakh” and “King of Mukiš” alternately, it first seems that the land of Mukiš, which roughly coincides with the Amuq Plain, constituted the entire territory of this kingdom. However, revenue and census texts from this period leave no doubt that Mukiš was only one of the several territories of the kingdom. Besides, based on the implied locations of border towns mentioned in documents, some scholars are inclined to envisage that the kingdom should have occupied a larger piece of land stretching from the sea in the

²² Beal (1986, 431) and Bryce (1998, 121-22) think that the treaty partner of Eheya was likely Hantili II, who ruled between Tahurwaili and Zidanta. This would place Padatiššu between Eheya and Pilliya on Kizzuwatnean throne.

²³ Zidanta is either the first or the second Hittite king after Tahurwaili (Dinçol 2006).

²⁴ The sequence proposed by Smith (1949) as Niqmepa-Ilmilimma-Idrimi, which was followed by Woolley (1955, 387-95), is no longer accepted.

west to the proximity of Aleppo in the east (von Dassow 2008, 64-67, 503, 504, fig. 2). Thus, it seems more likely that Mukiš designates the area that constitutes the heartland rather than the entire territory of the kingdom.

The first ruler to be associated with Level IV was Idrimi, whose deeds are well known from the inscription that adorns his famous stone statue²⁵. In this text, Idrimi hands down the list of events leading to his accession to the throne of Alalakh and his deeds during his kingship of thirty years (Oppenheim 1969). According to his narrative, Idrimi, son of Ilimilimma, left his mothertown Aleppo after some “evil deed” had happened; and fled to Emar with family members. From there he ventured south, to the land of Canaan, where immigrants from north Syrian territories, such as Aleppo and Mukiš, gathered around him to express their loyalty to the son of their former overlord²⁶. During his seven year stay in Canaan, he amassed an army and a naval power before moving north to Mukiš by sea, where he was welcomed by the people of Alalakh and other towns. Having treated him as an enemy for seven years, Parattarna, “the king of the Hurri” (obviously the Mittanian king), finally acknowledged Idrimi’s kingship at Alalakh. To express his loyalty, Idrimi sent him an embassy and discussed his forefathers’ services under the rule of Parattarna’s ancestors. Moreover, Idrimi also increased his “gift”, apparently the tribute, to Parattarna. Having established himself as the king of Alalakh and secured his relations

²⁵ This inscription consists of 101 lines covering the front of the figure with a postscript carved on the beard and the right cheek of the figure. The attribution of the context by the excavator to a much later date (Level IB pit by the temple, late 13th century BC), resulted in a vast array of conflicting ideas about when the statue could have been made (von Dassow 2008, 23-33). However, a reexamination of Woolley’s plans and descriptions within the frame of the recent fieldwork has concluded that the stratigraphy had been misinterpreted by the excavator and the pit should instead be associated with Level IV (Fink 2010, 16-30).

²⁶ The ‘evil deed’, which forced Idrimi to leave Aleppo, has been interpreted by some scholars to be the westward expansion of the Mittani Kingdom (von Dassow 2008, 44). Alternately, the Hittite conquest of Aleppo under Tudhaliya I/II is also considered a possibility (Zeeb 2004; Bergoffen 2005). This event is accounted in a later (early 13th century BC) treaty between the Hittite king Muwatalli II and Talmi-Šarumma of Aleppo (Beckman 1999, 93-95). In either case, the narrative does not refer to any external agent as the cause of this evil event. Accordingly, a conflict within the kingdom itself is also a possibility.

with the Mittanian king, Idrimi campaigns north and sacks seven fortified Hittite cities, including the Kizzuwatnean towns of Zise, Zaruna and Ie. With the spoil he gathered from these towns he built a palace in his capital in a monumental scale. Finally, Idrimi accounts how he prospered his territory, fulfilled his cultic obligations and appoints his son Addu-nirari as his heir to take over these responsibilities.

Idrimi's arrival at Alalakh was clearly a military undertaking and might have involved conquest, even though he claims to have been welcomed friendly by local people. His army possibly consisted of both his countrymen and the *habiru* that he assembled in Canaan²⁷. First, his activities in northern Syria were certainly not welcomed by the Mittanian king, the dominant power in the region. However, once Idrimi acknowledged Parattarna as his overlord and declared his loyalty to him, he was in turn acknowledged as the king of Alalakh.

Idrimi's relation to Parattarna and his northward expansion into Hittite-controlled Kizzuwatna become especially interesting in the light of another document from his reign. This is a copy of the treaty between him and Pilliya, king of Kizzuwatna. This Pilliya could be the same Pilliya, who concluded another treaty with the Hittite king Zidanta II as discussed above. The copy found at Alalakh was sealed by Pilliya and concerns the mutual return of fugitives between the two kingdoms. The document clearly implicates a Mittanian suzerainty over Alalakh as Parattarna appears as the overseer of the treaty on Idrimi's side, while this is not ascertained concerning Kizzuwatna (Wiseman 1953, 31-32)²⁸.

²⁷ Habiru is a term frequently attested in second millennium BC texts. It refers to people or communities living in mountain or desert areas outside the control of a state. Although they were considered a threat to the stability of a region, palaces frequently hired them as laborers or mercenaries (Van de Mieroop 2007, 170, 198-99). During the reign of Niqmepa, Idrimi's son, half of Alalakh's Army was made up of habiru. (von Dassow 2008, 43).

²⁸ Beal (1986, 429n26), and von Dassow (2008, 34) argue for a Mittanian domination of Kizzuwatna. Astour (1989, 21), and Wilhelm (1989, 26) envisage an independent Kizzuwatna.

At least two of the three tablets from Idrimi's reign can be securely placed into Level IV. Since one of these tablets was found in the Level IV palace, Idrimi is generally credited with the building of this palace. If this was the case, its much smaller predecessor in Level V can be interpreted as Idrimi's early residence used until the completion of the Level IV palace (Na'aman 1974, 267; Collon 1975, 167; von Dassow 2008, 34-37). However, some researchers think that if Idrimi indeed built the palace of Level IV, tablets from his reign must have been more numerous. In this alternative scenario, Idrimi and his son Niqmepa are respectively associated with the Level V and Level IV palaces (Gates 1981, 8; Astour 1989, 20; Bergoffen 2005, 61).

Textual evidence leaves little doubt that Idrimi was succeeded by his son Niqmepa²⁹, even though he clearly appoints his other son, Addu-Nirari, as his heir in his statue inscription. This is particularly confusing since there is no single evidence that an Addu-Nirari ever ruled Alalakh. He might have died before or shortly after ascending to the throne without leaving any records (von Dassow 2008, 26-28).

The vast majority of textual sources from Level IV belongs to Niqmepa's reign, who, like his father, was a loyal vassal to the Mittani. This is clearly indicated as Sauštatar, who was the king of Mittani during this time, commonly appears as an arbitrator between the sides in cases of interstate disputes (Astour 1989, 53; von Dassow 2008, 47n109)³⁰. Such a conflict occurred between Niqmepa and Sunaššura, the king of Kizzuwatna, over the possession of Alwari, apparently a city in the border zone between the two countries. Thus, Mittani's authority not only over Alalakh but also over Kizzuwatna is now well demonstrated. Sauštatar's verdict concerning this territorial conflict was in favor of Niqmepa (Wiseman 1953, 39; von Dassow 2008, 48-49).

²⁹ This is explicitly stated in tablet ALT 15 (Wiseman 1953, 39).

³⁰ Sauštatar's reign is commonly dated to mid-to-late 15th century BC.

Further insight into the international affairs of Niqmepa's reign can be gained through his treaty with the neighboring kingdom of Tunip (Wiseman 1953, 31-32; von Dassow 2008, 52-54). This time, the Mittanian king does not appear as an arbitrator. However, the treaty is concluded with a statement of loyalty to the Mittanian king, whose name is not preserved. Once again Mittanian suzerainty over these lesser kingdoms of the region is indicated. On the other hand, the capacity of these vassals to wage war against each other implies that they had a significant degree of autonomy.

Mittanian kings not only act as intermediaries in inter-state conflicts but also as judges in personal disputes on property. In such a case, a man, possibly a local official, was ordered by the Mittanian King to set free Niqmepa's donkeys and not to collect any customs duty. Another letter contains a verdict against Niqmepa, who was being ordered to return some women to a Mittanian official (Wiseman 1953, 58; von Dassow 2008, 54).

Sunaššura, the king of Kizzuwatna who had a border conflict with Niqmepa, is also known by the treaty he concluded with a Hittite king (Beckman 1999, 17-26). The identity of Sunaššura's counterpart is a matter of debate and both Tudhaliya I/II and Šuppiluliuma I have been proposed as candidates³¹. However, if this Sunaššura was indeed the same person as Niqmepa's opponent and likely dates around 1400 BC, Tudhaliya would appear as the more probable treaty partner. The Hittite king, whose superior position is made clear in the text, makes Sunaššura accept the reciprocal duties of providing military support in case of an internal revolt or external threat, specifically from the Mittani³².

³¹ For the attribution of this treaty to Tudhaliya I/II see Beal 1986, 435, 442-45; Wilhelm 1988, 365-70, Beckman 1999, 13; Bryce 1998, 151. For the attribution to Šuppiluliuma I see Götze 1940, 4; Goldman 1956, 63; Freu 1992, 49.

³² It is not entirely clear whether Kizzuwatna was a vassal or just an ally at that time. Wilhelm (1989, 30) and Götze (1940, 37) favor the former, while Beal (1986, 433) favors the latter possibility.

The treaty testifies the swinging of the loyalty of this country between the Mittani and the Hittites. In the introduction part of the text the Hittite king discusses that in the time of his grandfather Kizzuwatna was “on the side of the Hittite”, but later turned towards the Mittani and remained its subject until the conclusion of this treaty. He is now celebrating the re-alliance of Kizzuwatna with the Hittite Kingdom, claiming to have freed this country from the Mittanian yoke and made Sunaššura a free king. When he asks Sunaššura to erase and discard “the word of the king of Hurri”, he implies that Kizzuwatna’s former allegiance to Mittani had been established also through a written treaty. The Hittite king accepts the legitimacy of any person, who Sunaššura would appoint his successor and imposes no tribute on him, in an act of guaranteeing a certain degree of autonomy.

At Alalakh, Niqmepa was succeeded by his son Ilimilimma, who became the last ruler associated with Level IV³³. Unfortunately, the events during his rule cannot be accurately reconstructed as only nine tablets belong to his reign and none of these account his personal deeds³⁴. On the other hand, his name appears in a fragmentary tablet from the Hittite capital, which bears a treaty between Hatti and the country of Tunip. In this text Ilimilimma appears as the aggressor, who seized some of Tunip’s towns. Even though the treaty has commonly been attributed to Šuppiluliuma I, the fragmentary state of the tablet prevents any encompassing interpretations about the events leading to its conclusion (von Dassow 2008, 60-63; Astour 1989, 58, 67).

³³ Ilimilimma also appears in two tablets from his father’s reign and bears the title “son of the king”. (von Dassow 2008, 56).

³⁴ von Dassow (2008, 59) argues that Ilimilimma might have left Alalakh before its destruction, proposing an explanation for the paucity of tablets from his reign and the absence of his personal accounts.

2.3.3. Hittite Hegemony

Even though two Hittite kings, Tudhaliya I/II and Šuppiluliuma I appear as likely culprits, there is no sufficient evidence to determine who destroyed Alalakh Level IV and its palace. A text, which dates to the reign of Muršili II (late 14th century BC), and thus postdates Level IV, accounts a treaty between this Hittite king and Talmi-Šarumma, his vassal at Aleppo. The document attests that Tudhaliya had destroyed Aleppo and put an end to its kingdom³⁵. Two generations and roughly half a century later Šuppiluliuma I campaigned actively in northern Syria, eventually leading to the disintegration of the once powerful Mittani Kingdom. The situation of Alalakh during these events and its relation to the Hittites is not certain, as neither Hittite king claims to have attacked Alalakh (Astour 1989, 58; von Dassow 2008, 60).

Nevertheless, there are references in Šuppiluliuma's accounts to the Land of Mukiš, the territory over which Alalakh's kings had ruled. In his treaty with the Mittanian king Shattiwaza, Šuppiluliuma narrates how he overpowered the lands of Mukiš and Aleppo in one of his campaigns west of the Euphrates, without, however, speaking of Alalakh (Beckman 1999, 42-48). The land of Mukiš is also mentioned as a hostile kingdom in Šuppiluliuma's treaty with Niqmaddu, the king of Ugarit (Beckman 1999, 34-36). According to the historical introduction of this treaty, Ugarit had been oppressed by three of its neighbors, Nuhašše, Niya, and Mukiš, which led Niqmaddu to seek help from the Hittite king in distress. Consequently, Šuppiluliuma dispatched his troops that chased the enemies away and restored the captives taken

³⁵ The text is known to us in its version from the time of Muwatalli, who updated his father's treaty with Talmi-Šarumma. (Beckman 1999, 87-93) Some scholars think that the kingdom of Alalakh incorporated the territory of Aleppo at that time and the king of Aleppo mentioned in the text might actually be the king of Alalakh. (Astour 1989, 58-59; 67-68; Bryce 1998, 152n60; von Dassow 2008, 61).

from Ugarit. Eventually, Šuppiluliuma accepted Niqmaddu at Alalakh, who proposed his loyalty to his overlord.

If such an incident indeed took place, it proves that Alalakh was under firm Hittite control during these events. In this narrative, Itūr-Addu is attested as the king of Mukiš but without any association with Alalakh and any reference to his ancestry. Apparently, following the downfall of Alalakh, which now seems to be in Hittite hands, the territory of Mukiš does not seem to have ceased to be a political entity. The ruler of this polity was evidently situated somewhere other than Alalakh³⁶.

These events were also memorized in a letter between Šuppiluliuma and Niqmaddu, where the Hittite king continued to accuse Nuhašše, Niya, and Mukiš for renouncing their treaty with Hatti. Hence, the former allegiance of these kingdoms to the Hittites is signified (Beckman 1999, 125-26)³⁷. One further reference to Šuppiluliuma's intervention in the area is found in a later tablet from the reign of his son and successor Muršili II. This document testifies that Šuppiluliuma had given some of Mukiš's territory and cities to the king of Ugarit, evidently as a punishment of the former and a reward for latter's loyalty (Beckman 1999, 174-75). However, there are also instances, when Mukiš and Aleppo are listed among the countries "at peace with Hatti". This is evident in a treaty between Šuppiluliuma and the king of Nuhašše (Beckman 1999, 54-58), as well as in a later treaty between Muršili II and Niqmeppa of Ugarit (Beckman 1999, 64-69).

In sum, even though there is no direct evidence, Hittite aggression in northern Syria seems a likely culprit for the destruction of Alalakh Level IV. If we assume that the Level IV palace had been destroyed shortly before or after 1400 BC, as generally

³⁶ von Dassow (2008, 62) proposes that Mukiš might also denote the name of a city with unknown location, which might have served as the new capital of the kingdom.

³⁷ The incidents are also discussed in a second letter from Šuppiluliuma to Niqmaddu (Beckman 1999, 151).

but not universally accepted in current scholarship, Tudhaliya I/II would become the most likely convict. At the time of Šuppiluliuma the city seems to be firmly in Hittite hands. However, the region of Mukiš, now ruled from elsewhere, continued to be an adversary of the Hittites until its suppression by Šuppiluliuma to become a land “at peace with Hatti”, namely a vassal.

As far as the period of Hittite rule is concerned, textual material from the site itself is not particularly rich and thus, unable to draw a coherent picture of historical events. Nevertheless, the combined textual evidence from Alalakh, Hattuša and Ugarit, provides the names of at least some possible Hittite governors at Alalakh. The first of these persons is Tudhaliya, whose stela was found at Alalakh. In the inscription of the stela, Tudhaliya calls himself “king’s son” and was possibly a relative of the Hittite Great King (Woolley 1955, plate XLVII; Yener 2005, 112; Yener 2013, 18). Paluwe, who also calls himself “king’s son and ruler of the land” on his seal, was another Hittite ruler at Alalakh (von Dassow 2008, 78). Šukur-Tešup, a Hittite ruler of Mukiš residing at Alalakh, is known from his letter to Ammištamru of Ugarit (Niedorf 2002, 524).

Finally, there are some Hittite sources accounting wine and grain of Mukiš that was shipped to Hatti. The shipment of grain appears particularly crucial since this took place during a period of food shortage in Hittite lands (Bryce 1998, 365). Hence, the importance of this area for the Hittite Kingdom as an agricultural land is clearly evident.

If we turn to the situation of Kizzuwatna, this country seems to have been taken under direct Hittite control also during the 14th century BC. However, neither the definite date, nor the circumstances of this incident are securely determined. There is little doubt that Kizzuwatna was under Hittite control in the time of Šuppiluliuma I,

who early in his reign appointed his son Telipinu the “Priest of Kizzuwatna” with duties resembling those of a vassal king. There is also a “Telipinu, the priest”, who is known to have lead armies in one of Šuppiluliuma’s Syrian campaigns and was very likely the same Hittite prince installed in Kizzuwatna. (Götze 1940, 12-14; Beal 1986, 435).

There are also sources to indicate that Hittite involvement in Kizzuwatna predates Šuppiluliuma I. A document from the reign of Arnuwanda I, successor of Tudhaliya I/II (early 14th century BC), attests certain men stationed by the Hittite king in some cities of Kizzuwatna. The aim of this undertaking was to punish acts of treason, presumably against Hatti. More significantly, the text also refers to the highest official of Kizzuwatna, who bears the title of Hittite provincial governors (Beal 1986, 437-38). A later ritual text from Muṣili’s reign records a Tudhaliya as one of his ancestors, who had moved a god, presumably a cult statue, from the city of Kizzuwatna to Hatti. Also, the joint annals of Tudhaliya I/II and Arnuwanda I narrate the building or fortification by the Hittite king of three Kizzuwatnean cities including Adaniya (Beal 1986, 439-40). Obviously, none of these acts would have been possible if the Hittites did not have certain control over at least some part of Kizzuwatna. In sum, Hittite interventions in Kizzuwatna started in the time of Tudhaliya I/II, even though it is not certain whether this country was a vassal to the Hittite kingdom during these events. Later, during the reign of Šuppiluliuma I Kizzuwatna appears as a truly annexed country and remains a Hittite province until the fall of the Hittite kingdom at the end of the 13th century BC.

In addition to its strategic location, the cultic importance of Kizzuwatna for the Hittites is also fairly well testified, as several Hittite religious or cultic texts refer to the deities, priests or magicians from this country. Surely, the most important native

of Kizzuwatna was Puduhepa, who became the wife of Hattušili III and the best known Hittite queen. Hattušili III met and married Puduhepa when he was the crown prince, during his cultic visit to Ištar of Lawazantiya, a prominent cult center in Kizzuwatna. Puduhepa was the daughter of Pentipsarri, the priest of Ištar of Lawazantiya and herself a priestess of the same deity (Bryce 1998, 273-74). Another Hittite king to visit Kizzuwatna for cultic duties is Muršili II, who is known to have attended the festival of goddess Hepat at Kummani in Kizzuwatna (Götze 1940, 10; Bryce 1998, 219-20).

2.4. SUMMARY AND CONCLUSIONS

The history of Cilicia and the Amuq during the second millennium BC can be summarized as follows: Sometime in the 17th century BC, the area of the Amuq Plain was organized by the king of Iamhad as a small, dependent kingdom with its capital at Alalakh. Even though this palatial center was destroyed in the late 17th or early 16th century BC, perhaps by Hattušili I, it seems possible that the regal family continued after the destruction. Following the demise of Iamhad in the 16th century BC, the polity ruled from Alalakh possibly became autonomous and remained so until the Mittanian hegemony of the 15th century BC. As for Cilicia, the Hittite Old Kingdom seems to have exercised a certain degree of authority in this region, at least for a brief period, in the 17th or 16th centuries BC. However, when the Hittite Kingdom was in a weakened state during the later 16th and 15th centuries BC, the kings of Kizzuwatna corresponded with Hittite kings in equal terms, representing an independent political entity.

The late 15th century BC was the period when the kingdom of Mittani was the dominant power in north Syro-Mesopotamia. It was also during this period that king Idrimi of Alalakh made himself a Mittanian vassal on his own will. The Mittani kingdom also seems to have had a certain control over Kizzuwatna around this time. It was after the attenuation of the Mittani kingdom that the Hittites gained control of both Cilicia and the Amuq in the early or mid-14th century BC. Hittite rule is well represented in material culture of the Late Bronze Age II levels in both regions. Interestingly, the end of this period appears to have been experienced as a different phenomenon in the three sites studied. According to recent investigations, Alalakh seems to be abandoned, with the exception of its temple, around 1300 BC. At Kinet, the final phase of the Late Bronze Age (Period 13.2) reflects a loosening of Hittite involvement. In contrast, our current knowledge implicates that Hittite presence remained strong at Tarsus until around 1200 BC. Interestingly, recent fieldwork in western Cilicia also revealed some evidence for the attenuation of Hittite presence at Mersin and Kilisetepe towards the end of the 13th century BC (Postgate 2007, 148). In this respect, it might be hard to visualize why Tarsus would deviate from this broader Cilician phenomenon. Perhaps the current fieldwork at the site will one day identify parallel evidence to its western and eastern neighbors.

As far as the external contacts of Cilicia and the Amuq are concerned, textual information only illuminates relations with their immediate neighbors or political overlords. Therefore, we depend entirely on archaeological evidence to explore the connections of the study region with other areas such as Mesopotamia, Egypt, Cyprus and the Aegean. In this respect, the relative abundance of imported commodities, especially pottery, becomes our primary focus, as it is regarded an indicator of the intensity of the external commercial contacts.

To start with Alalakh, this site displays the characteristic features of Levantine towns of the second millennium BC, with both Cypriot and Mycenaean ceramic imports occurring in substantial quantities. Cypriot pottery is represented by about 400 vessels found in Woolley's excavations and more than 250 vessels recovered during the first two excavation seasons of the current fieldwork (Kozal 2010). Mycenaean pottery, which is recently attributed exclusively to the LH III A2 phase, is found in a relative abundance that is typical of the major sites in the Levant (Koehl 2010, 81). The site also displays contacts with northern Mesopotamia, as documented by the presence of Nuzi Ware in the late 15th and 14th century BC contexts. Red Lustrous Wheelmade Ware, which was in interregional circulation between Cyprus, Levant, and central Anatolia during the Late Bronze Age, was also recovered in noticeable quantities (Kozal 2003, 66, fig. 1). Finally, the international character of the elite art of Alalakh is well reflected, at least in Level VII, by the Minoan designs observed in palace frescoes (Niemeier and Niemeier 1998, 82-85), and the Babylonian, Egyptian and Cappadocian motifs that occur in local glyptic (Collon 1975, 198).

The situation in Cilicia looks quite different, as the typical pottery types in interregional circulation only occur as sporadic imports. Red Lustrous Wheelmade Pottery was found in insignificant numbers at Tarsus, Kinet and Mersin. In contrast, the ware occurs in more significant quantities at Kilise Tepe, situated in Göksu Valley to the west of Cilician Plain (Kozal 2003, 66, fig. 1). Mycenaean LH IIIA and B pottery is represented in Cilicia by only less than 10 pieces distributed between Kinet, Mersin, Kazanlı, and Kilise Tepe, while it is completely absent at Tarsus (Kozal 2003, 68, fig. 1). Cypriot pottery is attested in somewhat more notable numbers, represented by about 50 sherds from Tarsus and Kinet, and a few examples from Mersin and Soloi (Kozal 2003, 69, fig. 1). However, even these numbers appear quite insignificant

compared to several hundreds from Alalakh and many other Levantine sites. The scarcity of Cypriot imports in Cilicia correlates with the almost complete absence of Cilician goods on Cyprus (Kozal 2005, 137).

In a broader context, the scarcity of imported goods, particularly Cypriot and Mycenaean pottery, in Hittite-controlled areas is a known phenomenon. This situation is considered as a possible outcome of economic policies of the Hittite state, which might have hindered the flow of these imports into its provinces. If this was indeed the case, Cilicia would be expected to be affected by such policies as it was under Hittite political and possibly economic influence during most of the Late Bronze Age (Cline 1991, 133-43; Cline 1994, 71-74; Kozal 2003, 72; Kozal 2005, 137). This assumption is in accord with Gate's observation of an increase in Cypriot pottery and Red Lustrous Wheelmade Ware in Kinet Period 13.2, which is characterized by the loosening of Hittite control at the site (Gates 2006, 304). However, we should also note that Alalakh does not seem to have had any problems in importing Cypriot and Mycenaean pottery in the 14th century BC, which was the period of the Hittite rule.

In general terms, the external contacts of Cilicia during the second millennium BC were not as diverse as those of a major Levantine site, such as Alalakh. The truly significant contacts of the region are observed only with northern Syria during the Middle Bronze Age, and with Hittite-dominated central Anatolia during the Late Bronze Age. The lack of evidence for consistent commercial contacts between Cilicia and Cyprus is particularly difficult to rationalize given the close proximity between the two regions. One possible explanation is that the exchange between them could have been in perishable commodities that are not possible to track archaeologically (Kozal 2005, 137).

One would naturally presume that economic prosperity and extensive interregional trade would lead to increased access to metals, especially to tin. Therefore, the limited Cilician contact with the rest of the eastern Mediterranean, which was perhaps the outcome of Hittite political or economic domination, might be reflected in metal industries in the form of relative scarcity of tin and relatively less diversified metal sources, at least compared to the eastern neighbor, the Amuq. Likewise, shifting of political or economic alliances of one region may change the extent of alloy use, as well as the utilized sources of copper, or their relative importance. The evidence from geochemical and lead isotope data will be interpreted against this background.

3. COPPER-BASED METALS DURING THE SECOND MILLENNIUM BC

3.1. INTRODUCTION

Copper and its alloys were the material from which the most essential commodities of the Bronze Age, namely weapons, tools and prestige objects were manufactured. As a result, the production of copper and its alloys, and the procurement of copper and tin constituted an intrinsic part of Bronze Age economies. The aspects of this industry and the trade of these two crucial metals during the Middle and Late Bronze Age will be addressed in this chapter.

The discussion begins with the background information on copper alloys used during the second millennium BC, with a focus on their history, production methods and properties (Section 3.2). As the predominant alloys of the period were arsenical copper and tin-bronze, the discussion will primarily explore the situation of these two alloys. The proceeding Section 3.3 will present the review of major copper sources in the Near East and the eastern Mediterranean, as well as the potential sources of tin, arsenic and other common alloy constituents.

The subsequent section (3.4) includes a detailed discussion of our existing knowledge of production and trade of copper and tin during the Middle and Late Bronze Age, combining archaeological, textual and lead isotope evidence. A special attention will be paid to the situations of the study region and also Cyprus, which is not only a neighbor of Cilicia and the Amuq, but also a primary center of copper production during this period.

3.2. COPPER ALLOYS IN THE SECOND MILLENNIUM BC

Forming a copper alloy, that is inserting atoms of another metal into the crystalline structure of copper, enhances the mechanical properties such as hardness and ductility³⁸. Besides improving these qualities, alloying also augments the casting properties of molten copper, as it lowers the melting point and makes the metal less viscous (Craddock 1995, 112). As a natural outcome, metal objects of complex forms started to be cast with the beginning of copper alloying.

3.2.1. Arsenical Copper

The first copper alloy that enjoyed a consistent use throughout western Asia and the eastern Mediterranean was arsenical copper, the earliest examples of which date to the fourth millennium BC. In its as-cast state, this alloy enhances the hardness of copper at arsenic concentrations between 2 and 6 percent. Moreover, due to its excellent ductility it can be work hardened either cold or hot to a great extent without breakage (Charles 1967, 24; Northover 1989, 112-13, Lechtman 1996, 488, 506, 510). Besides these mechanical advantages, the silver-like color of the alloy must be considered as another desired property, at least concerning ornamental or luxury objects.

The earliest examples of arsenical copper date to the early fourth millennium BC and are primarily found in the Iranian Plateau (Pigott 1999, 81), and Anatolia (Begemann, Pernicka, and Schmitt-Strecker 1994). In Palestine, the alloy was commonly used in the production of prestige items such as mace-heads, crowns and

³⁸ Ductility is the measure of the extent, to which a metal can be deformed without fracture (Lechtman 1996, 498).

standards during the mid-fourth millennium BC. The best known collection of such items is the famous hoard of Nahal Mishmar in Israel, which consists of more than four hundred metal artifacts. All arsenic-containing specimens from this hoard also have high antimony contents, and thus represent a ternary alloy (Shalev and Northover 1993; Tadmor et al. 1995). As the fourth millennium progressed, the use of this alloy spread to Mesopotamia (Moorey 1994, 251) and the Aegean (Tzachili 2008, 12). It was, however, during the proceeding third millennium BC that arsenical copper was widely used throughout western Asia and the eastern Mediterranean. Even though the utilization of this alloy did not cease until the end of the Bronze Age, after 2000 BC it started to lose its importance in favor of a new alloy, tin-bronze.

Since the occurrence of native arsenic is extremely rare, and the element itself is highly volatile, it is not likely that this metal was available in its pure form in antiquity. Thus, it does not come as a surprise that no word in ancient texts could be identified as a designation for arsenic (Weeks 2003, 116; Muhly 2006, 163).

Therefore, it was also not possible to produce copper-arsenic alloy by means of adding metallic arsenic to molten copper. Nonetheless, experimental studies demonstrated that ancient copper-arsenic alloy could be produced through three distinct mechanisms (Charles 1967, 24-26; Lechtman 1996, 479; Lechtman and Klein 1999; Moorey 1994, 250, Weeks 2003, 114). One proposed method is the direct smelting of copper-arsenide ores, namely copper ores that naturally incorporate arsenic as part of their mineral composition. The occurrence of high arsenic contents in some copper prills found entrapped in ancient slag samples has been regarded evidence for this process (Gale et al. 1985, 89-92).

Alternatively, copper arsenic alloys can be produced by co-smelting arsenic-bearing minerals together with any copper ores. Certain copper deposits occur as a

combination of different minerals, some of which are arsenic-containing. Such deposits provide a readily available charge, the direct smelting of which would naturally yield the copper-arsenic alloy. It is quite likely that these naturally occurring co-smelting charges might have been the source of ancient arsenical copper (Lechtman and Klein 1999, 498-99). Finally, arsenical copper can be produced by the addition of arsenic-bearing minerals directly to molten copper. Pieces of ore with significantly high arsenic contents that are found at certain prehistoric metal workshops are considered as possible indicators of this process (Weeks 2003, 116). Even though all three mechanisms are experimentally demonstrated to be possible by means of prehistoric technology, it is difficult to determine which one prevailed in antiquity as the standard method of producing the copper arsenic alloy.

3.2.2. Tin-Bronze

The advent of tin-bronze, the earliest examples of which date to around 3000 BC, represents another milestone in the development of copper metallurgy. The most common mineral of tin is cassiterite (SnO_2), which is deposited in veins and lodes within the host granite. This mineral generally occurs together with gold, and just like gold it can be collected from the streambeds by means of panning (Moorey 1994, 297; Thornton 2007, 131). The most significant feature of tin within the context of ancient technology is that it could be easily smelted from cassiterite. Thus, in contrast to arsenic, tin could be obtained and utilized in its metallic form in antiquity. Not surprisingly, there is substantial textual evidence from the third and second millennia

BC demonstrating that tin was exchanged, as well as added to copper in its metallic form³⁹ (Muhly 1985b, 282, Archi 1993; Potts 1994, 153; Moorey 1994, 251-52).

As far as mechanical properties are concerned, at its ideal degree of work-hardening tin-bronze achieves the same degree of hardness as arsenical copper (Lechtman 1996, 503). However, the major difference between the two alloys is that arsenical copper can be worked hot and cold without losing its ductility, whereas tin-bronze becomes extremely brittle when worked hot (Lechtman 1996, 501, 506). With respect to color properties, alloying copper with tin yields a gold-like color in contrast to the silver-like appearance of arsenical copper.

The earliest objects of tin-bronze date to the early centuries of the third millennium BC, while a few examples might slightly predate 3000 BC⁴⁰. However, before about 2600 BC, tin-bronze objects are pretty scarce, even though they are found in a broad geography stretching from the Adriatic coast in the west to western Iran in the east. At each locality of its occurrence, generally only up to three tin-bronze items have been recorded. Only Tell Qara Quzaq (Montero Fenollos 1997) in northern Syria, Tell Judaidah (Braidwood, Burke, and Nachtrieb 1951) in the Amuq, and Kalleh Nissar (Helwing, 2009) in western Iran stand out as exceptions, as they yielded fourteen, eight and five tin-bronze objects respectively. Thus, during this period there was neither a consistent use of this alloy, nor a regional concentration of

³⁹ It has been firmly established that the Akkadian words *annaku* (Sumerian AN.NA) and *siparru* (Sumerian ZABAR) respectively mean tin and tin-bronze. Frequent references to *annaku*/AN. NA, which explicitly mention that this metal is mixed with *erū*/URUDU (copper) at fixed ratios to produce the alloy *siparru*/ZABAR, leave little doubt for the accuracy of these identifications (Muhly 1985b, 279-81; Moorey 1994, 297-98).

⁴⁰ Tin-bronze items securely datable to the early centuries of the third millennium BC are found at three sites in the northeastern Aegean (Pernicka, et al. 1990; Begemann, Schmitt-Strecker, and Pernicka 1992; Begemann, Schmitt-Strecker, and Pernicka 2003), at three sites in central and southern Anatolia (de Jesus 1980, 127, 132; Kuruçayırılı and Özbal 2005), at two sites in northern Syria (Braidwood, Burke, and Nachtrieb 1951; Montero Fenollós 1997). Western Balkans (Primas 2002), northern Greece (Renfrew and Slater 2003), northern Mesopotamia (Stech 1999, 63), western Iran (Helwing 2009), Caucasia (Tedesco 2006, 291), and Egypt (Muhly 1993, 63) have one single site with evidence for tin-bronze use.

its distribution. As neither tin, nor tin-bronze were in common circulation, there is a lack of textual reference to either metal. Only one single Mesopotamian document from the first half of the third millennium BC (Early Dynastic I period) refers to tin-bronze (Potts 1994, 153).

The real consistent use of tin-bronze begins in the second half of the third millennium BC. However, unlike in the case of arsenical copper, the utilization of tin-bronze was not a common practice throughout southwest Asia, southeast Europe, and the eastern Mediterranean. Instead, the frequent use of the alloy was confined to particular parts of this geography as it was common only in Mesopotamia, Anatolia, northeastern Aegean, southeastern Arabia, and at the Harappan sites of the Indus Valley.

In Mesopotamia, tin-bronze objects are predominantly recovered at cemetery sites starting with the Early Dynastic III period. The best known examples of these sites are the royal cemeteries at Ur and Kish (Stech 1999, 64-66). Likewise, the frequent occurrence of the alloy in Anatolia is primarily attested at elite burial sites of the Early Bronze II and III periods, such as Alacahöyük, Mahmatlar, and Horoztepe in central Anatolia (de Jesus 1980, 125-27, Graph 5; Muhly 1993, 240) and Gedikli in southeastern Anatolia (Bengliyan 1985). Another region, where tin-bronze objects from the third millennium BC are predominantly found in noble burials, is southeastern Arabia (Weeks 2003, 188-91). However, there is also good evidence for the occurrence of the alloy in settlement contexts, as apparent in the northeastern Aegean (de Jesus 1980, graph 10; Pernicka et al. 1990; Stos-Gale 1992), in the Indus Valley (Agrawal 1984, 164; Kenoyer and Miller 1999, app. A; Lahiri 1995, table 2), and in Mesopotamia (Stech 1999, 62-64).

In some parts of western Asia and the eastern Mediterranean, tin-bronze displays a limited occurrence in the third millennium BC. These regions are central Asia (Ruzanov 1999, 104), the Caucasus (Kavtaradze 1999, 84-86), western Iran (Malfoy and Menu 1987, table D, 361, Weeks 2003, 175), Syria and Palestine (Phillip 1991, 93-98; Rosenfeld, Ilani, and M. Dvorachek 1997, tables 1,2; Phillip, Clogg, and Dungworth 2003), the southern Anatolian coast (de Jesus 1980, graph 8-9; Kuruçayırılı and Özbal 2005), and Cyprus (Gale and Stos-Gale 1989b, 252-54; Balthazar 1990, 161, 431).

In Egypt (Weeks 2003, 175) and throughout the Iranian Plateau (Pigott 1999, 81-84) tin-bronze was particularly scarce. In the western and southern Aegean, the situation seems more heterogeneous. In central Greece, the consistent use of this alloy occurs only towards the end of the third millennium BC (Liversage 1994, table XVII, Primas 2002, 307, fig. 4; McGeehan-Liritzis and Gale 1988, table 8). In southern Greece and the Cycladic islands, tin-bronzes are found only at those particular sites, which show evidence for strong contacts with the east coast of the Aegean, such as Kastri on Syros, Manika and Lithares on the mainland (Stos-Gale, Sampson, and Mangou 1996, 58, table 1, 2, 3; Stos-Gale and Gale 2003, table 5). Finally, the alloy had a limited occurrence on Crete during the third millennium BC (Stos-Gale 2001, 204-6).

In these regions, the use tin-bronze became more common in the early centuries of the second millennium BC. The increase in the availability of tin during this period is also evidenced by textual sources, such as the archives of Kaneš (Kültepe) (ca. 1950-1750 BC) in central Anatolia (Larsen 1976, 90-91, 102-5; Larsen 1987, 50) and Mari (late 19th, early 18th centuries BC) on the central Euphrates (Dossin 1970; Klengel 1992, 77-78; Knapp and Cherry 1994, 145). Tin-bronze

became even more abundant through the course of the second millennium, gradually replacing arsenical-copper and ultimately becoming the predominant copper alloy in the Late Bronze Age (ca. 1600-1200 BC) (Pare 2000, 25-27, fig. 1.14, Muhly 2003, 144; Tzatchili 2008, 20). The large scale circulation of metallic tin during this period is well evidenced at the Uluburun Shipwreck from the late 14th century BC, the cargo of which contained one ton of tin shipped in ingot form along with ten tons of copper (Pulak 2000, 150-56).

As I will discuss in detail in Section 3.3.4, the provenance of tin used in the Bronze Age has not been determined and the issue constitutes a matter of scholarly debate. Nevertheless, there is strong evidence that the communities from the Aegean to Mesopotamia were importing this metal primarily or exclusively from distant sources, most likely from farther east. As a result, several explanations have been proposed to rationalize how tin-bronze, the procurement of which depended on long distance exchange, was capable of replacing the more readily available arsenical copper. The obvious comparison between the two alloys would be between their mechanical properties. However, as discussed above, experimental studies demonstrated that at ideal mixing ratios and with an optimum degree of work hardening comparable mechanical qualities can be obtained with both alloys (Lechtman 1996, 503).

It has also been argued that the poisonous fumes from arsenic-based material may have led to the gradual abandonment of arsenical copper industry in favor of the tin-bronze alternative (Charles 1967, 26). Contrary to this proposition, it has been stated that these fumes become significantly hazardous only when the arsenic content exceeds 7 percent, which is higher than found in most ancient arsenical copper objects. Furthermore, if working with arsenic ores were that dangerous, one would not

expect that the practice of arsenical copper metallurgy would have lasted as long as it did (Pernicka 1998, 136; Muhly 2006, 163).

The consistent occurrence of early tin-bronze artifacts in elite burials along with its selective use in prestige objects led some researchers to consider the exotic nature of this alloy as the primary reason for its preference over arsenical copper (Stech and Pigott 1986, 41; Moorey 1994, 252-53; Weeks 2003, 125-28). The strong evidence for this phenomenon is undeniable, at least in some specific contexts, such as the rich tombs of Anatolia, Mesopotamia and southeastern Arabia. However, as noted above, the third millennium BC finds from such regions as the northeast Aegean (Pernicka et al. 1984, table 4) and the Indus Valley (Kenoyer and Miller 1999, 114) indicate the common use of this alloy also in non-prestige contexts and for utilitarian implements. This evidence demonstrates that the correlation of tin with elite contexts is not necessarily a universal phenomenon.

Finally, the simplicity of its production mechanism has been stressed as the main advantage of tin-bronze metallurgy. As tin was available in pure metallic form, tin-bronze was produced by simply adding metallic tin to molten copper, which would enable a significant degree of control over the chemical composition of the product (Northover 1989, 113, Lechtman 1996, 478). Such a property should be considered a significant advantage because greater control over the final composition facilitates the ease of obtaining the intended hardness, ductility, casting ability, or color. The same degree of managing these properties cannot be achieved in arsenical copper metallurgy, where the alloying element cannot be added to base metal in its pure metallic form.

3.2.3. Other Alloys of Copper

Zinc (Zn), nickel (Ni), antimony (Sb), and cobalt (Co) are other elements that are found in ancient copper objects in sufficiently high concentrations to indicate deliberate alloying. The alloy of copper with zinc is called brass, which has a distinctive gold-like color. The early occurrence of this alloy is discussed in detail by Thornton (2007), who investigates the contexts, as well as the geographical and chronological distribution patterns of brass objects from the Bronze and Iron Ages⁴¹. In his study, Thornton particularly stresses the geographical and chronological overlap between the occurrences of early brass and tin-bronze objects. He further notes that the ternary alloy of copper, tin and zinc is commonly attested, whereas zinc never co-occurs with arsenic. Accordingly, Thornton concludes that brass and tin-bronze could be used interchangeably, serving the same purpose of obtaining the gold-like color, which must have been the desired property (Thornton 2007, 129-32).

Zinc occurs in nature in its sulfide and carbonate mineral forms, that are found together with copper and lead ores. The possibility of forming copper-zinc alloys by directly co-smelting copper ores and zinc oxides was experimentally demonstrated. As for the zinc carbonates, the most common zinc minerals in the Near East, need first to be oxidized to zinc-oxides, prior to co-smelting with copper (Thornton 2007, 124-25).

Antimony, nickel and cobalt are primarily found in copper objects with high arsenic contents. This is not surprising given the close geological associations of the minerals of these chemical elements with arsenic. In the Near East, copper objects with high contents of both arsenic and nickel (with an occasional presence of cobalt) were particularly common during the late fourth and third millennium BC. Copper

⁴¹ Thornton's survey lists a total of fifty-five brass objects known from Bronze and Iron Age southwest Asia and southeast Europe. His study only incorporates copper objects with zinc contents in excess of 5 percent.

deposits found in association with ophiolitic rocks tend to incorporate significant concentrations of arsenic, nickel, and cobalt, and are thus considered the possible source of copper objects with high contents of these elements (Hauptmann, Hess, and Palmieri 2000, 79-80; Hauptmann 2007, 297-98). Less frequently, high concentrations of nickel occur in copper objects without the presence of arsenic. Like other alloying elements, nickel improves the hardness and strength of copper and provides a silvery color. Since nickel was not available in pure metallic form in antiquity, the production of this alloy must have been achieved in a similar way to those of arsenical copper and brass (Weeks 2003, 113).

There are several examples of ancient copper-antimony alloy reported from the Near East and the Caucasus. These objects commonly, but not necessarily, contain arsenic as well. In the absence of arsenic, the presence of up to 10 percent antimony in copper creates a gold-like color, which was likely the desired property of this alloy. However, the major drawback of this alloy is that it becomes extremely brittle once the antimony content exceeds a few percent (Charles 1980, 170-72). Ancient copper-antimony alloy was likely produced by directly smelting the so-called “fahlerz” type of copper ores. These ores consist of chemically complex, antimony or arsenic-bearing sulfide minerals, such as tetrahedryte ((CuFe)₁₂Sb₄S₁₃) and tennantite ((CuFe)₁₂As₄S₁₃) (Craddock 1995, 28-29; Hauptmann 2007, 295-97). In addition to items of copper-antimony alloy, there are also a few Bronze and Iron Age objects of pure antimony from the Near East and the Caucasus. Antimony used in these artifacts is most likely of native and not smelted origin (Moorey 1994, 240-42).

There are two areas in southwest Asia that display a consistent use of copper-antimony alloy in prehistory. The first of these regions is Palestine, where the ternary alloy of copper, arsenic and antimony appears as the preferred material of such

prestige items as maceheads, crowns and standards during the fourth millennium BC. Strikingly, hematite artifacts of exactly the same typologies have been recovered in the region. Apparently, the alloy was employed in these prestige items for its distinctive purple-grayish color, in order to imitate the appearance of hematite (Craddock 1995, 291). As discussed above, this tradition is best represented by the finds from the Nahal Mishmar hoard, the objects from which display antimony contents of up to 25.5 percent (Shalev and Northover 1993, Tadmor et al. 1995, 129, 136).

The second region is the Caucasus, where about twenty objects of this alloy are reported from the Middle Bronze Age contexts (Hauptmann and Gambaschidze 2001, 277-85; Pike, Cowell, and Curtis 1996). In contrast to chalcolithic Palestine, the artifacts from the Middle Bronze Age Caucasus are devoid of arsenic, since a high arsenic content is observed only in one object. Isolated examples of high antimony copper artifacts are also known from third millennium BC Anatolia, where the alloy was particularly used in metal stamp seals (Özbal, Kuruçayırılı, and Mısırlı 2005).

3.3. SOURCES OF ANCIENT COPPER AND ITS ADDITIVES

3.3.1. Major Copper Deposits

Rich sources of copper exist in the eastern Mediterranean and the Near East thanks to complex geological processes, which led to the formation of the so-called Tethyan Eurasian Metallogenetic Belt. This term refers to the chain of mountain ranges, which extends from Cyprus to eastern Anatolia and then turns southeast into Iran and eastern Arabia. This mountainous belt, which constitutes a part of the larger

Alpine and Himalayan mountain systems, incorporates the Troodos massif on Cyprus, the southeastern Taurus Mountains of eastern Turkey, and the Zagros Range of western Iran. Along its entire extension, this belt hosts rich ore deposits that are of particular importance for both modern and ancient metal industries (Hauptmann 2007, 55-59).

Cyprus

The Tethyan Eurasian Metallogenic Belt has the most important concentration of copper deposits at its westernmost extension, namely on the island of Cyprus. The vast majority of these are situated in the Troodos Mountains, a mountain range extending roughly ninety kilometers in length and thirty kilometers in width. In this relatively narrow mountainous area ninety occurrences of copper mineralization are recorded, some of which are of great economic importance for modern Cyprus (Hauptmann 2008, 60; Stos-Gale and Gale 1994, 93-97).

Copper mineralizations on Cyprus are primarily sulfides associated with ophiolitic formations. Archaeometallurgical investigations showed that these deposits were being exploited as early as the Middle Chalcolithic period (Knapp 2012, 14). The intensity of ancient copper exploitation is well demonstrated by huge heaps of slags found all over the Troodos Massif. The total mass of ancient slag accumulated over a period of roughly three thousand years of activity has been estimated around four million tons, which further implies the production of an estimated two hundred thousand tons of copper during this time span (Constantinou 1982, 22; Muhly 1996, 46).

Anatolia

Major sources of copper occur in those parts of eastern Anatolia that lie on the Tethyan Eurasian Metallogenetic Belt. In this region, the site of Ergani Maden hosts major copper deposits, which constitute the second most important source area in the Near East after the Troodos Massif. Similar to the copper sources of the Troodos, the major mineralization at Ergani is also sulfidic. Even though ancient mines and slag heaps have been identified in association with Ergani, these could not be securely dated (Seeliger et al. 1985, 638-39; Hauptmann 2007, 61).

Besides those areas forming part of the Metallogenetic Belt, copper ores are found throughout Anatolia. A survey by archaeometallurgists inspected ninety-one known copper sources, thirty-six of which displayed traces of prehistoric mining. However, only three of these could be securely assigned to the Chalcolithic and Bronze Age periods by means of carbon dating (Wagner and Öztunalı 2000).

Iran

Situated on the eastern sector of the Metallogenetic Belt, Iran is another region, where important copper sources are known. More than four hundred occurrences of copper have been recorded in Iran, seventy-eight of which bear evidence for ancient mining (Nefazati, Momenzadeh, and Pernicka 2008, 309). The most important of these is the Anarak-Talmesi mining district in the western part of Desht-i Kebr. Covering an area of roughly ten thousand square kilometers, this source area is one of the largest and richest in the entire Near East. Veshnoveh is another important copper source, where evidence for ancient exploitation has been observed,

which was not possible at Anarak. Ancient mining activity at this site has been determined to go back as early as the first half of the fourth millennium BC (Pigott 1999, 78-79; Nefazati, Momenzadeh, and Pernicka 2008, 311-12).

Southeastern Arabia

Situated on the southeastern fringe of the Metallogenetic Belt, the southeastern tip of the Arabian Peninsula (modern Oman and United Arab Emirates) constitutes another prominent source area of copper. In this region, more than 150 copper deposits are known that are found in association with ophiolitic formations. Research at the sites of ancient metallurgical activity demonstrated that the exploitation of these deposits started in the late fourth millennium BC, and reached its highest intensity during the late third millennium BC (Weeks 2003, 57-58).

Oman is identified as Magan, the land, from which the Mesopotamians obtained their copper during the second half of the third millennium BC (Weeks 2003, 14-16; Begemann et al. 2010, 157-60). However, after 2000 BC, Magan is no longer mentioned in Mesopotamian sources, parallel to a decline of copper production observed in archaeological record. Instead, copper now seems to have been imported into Mesopotamia from Dilmun, which has been identified as Bahrain. However, given the lack of copper sources on Bahrain, copper reaching Mesopotamia via Dilmun must still have been the copper of Oman. Therefore, it is likely that Mesopotamia continued to import copper from Magan, but now without any direct contact with the actual producers. By the beginning of the 17th century BC, there are no longer references to copper reaching Mesopotamia from the south. It was also

during this time that Alashiyan/Cypriot copper started to reach Mesopotamia, apparently replacing Omani copper in this market (Moorey 1994, 245-46).

Egypt and Northwest Arabia

Besides these regions situated along the Metallogenetic Belt, important copper sources also occur along the so-called Rift Valley, which extends in a north-south orientation from the Red Sea to to the Taurus Mountains of southern Anatolia (Hauptmann 2007, 55). In the southern part of this formation, copper and copper-manganese deposits occur in Sinai and Hejaz. Those deposits in Sinai are determined to have been exploited since the Old Kingdom period of Egypt (third millennium BC). At the largest mining site in this region, an estimated amount of one hundred thousand tons of slag has been accumulated since pharaonic times. Even earlier mining activity is documented at the copper deposits in the Eastern Desert of Egypt, the exploitations of which go back to the Naqqada II period (ca. 3500-3200 BC) (Hauptmann 2007, 62; Hauptmann 2008, 62-64).

Israel and Jordan

By far the most important copper deposits along the Rift System are located in Wadi Arabah, a valley that occupies the part of the Rift Valley between the Red Sea and the Dead Sea. Of the numerous copper deposits known in this area, those at Faynan in Jordan and Timna in Israel are the most prominent, and from an archaeometallurgical perspective, the best studied ones. At Faynan, where copper exploitation started around 3500 BC, mining activity reached its peak in the third

millennium BC and fell into decline after 2000 BC. Copper production at the site re-intensified at the end of the second millennium BC, perhaps correlating with the decline in Cypriot copper production (Hauptmann 2008, 62). At Timna, the earliest mining operations are also dated to the fourth millennium BC. But in contrast to long-lived Faynan, the peak of copper production at Timna lasted for only a short time period around the end of the third millennium BC, which corresponds to the period of decline at Faynan (Hauptmann 2007, 303).

The Aegean

Although the Aegean basin remains outside the major metallogenetic zones discussed above, several copper deposits are known in this region, which must have been important sources for local prehistoric communities. On mainland Greece, the primary site of interest is Laurion, which was a major source of lead and zinc in antiquity. Copper, which occurs as a secondary constituent of the deposit, must also have been exploited in prehistory, even though the absence of conclusive evidence has been noted (Muhly 2008, 72). In the Cyclades, copper deposits occur on the islands of Kythnos, Siphnos, Seriphos and Kea. On Kythnos and Siphnos, evidence for prehistoric mining and smelting has been detected and dated to the middle and late third millennium BC (Gale and Stos-Gale 1989a; Tzachili 2008, 13).

Even though the island of Crete made extensive use of copper throughout the Bronze Age, there is no considerable deposit on the island. The limited number of copper ores so far detected yielded only low grade copper ores (Muhly 2008, 72; Stos and Gale 2006, 304). The use of imported copper in the early metal industry of the island is best documented by the evidence from the copper workshop at

Chrysokamino from the Early Minoan III-Middle Minoan I period (end of the third, beginning of the second millennium BC) (Betancourt 2006). Lead isotope evidence points to Laurion, Siphnos, Kea, and Kythnos as the possible sources of copper found in slag samples (Stos and Gale 2006, 313-16).

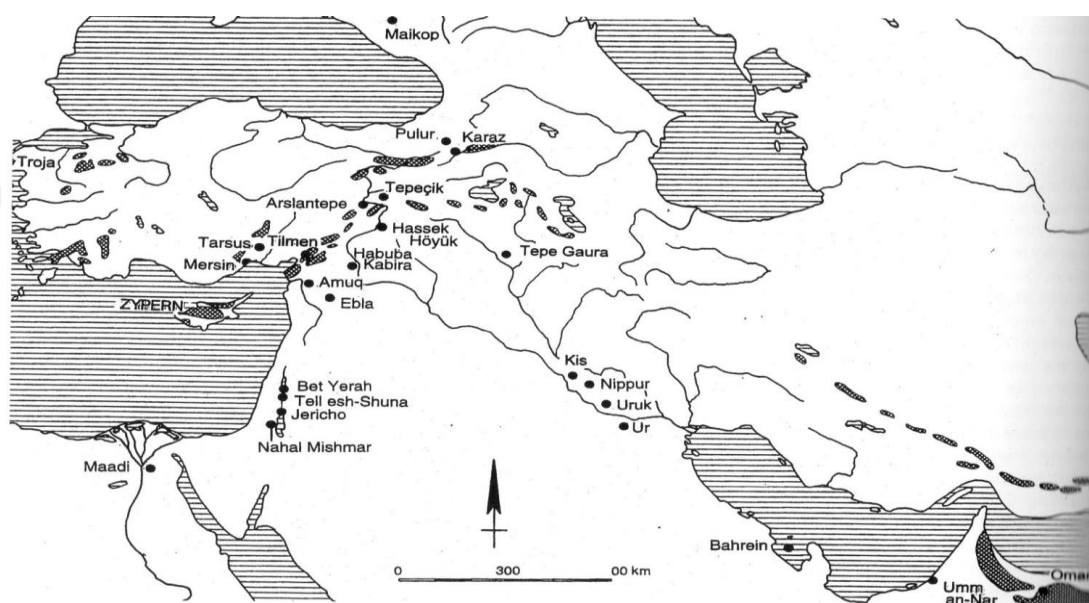
3.3.2. Sources of Arsenic, Nickel and Antimony

Many of the major copper deposits discussed above are rich in arsenic, and hence are considered as potential sources of ancient copper-arsenic alloy. Several copper deposits associated with the Tethyan Eurasians Metallogenetic Belt are of ophiolitic origin, which commonly incorporate arsenic and nickel as natural constituents (map 3.1). Examples of such deposits are common in eastern Anatolia, Iran and southeastern Arabia (Hauptmann, Hess, and Palmieri 2000, 79-81; Hauptmann 2007, 296-99; Weeks 2003, 109).

On Cyprus, in the western end of the Metallogenetic belt, copper deposits rich in arsenic, nickel and cobalt are reported only at Pevkos and Laxia tou Mavrou in the Limassol area, which appear to have been exploited at least since the Hellenistic and Roman times (Swiny 1982, 71; Webb et al. 2006, 274; Hauptmann 2007, 61; Hauptmann 2008, 60). In the west, high arsenic contents observed in slag samples from Kythnos implied the occurrence of arsenic-rich copper ores in the Cyclades, and their exploitation in the third millennium BC (Gale and Stos-Gale 1989a).

As discussed above, the fahlerz type of copper ores, which incorporate antimony and arsenic minerals, are considered as the most likely source of prehistoric copper-antimony alloy. In an ore body, these antimony-bearing and arsenic-bearing components are present in diverse quantities; and copper smelted from such ores can

naturally have high arsenic or antimony contents. Prehistoric objects of copper-arsenic-antimony ternary alloy, such as those from Nahal Mishmar, are most likely produced by direct smelting of fahlerz rich in both elements. Deposits of such ores commonly occur in Anatolia, Azerbaijan, Armenia, and in Transcaucasia (Craddock 1995, 28-29; Hauptmann 2007, 294-95).



Map 3.1. Distribution of ophiolitic formations in southwest Asia. Source: Hauptmann, Hess, and Palmieri 2000.

3.3.3. Copper Sources in the Region of Study

The central Taurus Mountains, which form the northern boundary of the Cilician Plain, host metallic deposits of various sorts. Even though the primary mineralization in this mountain range consists of lead and silver ores, occurrence of copper is also evident. On the slopes facing the Cilician Plain, directly north of Tarsus, three minor copper mineralizations are reported, without however any evidence for ancient exploitation (Ryan 1957, 35). The most important sources of metal in the central Taurus are the lead and silver deposits in the Bolkardağ Massif,

particularly those located on its slopes facing the central Anatolian Plateau. In the vicinity of these major deposits, a single occurrence of copper is recorded, which also yielded some evidence for prehistoric mining (Wagner and Öztunalı 2000, 58-59). Further to the north, copper deposits and an important antimony mineralization are known in the volcanic Niğde Massif (Özbal, Kuruçayırılı, and Mısırlı, 2005, 184).

The Amanos Mountains, which define the western boundary of the Amuq Plain, host ophiolitic formations that constitute part of the Tethyan Eurasian Metallogenic Belt and are genetically related to the ophiolites of Cyprus. In this zone, copper generally occurs together with arsenic minerals and thus could have been the source of arsenical copper locally used in prehistory (Hauptmann 2007, 61, 297-98). The most important mineralization in the Amanos is found at the Kisecik mine, which is primarily a gold deposit that is still being exploited. However, occurrences of copper, as well as the evidence for their ancient working are also reported at this site (Ryan 1957, 62). The second major copper source in the Amanos Range is located near Hassa, which consists of four different deposits. Ancient mines of undetermined date have also been recorded associated with this site (Ryan 1957, 62; Wagner and Öztunalı 2000, 58).

3.3.4. Possible Sources of Tin

The provenance of tin used in Bronze Age southwest Asia and the Mediterranean could not be securely determined and has been a matter of academic debate over the last decades. This issue constitutes one of the biggest problems in Near Eastern and Mediterranean archaeology; and is commonly referred to as the “tin

problem”⁴². This matter is largely constituted by the fact that tin mineralizations display a limited occurrence in the geological horizon of the Near East and the eastern Mediterranean. Besides, the few major sources known in the region do not seem to have been exploited in prehistory. Furthermore, the use of alluvial deposits of cassiterite, which could have been one of the sources of prehistoric tin, is not possible to detect archaeologically. Even though an absolute solution to the tin problem remains elusive, textual, archaeological, and geological studies provide certain clues about the possible provenance of Bronze Age tin.

Textual Evidence

Textual evidence from third millennium BC Mesopotamia commonly refers to tin reaching Mesopotamia from Dilmun, Magan, and Meluhha that have been respectively identified as Bahrain, Oman and the Indus Valley (Muhly 1973, 306-7; Moorey 1994, 298; Foster 1997, 55-56). Due to the absence of tin sources in these localities, they appear as way-stations on the route of shipment rather than the ultimate source of tin. Tin from this route is known to have reached as far west as Ebla in northwest Syria, as evidenced by references to “Dilmun tin” in the palatial cuneiform archive from the site (Muhly 1985b, 281). There are also a few third millennium BC accounts of tin reaching Mesopotamia from the Iranian highlands. However, these are attested in mythological texts and thus, can not be considered as conclusive references (Potts 1994, 155; Moorey 1994, 298; Weeks 2003, 179). Instead, along with gold, lapis lazuli and carnelian, tin seems to have been obtained

⁴² For summaries of this subject see Muhly 1985b; Weeks 2003, 165-95; Yener 2009, Pigott 2011.

primarily from the east through the maritime route crossing the Gulfs of Oman and Persia (Potts 1993, 392, 394; Potts 1994, 280-81; 284).

In the early second millennium BC, more substantial information on the trade of tin is provided by documents from Kaneš and Mari. These texts shed light on two primary routes, through which large quantities of tin were shipped from east to west. Even though we know that tin was being imported from Assur to central Anatolia and from Susa and Anshan to Mari (and ultimately to the Mediterranean coast), the documents do not indicate the actual sources of tin. Texts from Kaneš at least testify that tin reached Assur from the east across the Zagros Mountains without, however, any indications of the route of shipment. A route reaching Assur from the northeast (Muhly 1973, 306; Moorey 1994, 298), and one from the southeast (Dercksen 2005, 19) have been proposed as possibilities.

Central Asia

Besides textual evidence, geological and archaeological research adds to our reasons to consider an eastern origin of Bronze Age tin as a serious possibility. In Uzbekistan and Tajikistan, Bronze Age mining and smelting activities for tin are clearly documented. The prehistoric tin mine at Karnab in Uzbekistan and the associated smelting operation at a nearby site have been determined to date to the early second millennium BC. The mine is believed to have produced an estimated amount of sixty tons of cassiterite during its period of operation. The exploitation of the prehistoric tin mine at Mushiston in Tajikistan also belongs to the same period. (Alimov et al. 1998; Boroffka et al. 2002; Cierny, Stöllner, and Weisgerber 2005, 432-40). There are also prehistoric tin workings reported from eastern Kazakhstan,

which, however, did not provide any securely datable material (Cierny, Stöllner, and Weisgerber 2005, 440-41).

Afghanistan

Another region that is frequently cited as a potential source of Bronze Age tin is Afghanistan, where significant cassiterite occurrences are known (Stech and Pigott 1986, 44-46; Weeks 2003, 170). In addition to veins of cassiterite, deposits of cassiterite-bearing sand are also detected on riverbeds in western Afghanistan (Cleuziou and Berthoud 1982). The location of the third millennium BC site of Shortugai in proximity of rich tin deposits is significant concerning Bronze Age tin trade. The material culture of this site predominantly displays the characteristics of the Harappan Culture of the Indus Valley. This evidence seems so strong that the site is generally considered as an outpost or a colony of Harappan communities (Potts 1995, 1457; Pigott 2011, 280). Accordingly, this site could have facilitated the shipment of tin from its sources in the mountains of Afghanistan to the Indus valley, namely the land of Meluhha, which was one of the localities to supply tin to Mesopotamia during the third millennium BC. Even though these geological and archaeological considerations render Afghanistan a likely source of Bronze Age tin, more extensive research needs to be carried out to support this proposition.

Anatolia

The discovery of the prehistoric Kestel mine and the nearby smelting site at Göltepe in the central Taurus Mountains became a major focus of research and an

issue of academic debate on the provenance of tin. The activities at these sites started early in the third millennium BC and intensified throughout the millennium. Both sites were, however, abandoned by the end of the millennium, apparently in consequence of the depletion of the mine. Based on the observation of low-grade cassiterite within the matrix of the polymetallic ore samples, the research team interpreted the mine as a place of prehistoric tin working (Yener and Özbal 1987; Yener and Vandiver 1993; Yener 2000, 71-76). However, many researchers in the field approached this proposition with skepticism. First of all, despite its richness in various types of metal ores, Anatolia is not known to host any significant tin mineralizations. Besides, although Anatolia was one of the primary users of tin during the Bronze Age, it appears as a major importer of this metal, at least in the early second millennium BC, as evidenced by the Kaneš texts. As a result of these, the presence of a Bronze Age tin mine in Anatolia did not seem very likely. Finally, the low concentration of tin detected in the ore samples led skeptic researchers to interpret the mine as a more likely source of gold or iron (Hall and Steadman 1991, 229; Pernicka et al. 1992, 195; Muhly 1993, 251-52).

As a response, the research team associated with Kestel and Göltepe stressed that the recovered ore samples are representatives of the stage, when the ore of Kestel was no longer considered exploitable. Hence, they argued that the mine had likely supplied ores with higher tin contents at the peak of its exploitation (Yener and Vandiver 1993, 215). They further note that the tin content in the ore progressively increases from the samples collected at the mine to the lumps found at the smelting site and ultimately to the powdered deposits ready for smelting. Such a sequential increase is considered to indicate an intentional enrichment of tin, which is not detected for any other ore constituent such as iron (Earl and Özbal 1996; Yener 2000,

112-14). However, these researchers agree that gold could also have been mined at Kestel along with cassiterite (Earl and Özbal 1996, 295; Yener 2000, 73).

More recent archaeometallurgical inspections recorded another tin deposit near Kayseri in central Anatolia, the exploitation of which goes back to prehistory. However, once again the deposit is of polymetallic character, which makes it difficult to determine whether the prehistoric exploitation indeed aimed for tin (Yalçın and Özbal 2009). After nearly two decades of debate, a growing number of researchers now believe that the occurrence of a third millennium BC tin working in Anatolia is indeed possible, even though conclusive evidence is still needed (Weeks 2003, 180; Pigott 2011, 276-77).

Iran

A recent discovery identified an ore deposit at Deh Hosein in the eastern part of the central Zagros Mountains, which incorporates both copper and tin minerals. The ancient exploitation of the deposit apparently continued from the early second millennium until the first millennium BC. Even though the dating of its activity does not predate the second millennium BC, several third millennium BC artifacts from the Near East and the Aegean were found to have matching isotopic characteristics with this deposit. Based on this evidence, the researchers associated with Deh Hosein consider the site as a potential source of tin in both the third and second millennia BC (Nefazati, Pernicka, and Momenzadeh 2009; Pigott 2011, 284-85).

Other Regions

There are certain significant cassiterite mineralizations in the Near East. Several valleys in the Eastern Desert of Egypt are known to host rich tin deposits that have been exploited during the last century. Another important tin deposit is located at Jebel Silsilah in the Arabian Desert. However, in neither case can the exploitation of these sources be dated earlier than the first millennium BC (Weeks 2003, 166-67). Similarly, tin from the rich sources of the Iberian Peninsula and Cornwall in southern England started to reach the eastern Mediterranean only in the Iron Age and classical antiquity. There are also rich tin deposits in the Erzgebirge in central Europe, Tuscany, Sardinia, Brittany, central France, and the Balkans. However, these localities did not yield any secure or datable evidence for ancient exploitation (Weeks 2003, 172-73). At least some of these sources must have played an important role in the development of tin-bronze metallurgy in Europe. However, their contribution to tin used in the Bronze Age eastern Mediterranean and Near East is far from certain. Nevertheless, certain authors envisage that Cornish and central European tin might have reached the eastern Mediterranean in the Late Bronze Age through the same trade routes that brought central European finished goods and Baltic amber to the Mediterranean basin (Muhly 1985b, 287-88; Pare 2000, 32).

3.4. PRODUCTION AND TRADE OF COPPER AND TIN IN THE SECOND MILLENNIUM BC

3.4.1. Agents of Production and Exchange in the Second Millennium BC

Assessing the Means of Ancient Production and Exchange

The social organization of the production and exchange of commodities in antiquity has always attracted scholarly interest of archaeologists, linguists, and historians alike. Researchers particularly attempted to delineate the degree of political control over production and circulation of goods, as this is considered the key to understanding the mechanisms by which early complex societies operated (Childe 1936, 132-37; Childe 1942, 61; Costin 1991, 11-13; Wailes 1996, 5; Sherratt 2000, 83).

The spatial investigation of industrial facilities proved an effective way of assessing the degree of control over production by ruling authorities. An important parameter in this research is the identification of architectural features as public or private, with which production loci are associated. As a common presumption, production facilities under political administration tend to be integrated into or located in proximity to some public building such as a palace or temple. Clearly, such a spatial organization would enable more efficient supervision of production by authorities (Costin 1991, 14-15, 25). Conversely, production loci associated with non-public architecture likely, but not necessarily, indicates an industry that operates independently of state institutions (Costin 1991, 25).

The second major parameter that links archaeological evidence with the social context of ancient industry is the degree of spatial concentration or dispersion of

production facilities within a study area. As a general phenomenon, production loci operating under some political administration tend to be clustered near the institutions, of which they are dependents (Costin 1991, 14-15). Independent production facilities, on the other hand, might display varying degrees of spatial clustering depending on such factors as the access to raw materials, or the ease of transportation and storage (Costin 1991, 13-14).

As far as ancient exchange is concerned, archaeology can illuminate its mechanisms and patterns by means of distribution analysis and provenance studies of materials. However, certain aspects of ancient trade are not possible to investigate with the methods of archaeology and can be deduced exclusively from textual information. In this respect, whether trade was operated by state-dependent or freelance agents cannot be determined in the absence of texts.

The Situation in the Second Millennium BC

Throughout the second millennium BC, significant quantities of raw materials, as well as finished goods were in interregional circulation. Under the light of textual evidence, both state-dependent and independent agents appear to have played roles in this exchange. Moreover, the ruling elites themselves were directly involved in the mobilization of goods. This was commonly carried out by means of reciprocal gift exchange between the political aristocracies of distinct polities. Such exchanges of gifts are documented as early as the first half of the second millennium BC, as indicated by textual accounts from the palaces of Mari and Babylon (Zaccagnini 1983). Theban tomb paintings from the early 15th century BC, which depict Syrians and Cretans presenting a variety of commodities to Egyptian nobles, also evidence

this practice during the early phase of the Late Bronze Age (Wachsman 1987; Knapp and Cherry 1994, 150-51). However, it was during the later stage of the Late Bronze Age, namely in the 14th and 13th centuries BC, that interpalatial gift exchanges intensified and became an integral part of international diplomatic correspondence (Sherratt and Sherratt 1991, 371; Knapp and Cherry 1994, 146-51).

Even though the presented gifts primarily involved low bulk, high value objects, these luxuries were commonly accompanied by large quantities of raw material. As an example, the Amarna archive of the 14th century BC accounts that nearly fifteen tons of copper was sent from the king of Alashiya to the Egyptian pharaoh in one single shipment alone (Moran 1992, 107; Knapp and Cherry 1994, 147).

Market exchange was also in operation during the second millennium BC, in which palaces once again appear as prime actors. Royal courts are known to have employed official trade agents who were sent to expeditions to carry out commerce on behalf of the palace (Monroe 2009, 282). At the first sight, these agents appear to be officials acting exclusively under royal authority, rather than professional merchants seeking private profit. However, at many instances these individuals are also known to have conducted their own commercial businesses independent of the authorities they worked for. It was even a common phenomenon that the capital entrusted to these envoys by the palace was used for both palatial and private merchandize (Liverani 2005, 54-56; Monroe 2009, 199-202, 289). Furthermore, there are cases when trade expeditions were co-sponsored by wealthy merchants and political rulers (Linder 1981, 34). Apparently, in addition to its own commercial activities, palaces appear as the sponsors of freelance, long distance trade as they profited from it by imposing

taxes and custom duties on merchandize (Berdan 1989, 106-7; Sherratt and Sherratt 1991, 365; Knapp and Cherry 1994, 134; Monroe 2009, 209, 278-79).

The entrepreneurial activities of high-ranking state officials are well documented in the 14th and 13th century BC at Ugarit and in the Middle Assyrian kingdom, where private archives of some of these individuals have been recovered (Knapp and Cherry 1994, 145-46; Monroe 2009, 199-205, 278-82). Egyptian and Hittite texts also refer to merchants involved in foreign trade. Hittite kings are known to have issued several lawsuits to protect their merchants and guarantee the security of their cargoes. However, the evidence is not conclusive to identify these men confidently as freelance merchants or state envoys (Bleiberg 1995, 1376-85; Bryce 2002, 87-97; Monroe 2009, 193-97).

Interregional commerce without the direct involvement of the palaces is best documented in the earlier second millennium BC. The private archives of the Assyrian merchants at Kaneš evidence that their businesses was an entrepreneurial activity aiming to make profit by taking advantage of the price differences between Assur and Kaneš. The local palace at Kaneš profited from this trade by imposing taxes on merchandize, whereas the Assyrian palace is almost entirely absent in these records. The archives also document that several aspects of modern economies were in action during this period. Professional, profit-seeking merchants, risky investments, financial losses, sponsors, debts, even smuggling appear to have played their roles in this commerce (Larsen 1976, 92-105, 243-46; Larsen 1987, 50; Berdan 1989, 100).

3.4.2. Textual Evidence for the Production and Exchange of Copper and Tin

Middle Bronze Age (ca. 2000-1600 BC)

Two major textual archives from the Middle Bronze Age shed light on the circulation of metals in two distinct exchange networks. The first of these linked Assur with Kaneš (Kültepe) in central Anatolia during the period roughly between 1950 and 1750 BC. Nearly twenty thousand tablets from this site, which constitute the private archives of Assyrian merchants resident in this town, provide substantial information on the nature of trade between Anatolia and Mesopotamia. The backbone of this trade was constituted by the export of tin and textiles by Assyrian merchants from Assur to Kaneš to be exchanged with Anatolian silver. The shipment was carried out by means of donkey caravans, which were capable of transporting tin amounts of as large as fifteen tons in a single shipment. The total amount of tin that reached Kaneš in this way during a period of forty-fifty years is estimated to be around eighty tons (Larsen 1976, 90-91, Larsen 1987, 51).

The first stop of the cargo brought from Assur was the local palace at Kaneš, where the local ruler had the first priority to select and buy goods from the shipment. Assyrian merchants were obliged to pay a certain tax to the local palace. For tin, this portion was two units for every sixty-five units of imported metal. In return, the rulers of Kaneš provided security and storage for Assyrian cargoes. Once the palace purchased a small portion of the total cargo, the merchant was free to administer the rest of his commodities at his own will, selling it either on the local market of Kaneš or distributing it to other trade colonies in central Anatolia (Larsen 1976, 104, 245;

Larsen 1987, 50; Dercksen 2005, 20-21)⁴³. Thus, Assyrian merchants not only imported tin from Assyria, but also facilitated its circulation within central Anatolia.

Copper trade seems to have occupied a secondary significance for Assyrian merchants. They were, however, involved in the circulation of copper exclusively within a central Anatolian network as opposed to the interregional shipment of tin. Slab or round-shaped ingots were the common forms in which copper was transported by means of equid caravans, chariots or even porters, who were hired for very short distances (Müller-Karpe 1994, 61; Dercksen 2005, 24).

As far as the local metal industry is concerned, Kaneš documents clearly distinguish metal-smiths of gold, silver, iron and copper. Because the evidence indicates that these men appear as either debtors or payees, they are more likely to have been specialists privately hired temporarily for their services⁴⁴. The documents further imply that these craftsmen can be hired not only by the palace but also by state officials, as well as non-official individuals (Müller-Karpe 1994, 64; Dercksen 2005, 30). Textual information also testifies the presence of a palatial metal production at Kaneš. First of all, there are references to certain officials, who bear such titles as the “chief-overseer of smiths” or the “chief overseer of bronze”. The activities of this palatial metal industry are documented archaeologically by the discovery of casting molds for ingots and artifacts at the palace of Kültepe (Müller-Karpe 1994, 60).

The second interregional tin route of the early second millennium BC was illuminated by about twenty thousand cuneiform tablets from the archive of Zimri-Lim’s palace at Mari (1776-1762 BC). Even though the earliest tablets in the archive date back to the last quarter of the third millennium BC, the vast majority of them

⁴³ Fourteen major and twelve minor Assyrian merchant colonies are identified in the archives from Kültepe (Larsen 1976, 236-40).

⁴⁴ The names of six metal-smiths are identified. Five of these bear local Anatolian names, while the sixth person is an Assyrian (Müller-Karpe 1994, 60).

span the period from the late 19th century BC to the destruction of the palace (Klengel 1992, 46). Strategically situated on the Euphrates, Mari appears as a major center that transshipped Mesopotamian and Elamite raw materials and products to the west. Eastern tin once again appears as a crucial material mobilized in this east-to-west shipment.

A notable aspect of tin trade was that many times kings or other members of royal families and royal courts are involved as shippers or receivers of the metal. As an example, Sheplarpak, king of Anshan is known to have sent tin to the palace at Mari (Muhly 1973, 293). Likewise, the palace at Mari sent tin directly to the rulers of western polities such as Urshum, Aleppo, Carchemish, and Ugarit. At Aleppo, besides king Yarim-Lim, members of his family, his vizier and other persons appear among the recipients of tin. There is also one single reference to tin shipped to Aleppo directly by Hammurabi of Babylon (Klengel 1992, 69-70, 75-77).

Despite this occasional involvement of the ruling elite in the exchange of tin, tin trade was generally the business of merchants. Unfortunately, the current state of information is not sufficient to identify these men as freelance traders or state agents. Shipment of tin from Elam to Mari was administered by merchants of both sides. Merchants of Mari were also active in the delivery of tin to Ugarit. Perhaps the best known Mari document about tin trade is a tablet from the period of Zimri-Lim that accounts shipment of tin to Ugarit to be picked up by merchants from the Levantine cities of Qatna, Lashish, and Hazor. The same text also refers to merchants from Kaptaru, apparently Minoan Crete, one of whom has been identified as the chief merchant, as well as a translator. (Dossin 1970; Klengel 1992, 77-78; Knapp and Cherry 1994, 145).

The archive at Mari also shed light on the interregional exchange of copper. Cypriot copper reached Mari, along with Cypriot oil and grain, in the early 18th century BC, and Babylon towards the end of this century (Knapp and Cherry 1994, 145; Knapp and Kassianidou 2008, 135). Hence, Cyprus, which was to become the major producer of copper during the later second millennium BC, started to emerge as an important source of the metal during this period. The involvement of the palace at Mari in copper production is also evident in the texts. There is one tablet that records the allotment of one talent (ca. twenty-eight kilograms) of copper to a metal-smith for the manufacture of different types of objects, such as axes, crowbars, and spades (Muhly 1973, 212). Mari documents also imply that the palace predominantly obtained impure copper, referred to as the “copper of the mountains”. The “washing” of this impure copper, which is likely the process of refinement, appears to have taken place within the palace (Muhly 1995, 1510).

Late Bronze Age (ca. 1600-1200 BC)

With the advent of the Late Bronze Age, a drastic increase is observed in the quantities of metal artifacts, as well as the use of tin in Europe, the Near East and the Mediterranean (Iakovidis 1982, 214; Muhly 2003, 144; Papadimitriou 2008, 282). This phenomenon clearly correlates with the intensification of interregional commerce and diplomatic correspondence, which characterizes this period, particularly the 14th and 13th centuries BC. Large scale circulation of both copper and tin has been evidenced by textual sources, and the Uluburun Ship (late 14th century BC), the cargo of which incorporated ten tons of copper and one ton of tin (Pulak 2000; Pulak 2005, 59-65). In the light of this particular discovery, it became easier to rationalize the

large amounts of copper recorded in the Amarna texts (mid to late 14th century BC), which speak of nearly fifteen tons of copper sent to the Egyptian pharaoh by the king of Alashiya (Cyprus) in one single shipment alone. In this letter, the Cypriot king even apologizes for the low quantity of copper sent, stating that he could not have mobilized enough labor because his country was struck by some disaster (Moran 1992, 107-8).

This particular evidence clearly demonstrates the presence of a central authority on Cyprus that exercised certain control over the mass exploitation of the sources on the island, as well as the export of produced copper. A considerable extent of royal control over the circulation of copper is also observed at Ugarit, where the importation of Cypriot copper into the kingdom and its transshipment to various merchants was regulated exclusively by the palace. The significant position of copper for Ugarit is obvious as the same strictness of administration is not observed for other sorts of imported materials (Linder 1981, 33).

The involvement of palaces in metal industries is best documented in the royal archives of the Hittite kingdom, particularly in tax and inventory lists. The former group of texts accounts the quantities of commodities taken in fixed amounts as periodic taxes from the provinces of the kingdom. The latter group, on the other hand, delivers the lists of commodities kept in the storerooms of temples and the so-called “seal-houses”, apparently administrative buildings spread to all corners of the kingdom (Müller-Karpe 1994, 74; Siegelova 2005, 35). A comparison between the two types of documents with respect to the frequency and quantity of raw metals and metal objects provides invaluable information about the character of a state-administered metal industry. As far as raw metals are concerned, this group is attested in 25 percent of the tax lists, rendering them the second most important commodity

taxed by the state after textiles. They are, however, mentioned only in 6 percent of the inventory texts. On the contrary, the frequency of references to finished metal objects show an increase from 13 percent in the tax lists to 40 percent in the inventories. These discrepancies most likely implicate that some of the raw metal taken as tax must have been manufactured into artifacts under the administration of the Hittite state (Müller-Karpe 1994, 74-78; Müller-Karpe 2000, 114-16; Siegelova 2005, 36-38).

Of the raw metals received as tax, copper occupied the most significant place, constituting 60 percent of the total amount referred in the tax lists (Müller-Karpe 2000, 114-16). Commonly, copper is delivered in quantities in excess of 50 kilograms, while an amount of nearly 250 kilograms occurs in an exceptional case (Alparslan and Doğan-Alparslan 2011, 81). However copper amounts as small as 2.5 kilograms were also recorded in certain cases (Archi 1984, 201). Tin is also known to have been delivered as tax along with copper, but only in rare cases. Compared to the amounts of copper, tin was always taxed in smaller quantities. There are only two exceptional cases, where the amount of tin appears as large as one and two talents, nearly thirty and sixty kilograms respectively. (Siegelova 2005, 36-37). Inventory texts refer to tin-bronze ingots, which never occur in the tax documents, which implies that the alloying of the two metals into such ingots was likely carried out in state-administered workshops (Siegelova 2005, 37).

Hittite sources also provide certain clues about the situation of the personnel involved in metal industry. As in the earlier texts from Kaneš, metal-smiths of copper/bronze, gold, iron, and silver are distinguished in Hittite documents (Müller-Karpe 1994, 73; Müller-Karpe 2000, 115-16). These smiths can be “bought”, which could mean either that these were temporarily hired craftsmen, or slave laborers.

There is however, no conclusive evidence for full-time palace-dependent metal-smiths (Archi 1984, 201-2). The presence of metal-smiths producing goods for a general market is implicated in a Hittite lawsuit, by which the government fixes the prices of certain types of metal artifacts (Müller-Karpe 1994, 85). Interestingly, in certain cases metal-smiths appear to be buying slaves for themselves, which verifies the higher economic status of at least some smiths (Müller-Karpe 1994, 85-86, 182). Raw copper was entrusted to copper-smiths for the production of weapons, working tools and household items. In some cases, however, pre-alloyed tin-bronze is allotted instead, which is always provided in the form of finished objects (Siegelova 2005, 37).

The tablets from the final years of the Mycenaean Kingdom of Pylos in western Peloponnessos (late 13th century BC), draws a similar picture to what we observe in the Hittite Kingdom. Once again, metal-smiths appear as the craftsmen, who receive allotments of copper from the palace⁴⁵. The types of objects to be manufactured are noted only in one single tablet, which mentions javelins and arrowheads. The amounts of entrusted copper to one single smith vary between 1.5 and 12 kilograms; most commonly between 2.5 and 5 kilograms. Interestingly, about one third of the smiths do not receive any copper from the palace, even though their names appear in the lists. The presence of these non-employed copper-smiths, along with the small amounts of entrusted copper, likely imply that these individuals were temporarily hired by the palace, rather than being full-time state personnel (Shelmerdine 1998, 93-94; Bennett 1998, 130-31; Gillis 1997, 513; Nakassis 2013, 74, 79-80). Pylos tablets also indicate that at least some persons involved in metallurgical production could be members of the palatial or religious elite. This is evidenced by references to a “royal armorer”, who was rewarded with land for his

⁴⁵ The estimated number of these smiths varies from as low as 170 (Tzachili 2008, 25) to as high as 400 (Chadwick 1976, 140-41).

services. At least some of the smiths are also known to have servants, similar to their counterparts in the Hittite kingdom. In certain cases, the king of Pylos appears to have direct interest in the produced weaponry, since there is a reference to “javelin handles of (or for) the king” (Shelmerdine 2007a, 45-46; Nakassis 2013, 75-76, 91, 100).

Textual evidence from the Assyrian Kingdom and Ugarit documents the delivery of copper and tin to persons, who appear to be high-ranked state officials. The contexts of these allotments are, however, not always conclusive since it is not certain whether these deliveries were made as payments for the services of the receiver (Monroe 2009, 66-67, 182-84). In certain cases this official also appears to be a trade agent, who receives the entrusted metal to pay for the expenditures in a commercial expedition (Faist 2001, 176)⁴⁶. Sometimes, such individuals are also understood to have been involved in copper production besides copper trade. In a text from Ugarit, some copper merchants appear as supervisors of the casting of ingots (Monroe 2009, 256-57). Likewise, a case from Assyria demonstrates how a merchant instructs his men to procure copper and tin for the manufacture of bronze tools (Monroe 2009, 201).

In sum, the involvement of the political elite in copper industries is explicitly documented in various polities of the Middle and Late Bronze Ages. In certain cases, such as the evidence from Cyprus and Ugarit, a certain degree of control over the production and circulation of copper can be inferred. However, there is no conclusive evidence for a total state monopoly over the copper industry and trade. Also, the metal-smiths operating in association with the palaces cannot be certainly identified as permanent personnel of the state. Instead, they were more likely to have been temporarily hired craftsmen, who got paid for their short-term services.

⁴⁶ The noted evidence comes from the kingdoms of Middle Assyria and Ugarit of the 14th and 13th centuries BC. In the former case, the investor is a temple, while in the latter case it is the palace of Ugarit.

If we turn to the situation of tin, Late Bronze Age documents relating to the circulation of this metal provide no indices to imply any state involvement. In the case of Anatolia, tin was likely an import as in the earlier period of the Assyria-Kaneš trade. However, Hittite sources remain silent about any palatial involvement in the importation of this crucial material. Instead, the amount of tin owned by the Hittite state seems to have been exclusively obtained as taxes from its vassals and provinces, among which only Kizzuwatna could be localized (Siegelova 2005, 37). Thus, it seems more likely that tin was reaching Hittite territory through some exchange networks, in which the royal authority had no direct intervention (Archi 1984, 201-2). Likewise, tin is not mentioned in the Pylos tablets, even though one would expect it to have accompanied the copper entrusted to metal-smiths. Unless this allotted copper was pre-alloyed bronze, perhaps even in the form of scrap objects, we may assume that the smiths obtained tin through some non-palatial exchange (Gillis 1997, 512). The circulation of tin was particularly decentralized at Nuzi during the 15th century BC and in the Middle Assyrian Kingdom during the 14th and 13th centuries BC. In both contexts, tin functioned as the currency, in which the prices of commodities and land were expressed (Muhly 1982, 257; Muhly 1995, 1509; Snell 1995, 1493; Faist 2001, 64; Monroe 2009, 199-202).

3.4.3. Archaeological Evidence for the Production and Exchange of Copper and Tin

Agents in Copper Production and Exchange

Archaeological evidence from the second millennium BC identified metallurgical production facilities in association with public or administrative buildings⁴⁷, as well as those, which do not display such a connection⁴⁸. In the former case, archaeological information is in accord with textual sources as it testifies the presence of state-dependent metal industries. In the latter case, the evidence is more difficult to interpret because state-administered industries mostly but not necessarily operate in proximity to public buildings. State-dependent production does not even have to be located at or near administrative centers. This phenomenon is best demonstrated in the lists of metal-smiths from Pylos, as they demonstrate that these individuals were situated in towns of rural provinces of the Pylian kingdom, and not at the palatial capital (Chadwick 1976, 141). Accordingly, the absence of any spatial association between the production facilities and public or administrative buildings should not directly imply industries operating independent of state's supervision.

Moreover, metallurgical production does not necessarily take place in buildings serving exclusively as workshops. Instead, there are many examples of domestic houses, parts of which are associated with metallurgical activity. Generally, the owner of such houses, and hence, the supervisor of the workshop, appears as a wealthy merchant or a high ranking state official. As an example, at Middle Bronze Age Kaneš some of the Assyrian merchants had private homes, which also functioned

⁴⁷ Examples are known from Hittite Anatolia (Müller-Karpe 1994, 72-73, 79-84), Kültepe/Kaneš at the time of the Assyrian Colonies (Müller-Karpe 2000, 60-64), and Minoan Crete (Pelon 1987, 271, MacDonald 1987, 294).

⁴⁸ Examples are known from Hittite Anatolia (Müller Karpe 1994, 79-84), Kültepe/Kaneš at the time of the Assyrian Colonies (Müller-Karpe 1994, 60-64, 70), and Minoan Crete (Dimopoulou 1997, 435-37; Hakulin 2008, 205).

as business offices, and had embedded metal workshops (Müller-Karpe 1994, 60-66). This evidence also corresponds to the above-mentioned textual information from Ugarit and Assyria, as it demonstrates the involvement of such individuals in the production of copper (Monroe 2009, 201, 256-57).

Copper Industry and Ideology

An important aspect of metallurgical production evidenced by archaeological information is the role played by ideology in this industry. This is best demonstrated by the occurrence of production facilities in association with religious or ceremonial structures. The evidence for this relationship is especially abundant on Late Bronze Age Cyprus, where copper industry must have constituted a prominent portion of the total economy. Metal workshops embedded in or in close spatial association with religious or ceremonial buildings are attested on the entire island at both urban, as well as rural sites (Knapp 1996, 75-80; Smith 2009, 42-51)⁴⁹. It is also on Cyprus that several examples of miniature copper oxhide ingots are recovered that are likely to be votive offerings (Papasavvas 2009, 101-4; Giumlia-Mair, Kassianidou, and Papasavvas 2011). The best known find from the Cypriot Bronze Age to indicate the ideological connotation of metallurgy is the famous “ingot god”, the bronze statuette of a possible deity depicted standing on a base in the shape of an oxhide ingot (Papasavvas 2009, 93-101; Papasavvas 2011).

Metallurgical production facilities within or in association with temples or sanctuaries are also known in other parts of the eastern Mediterranean such as Hittite Anatolia (Müller-Karpe 1994, 79-84, 88; Müller-Karpe 1996, 73; Müller-Karpe 2000,

⁴⁹ In certain cases these religious or ceremonial buildings also incorporate facilities for textile production (Steel 2004, 179; Smith 2009, 34-42).

124) and southern Levant (Monroe 2009, 16). Textual evidence to complement this archaeological inquiry is provided in a Hittite document that refers to a “smith of the god” (Müller-Karpe 1994, 84). Similarly, at least some of the metal-smiths listed in Pylos tablets are mentioned to be in the service of the goddess Potnia (Shelmerdine 1998, 94; Chadwick 1976, 141; Nakassis 2013, 101). Further association of the metal industry with ideology is demonstrated by the discovery of several whole or broken copper ingots as dedications in sanctuaries or ritual deposits. This common practice is evident from Sardinia (Lo Schiavo 2009, 401-4), Crete (Hakulin 2008, 204), and Anatolia (Müller-Karpe 2005, 491). Parallel textual evidence is again found in a Hittite ritual text that refers to four copper ingots taken as tribute from Alashiya (Cyprus) and dedicated to four Hittite deities (Muhly 1996, 50).

Despite this evident association between the metal industry and religious symbolism, nowhere in the eastern Mediterranean and the Near East there seems to have been religious authorities that administered particular industries. Some researchers tend to interpret the evidence as the attempt of non-religious political authorities to use ideology in order to mobilize labor and ensure productivity (Knapp 1986, 117; Knapp 1996, 81, 92; Kassianidou 2005).

Recycling of Copper

Another aspect of copper industry, for which archaeology provides undoubted evidence, is the common practice of metal recycling. During the second millennium BC, pieces of scrap metal objects are regularly found in casting workshops all over the

eastern Mediterranean⁵⁰. In some cases, particular workshops appear to have depended exclusively on scrap metal for the casting of new artifacts (Hakulin 2008, 206). Complementary references to the circulation of copper in the form of scrap objects are found in the Kaneš texts of the early second millennium BC (Dercksen 2005, 25). Hittite documents of the later second millennium BC also testify that whenever pre-alloyed tin-bronze was entrusted to metal-smiths, it is always supplied in the form of scrap objects (Siegelova 2005, 37). Even though the circulation of scrap metal is commonly considered to have operated mainly outside of palatial contexts (Sherratt 2000, 87-89), this Hittite account indicates that palaces could have employed recycling in their own copper industries.

Copper and Tin Ingots

The most widely used type of copper ingot during the second millennium BC was the so-called oxhide ingot, which first appeared early in the Late Bronze Age. This type had a rectangular shape with protrusions on four corners to ease handling and transportation, which make the object resemble the hide of a skinned ox. The vast majority of such ingots are recovered in the eastern and central Mediterranean, particularly on Cyprus, Crete, and Sardinia. Those found outside the Mediterranean basin are few but widely distributed from southern Germany in the west to Babylonia in the east and the Bulgarian coast in the north. The biggest assemblages, however, were salvaged from the Bronze Age shipwrecks of Uluburun and Gelidonya, which yielded 354 and 39 examples respectively (Gale 1991; Gale and Stos-Gale 1999a, 267; Pulak 2000, 137; Kassianidou and Knapp 2005, 237).

⁵⁰ Examples are known from Hattuša (Müller-Karpe 1994, 82), Pylos (Smith 1993, 214), Crete (Popham 1984, 203-6, 218-220; Dimopoulou 1997, 435-37; Hakulin 2008, 206), Gelidonya Shipwreck, Cyprus and Levant (Sherratt 2000, 87-88; Smith 2009, 42).

The weight of an oxhide ingot can be as low as ten and as high as thirty-nine kilograms (Gale 1991, 198; Stos-Gale 2011, 221; Kassianidou 2009, 57)⁵¹. Despite this relatively great variance in the overall assemblage, individual find groups display more homogenous weight distributions. The intact ingots from the Uluburun Ship, for instance, have weights between 20.1 and 29.5 kilograms, with a mean weight of 23.9 kilograms (Pulak 2000, 143). Those from the later Gelidonya Ship have weights ranging between twenty and twenty-five kilograms, which demonstrates that the two largest assemblages are not significantly different in weight. Somewhat heavier ingots have also been recorded. The weights of ingots from Aghia Triada on Crete vary between twenty-seven and thirty-two kilograms, while all three intact examples from Cyprus are heavier than thirty kilograms (Kassianidou 2009, 57).

Even though the great majority of oxhide ingots date to the second half of the 13th and 12th centuries BC, the Uluburun assemblage and several fragmentary pieces from Cyprus belong to the 14th century BC (Kassianidou 2009, 58). More than thirty ingots found at six sites of Late Minoan IB Crete (16th or 15th centuries BC) are the earliest examples (Hakulin 2008, 203-5; Papasavvas 2009, 109-10; Stos-Gale 2011, 222)⁵².

It was once argued that an oxhide ingot of typical mass could be produced by a single smelting operation. This argument was based on the discovery of exceptionally large smelting crucibles at Enkomi and Kition on Cyprus that are capable of holding thirty kilograms of metal (Gale and Stos-Gale 1999a, 269). However, a close examination of oxhide ingots demonstrated that they actually consist of layered

⁵¹ Oxhide ingots occur in lengths varying between thirty and sixty centimeters; widths varying between twenty and forty-five centimeters; and thicknesses varying between four and eight centimeters.

⁵² Late Minoan IB period is dated to the 16th or 15th centuries BC respectively by the High and Low Aegean Chronologies (Shelmerdine 2007b, fig. 1.2).

batches, each of which is the product of a different round of casting (Pulak 2000, 141; Hauptmann 2007, 254).

The smaller ingots of bun or slab shapes, which had been in circulation since the third millennium BC, were also used throughout the second millennium BC, particularly during the Middle Bronze Age (Moorey 1994, 244). The biggest assemblage of bun ingots was once again recovered from the Uluburun Ship and consists of about 130 examples. The weights of ingots in this group vary between 3 and 10.5 kilograms, with a mean weight of 6.2 kilograms, displaying a less standardized weight distribution than the oxhide ingots from the same ship (Pulak 2000, 143-46). In contrast to oxhide ingots, the smaller bun or plano-convex ingots could be manufactured as the end product of a single smelting operation (Hauptmann 2005, 480-81). There is even evidence from the Late Bronze Age site of Alassa on Cyprus to demonstrate that these ingots can be produced in simple household workshops (Hadjisavvas 1996, 25).

During the second millennium BC, tin was also transported predominantly in the form of oxhide and bun ingots. All tin ingots discovered so far date to the Late Bronze Age and have been recovered from Bronze Age shipwrecks in the eastern Mediterranean (Raban and Galili 1985, 36-38; Galili, Shmueli, and Artzy 1986; Pulak 2000). Once again, the Uluburun Ship yielded the biggest assemblage, which consists of oxhide and bun ingots with an estimated total weight of one ton (Pulak 2000, 152). One single tin ingot from the ship has a unique shape resembling the stone ship anchors of antiquity, which is never observed among copper ingots. The only other context, where ingots of this shape are seen is the Theban tomb paintings from the 15th century BC, which depict such ingots as gifts presented by Syrians to Egyptian nobles (Pulak 2000, 151-52).

The intact ingots of oxhide, rectangular, and anchor shape from the Uluburun Ship respectively weigh 23.8, 27.1, and 24 kilograms and reflect the somewhat standardized weight of tin ingots regardless of their shapes (Pulak 2000, 152). However, with a weight of thirty-six kilograms, one complete hemispherical tin ingot found off the coast of Haifa (14th or 13th centuries BC) is significantly heavier than the examples from Uluburun (Raban and Galili 1985).

No tin ingot is found from the earlier centuries of the second millennium BC. Nonetheless, Middle Bronze Age textual sources testify that tin was transported in small ingots of standardized weights. The Kaneš documents refer to tin ingots of about 4.5 kilograms, while the single reference from the Mari archive accounts slightly heavier ingots of 4.82 kilograms (Dercksen 2005, 20).

3.4.4. Cyprus, A Major Source of Copper

Cyprus has been a major source of copper throughout its history (Stos-Gale and Gale 1994, 93). This situation goes back to the Bronze Age, as the second millennium BC toponym of Alashiya, which appears as a copper-exporting country, is now widely accepted to denote Cyprus (Muhly 1996, 49; Steel 2004, 183-86; Knapp 2008, 312-13). Thanks to its position as a prominent source of copper in antiquity, the operation and organization of the copper industry on the island has been studied more extensively than elsewhere in the Near East and the Mediterranean. Besides, the proximity of this island to the region of study adds to its significance for this research. Therefore, an entire section is reserved to discuss the aspects of Cypriot copper production and trade.

Textual Evidence

The earliest textual references to Alashiya occur in the Mari archive of the early 18th century BC and account that Alashiyan copper reached Mari during this period. In the east, records from the reign of Samsu-iluna of Babylon record the importation of Alashiyan copper into Babylonia towards the end of the same century (Knapp 2008, 76; Knapp and Kassianidou 2008, 135). However, the prominence of Alashiya as a copper source reached its peak during the later phase of the Bronze Age, from the mid-14th to the end of the 13th century BC. As discussed above, the Amarna archive of the late 14th century BC demonstrates that substantial amounts of copper were sent by the Alashiyan king to the Egyptian pharaoh as part of royal gift exchanges. The significance of Alashiya becomes even more obvious once we consider that raw copper is not attested among the gifts sent to Egypt from other countries.

Amarna texts EA 33, EA 34, EA 36, and EA 35 respectively record 200, 100, 120, and 500 units of copper received by the pharaoh. In the last case, these 500 units are said to constitute only a small part of the whole delivery yet to be received (Moran 1992, 104, 106, 107, 109, 110, 113)⁵³. The unit of copper mentioned in these documents is most likely a talent, that is equal to 28.2-30.3 kilograms (Zaccagini 1986, 414-16). Accordingly, the documented amount of Cypriot copper that reached Egypt during the period of the Amarna archive⁵⁴ adds up to roughly twenty-nine tons (Knapp and Kassianidou 2008, 135). These large quantities of copper imply that royal exchange of gifts also had a commercial emphasis rather than simple royal courtesy. There are other instances when Alashiyan copper was sent to Egyptian kings and

⁵³ There are also two references to the so-called “fine copper” from Alashiya, which was likely a highly purified form of copper (Moran 1992, 104, 113).

⁵⁴ Roughly the third quarter of the 14th century BC (Moran 1992, XXXIV-XXXIX)

high-ranking officials in relatively minor quantities such as five or nine talents (Moran 1992, 110, 113). Only in these cases Cypriot copper appears to have been sent as personal gift.

In the succeeding 13th century BC, Egyptian kings continued to receive copper from Alashiya in the form of gifts. Ramesses II states to have received countless quantities of silver and bronze from Alashiya. The Papyrus of Anastasi IV from around 1200 BC refers to many ingots of copper brought to Seti II by the “children of Alashiya” (Knapp 2008, 312). At Ugarit on the Levantine coast, a document accounts thirty-three ingots of copper (ca. 950 kilograms) sent by Kushmeshusha, the king of Alashiya to Niqmaddu, the king of Ugarit. Shipment of copper from Alashiya to Emar is also evident in the texts from Ugarit (Knapp 2008, 309-11).

Contrary to the evidence from Ugarit and Egypt, 13th century BC Hittite references to Alashiyan copper do not have a commercial character. Only one talent of copper constituted a part of the yearly tribute paid by the Alashiyan king to Shuppililiuma II, the last known Hittite king. Finally, a Hittite ritual text mentions copper and bronze from Mount Taggata of Alashiya that is used in a magical rite to sanctify a new palace (Knapp 2008, 311).

Archaeological Evidence for Copper Production

The earliest evidence for copper production on Cyprus is attested at the Middle Bronze Age sites of Alambra, Kalopsidha, and Pyrgos Mavroaki (Kassianidou 2008). The dating of the activities at these sites to the 19th century BC is in chronological correlation with the earliest textual references to Alashiyan copper, as they record its reception at Mari early in the 18th century BC. In the proceeding Late Cypriot I period

(ca. 1650-1450 BC), the best evidence for copper production is documented at Politiko Phorades in the Troodos (Knapp and Kassianidou 2008; Knapp 2012, 18-19). Situated in proximity to copper deposits, this site appears as a dedicated workshop of primary ore smelting. As far as the Late Bronze Age urban centers are concerned, the earliest finds are recorded at the first habitation phase of Enkomi, in the mid-17th century BC. Located on the east coast of the island, this site gradually became the most prominent urban settlement, as well as a center of metallurgical industry. In the early phase of the Late Bronze Age, there was no site on the island to match Enkomi in terms of the scale of urbanism and intensity of metallurgical production (Knapp 2008, 147; Kassianidou 2012).

It was with the beginning of the Late Cypriot II period (after 1450 BC) that new urban centers emerged on Cyprus and challenged the prominent situation of Enkomi. At all these centers copper production constituted a significant part of the total economy, which implies that the island-wide spread of urbanism during this period is accompanied by the expansion of the metal industry (Knapp 2008, 357-63; Knapp and Kassianidou 2008, 135). Enkomi, however, continued to host the most extensive copper industry until the end of the settlement around 1100 BC (Muhly 1989, 299; Knapp 2008, 147). This intensification of copper production on Cyprus in the last two centuries of the Bronze Age is in accord with the Near Eastern textual references to large scale shipments of Alashiyan copper during this period.

The organization of copper production on Cyprus could be reconstructed to a certain extent by the investigation of production loci. The primary smelting of copper ores generally took place at rural sites near the mines, such as Politiko Phorades (Kassianidou 2004, 100-101; Knapp and Kassianidou 2008; Knapp 2012, 18-19) or the Late Cypriot I and Apliki (Stech 1982, 107-108; Muhly 1989, 306-7; Knapp 2012,

19-21) of the Late Cypriot II periods. The product of primary smelting is the so-called “copper-cake”, which is a lump of copper prills and slag. This product was transferred to urban centers for further processing, which involved the crushing of lumps to release the entrapped copper prills. In the final stage of the production, the amassed prills are refined and melted for the casting of ingots or finished artifacts (Stech 1982, 106; Muhly 1989, 303; Kassianidou 2008, 264-65; Knapp and Kassianidou 2008, 144; Kassianidou 2012, 104).

Even though textual evidence from the second millennium BC speaks of a king of Alashiya, there is no archaeological evidence for the identification of an island-wide political or economic authority. Rather, the evidence can be best interpreted to indicate that several polities, which were centered at individual urban sites, existed side by side on the island. Each of these polities was also a regional center of copper production and had presumably access to particular deposits in the Troodos. Thus, the extraction and production of copper appears to have been primarily under the control of local rulers or entrepreneurs, and not of a single royal authority (Stech 1982, 112-13; Muhly 1989, 310; Webb and Frankel 1994, Knapp 1996, 93). Thus, the term Alashiya seems to refer to one of the many polities on the island that rose to prominence and became more active in international diplomacy than its peers, rather than a island-wide polity (Steel 2004, 183-86). However, certain researchers envisage a single political authority that ruled the entire island and administered the production and exportation of copper (Webb 2002, 139-40; Knapp 2008, 339-41; Knapp 2013, 443-47).

3.4.5. Evidence from the Region of Study

Tell Atchana

Of the three sites studied, Tell Atchana/Alalakh is the only one that provides textual evidence from the Bronze Age. The archive of the Level IV palace (15th century BC) testifies the presence of a palatial metal industry and illuminates the patterns of circulation of copper within the kingdom. The palace at Alalakh received considerable amounts of raw copper as tax from its provinces. This amount could be as large as 2094 talents (nearly sixty tons), which is the total mass of copper received from three provinces as a single payment (Wiseman 1953, 104; Yener 2006, 382). Similar to the situation in the Hittite and Pylia kingdoms, the palace allotted quantities of copper to metal-smiths for the production of various types of artifacts⁵⁵. This amount of copper could be quite large as demonstrated by a reference to seven talents (nearly 210 kilograms) of copper allotted to smiths for the manufacture of two thousand bronze vessels (Wiseman 1953, 105). In other instances, this amount could be much smaller as testified by a reference to only four hundred shekels (3.2 kilograms) of copper, which was allotted exclusively for the production of arrowheads (Wiseman 1953, 105).

Accounts of copper entrusted to smiths stationed at the town of Bereshna clearly indicate that as we observe in the Pylia Kingdom, the metal-smiths operating in association with the palace do not necessarily reside in the capital (Müller-Karpe 1994, 97). It is, however, to note that the tablets do not certainly indicate whether the referred metal-smiths were full-time dependents of the palace.

⁵⁵ The diverse repertoire of artifacts includes tools, weapons, vessels, rings, chains, braziers, door panels, furniture parts, and braziers (Wiseman 1953, 14).

At least for the manufacture of certain types of artifacts, copper is almost exclusively allotted in the form of pre-alloyed tin-bronze (“ZA-BAR”), which never occurred at Pylos. (Wiseman 1953, 14). This reference is completely in accord with the archaeological information that evidenced the use of scrap copper in casting workshops. There is also reference to metallic tin that occasionally accompanied copper allotted to metal-smiths, which constitutes another significant distinction from the case of Pylos (Wiseman 1953, 105).

As observed in the kingdoms of Assyria and Ugarit during the Late Bronze Age, copper is known to have been entrusted to persons other than metal-smiths. One such person received copper prior to his travel into the Hittite lands. By comparison with the evidence from Assyria and Ugarit, this individual was likely a merchant, who received copper to defray expenses on his travel (Wiseman 1953, 14)

As far as archaeological evidence is concerned, metal workshops are identified throughout the lifespan of the settlement from the early to the late second millennium BC. Particularly notable is the evidence for metallurgical production in association with both palatial structures of Levels VII and IV (Yener 2006, 376-79, fig. 99). Metal workshops also occur in non-public, domestic contexts of the Level IV settlement (Müller-Karpe 1994, 97-98; Yener 2006, 379, fig. 103, 104). Parallel to the evidence from the wider Mediterranean and the Near East, the association of metallurgy with the realm of religion is also documented at Alalakh. This is demonstrated by the discovery of a mold for shaft-hole axes in association with the temple of Level XIV (early second millennium BC). This find indicates that this particular type of ceremonial object was being manufactured by the temple for its own use (Müller-Karpe 1994, 94). Likewise the new excavations at Alalakh discovered a ceremonial bronze axe, the parallels of which are well known in Hittite religious iconography

(Yener 2011). It seems quite likely that this axe was also manufactured in a temple workshop.

Tarsus

At Tarsus, the facilities of metallurgical production are attested throughout the second millennium BC. With respect to the Middle Bronze Age and Late Bronze Age I phases, evidence for metallurgical activities is primarily recovered from domestic structures (Müller-Karpe 1994, 91). In the Late Bronze Age II phase, which was the period of Hittite involvement, metal workshops are identified again in domestic contexts, as well as in association with the large public building (Müller-Karpe 1994, 92). The discovery of a metallurgical facility embedded in this structure proves that a publically administered metal industry was in operation in Hittite-controlled Tarsus.

Kinet

As at Tell Atchana and Tarsus, evidence for the metal industry is observed throughout the second millennium BC at Kinet. The Middle Bronze Age settlement (Level 16) has a major public building, a sector of which was dedicated to industrial activities. The discovery of a fragmentary mold for tools and weapons evidences that casting of metal was one of the activities carried out in this structure (Gates 2000, 81-82). Similarly, the large public building of the Late Bronze Age I settlement (Level 15) displays evidence for metal casting, demonstrated by the discovery of crucibles, a mold, and a bun ingot (Gates 2006, 299). The more fragmentary evidence for

metallurgical activities in the Late Bronze Age II phase has been attested in the Level 13.2 settlement and recovered mostly from domestic contexts.

3.4.6. Lead Isotope Evidence

Lead isotope analysis, the principals of which will be discussed in detail in Chapter 5, is the primary method employed to determine the provenance of metals. This analysis is based on the geographical variation in isotopic composition of distinct ore deposits. Theoretically, when the isotopic composition of the metal in an artifact is determined, the origin of the utilized metal can be assigned to a specific ore deposit, or at least to a geographical locale, which displays a matching isotope composition. Even though it is now widely accepted that the determination of the absolute provenance of metals is most of the times problematic, the method proved valuable for distinguishing more and less likely deposits or source areas. The following discussion is an overview of the existing evidence from decades of research in the Near East and eastern Mediterranean.

Copper Ingots

Late Bronze Age copper ingots, particularly those of the oxhide shape, have been extensively studied in the last two decades by the research team at the Geological Age and Isotope Research Laboratory of Oxford University⁵⁶. Their results can be summarized as follows:

⁵⁶ For a review of this work see Stos-Gale and Gale 2009.

1. All oxhide ingots postdating 1400 BC were produced with great likelihood from the copper of a single source area, namely the Solea region of the Troodos Mountains on Cyprus. More specifically, the vast majority of these ingots can be attributed to one single deposit in Solea, namely the mine at Apliki. By contrast, only 15 percent of the finished artifacts sampled from Cyprus have matching isotope characteristics with Apliki. Accordingly, the research team argued that after 1400 BC Apliki mine became the primary source of copper, from which the oxhide ingots were cast, exclusively for an export market. The mine, however, was not a major source of copper that was used locally (Gale and Stos_Gale 1999a, 274-75; Gale 2011).

2. The oxhide ingots from the Uluburun Ship display somewhat different isotopic characteristics from the ore fields in Solea. On graphical representation, the cluster of the Uluburun assemblage has been interpreted to be “on a natural extension” of the Solea field, rather than directly overlapping it. As a result, the research team finds it likely that the copper of these ingots had its origins in a currently undiscovered deposit in the Solea region. The researchers support this argument by citing some artifacts and slags from Cyprus that displayed the same isotope ratios as the Uluburun ingots (Stos-Gale and Gale 2003, 97; Gale and Stos-Gale 2005, 119-22).

3. All studied oxhide ingots from Sardinia are isotopically compatible with the Apliki mine, just as other post 14th century BC examples. However, the contemporary finished objects from the island exclusively match local copper deposits (Gale 2006).

4. The oxhide ingots from Late Minoan Crete constitute the earliest examples of this type of ingot. Seventeen samples from Gournia, Mochlos, Kato Zakros, and Kato Syme are found to have similar isotope characteristics to those of the later Uluburun samples, and thus attributed by the Oxford team to Cyprus (Gale and Stos-Gale 2005, 125, 129; Kassianidou 2008, 266). However, sixteen samples from Hagia

Triada, Kato Zakros, and Tylissos display a unique isotopic composition that does not match any known source area in the Near East or the Mediterranean. Similar isotopic ratios are found only in some late third millennium BC copper artifacts from the Aegean. As an explanation, the Oxford team discusses the likelihood that these ingots have their origins in a possible eastern (Asian) source, the isotopic composition of which is yet to be determined (Stos-Gale 2001, 203; Stos-Gale 2011, 226-27).

These interpretations by the Oxford team, however, are not universally accepted. Firstly, archaeological evidence indicates the presence of several polities on Cyprus, all of which were most likely involved in the production and exportation of copper; and possibly had access to particular deposits in the Troodos Mountains. As a result, the presumed predominance of one single mine as the source of all oxhide ingots is not a convincing argument according to skeptical researchers in the field. The same critiques also raise the point that the importation of Cypriot ingots into Sardinia does not seem likely if they were not used in the production of artifacts (Knapp 2000, 41-42, 46; Muhly 2009, 26-30; Kassianidou 2009, 62-63; Knapp 2012, 22-23). On the other hand, a re-analysis of the Sardinian oxhide ingots by a German team also attributed their origins to Cypriot ore fields. The German team, however, was more hesitant to point to one single ore deposit as the only source of all ingots (Begemann et al. 2001).

According to the Oxford team, the study of copper ingots of other varieties revealed that they do not display significantly different isotopic compositions from those of the oxhide ingots. Almost all bun-shaped ingots (nineteen of the total twenty) and one slab ingot from the Gelidonya Ship of the late 13th century BC have been attributed to the Apliki mine, just as the contemporary oxhide ingots (Gale and Stos-Gale 1999a, 273; Gale and Stos-Gale 2005, 119). The majority of bun ingots from the

earlier Uluburun Ship and the single example from the Hittite site of Kuşaklı (16th to mid-14th century BC) have the same isotopic ratios as the Uluburun oxhide ingots, and are tentatively assigned by the Oxford team to the Solea region of Cyprus (Gale and Stos-Gale 2005, 122; Müller-Karpe 2005, 491).

On the other hand, not all copper ingots investigated by the Oxford team have been attributed to Cypriot ore fields. A few bun ingots from the Uluburun Ship, most slab ingots (five of total six) from the Gelidonya Ship, and some fragmentary round ingots from Late Minoan I Mochlos on Crete (16th or 15th century BC) are found to have matching isotopic characteristics with Laurion on mainland Greece (Stos-Gale and Gale 2003, 97; Gale and Stos-Gale 2005, 119, 122). Finally, twelve oxhide ingots from Uluburun and some fragmentary round ingots from Mochlos have been interpreted to match the Taurus ore fields of southern Anatolia (Stos-Gale and Gale 2003, 97).

Finished Artifacts

Besides ingots, lead isotope studies also involved the analysis of significant numbers of finished artifacts. If the cumulative results of extensive studies by the Oxford team are accurate, each part of the eastern Mediterranean appears to have predominantly used its local copper sources throughout the Bronze Age. This observation seems to be valid concerning the western and southern Aegean (Stos-Gale 2001, 200-204, fig. 10.2; Stos-Gale and Gale 2003, 89-97; Stos and Gale 2006, 313-19), the eastern Aegean (Stos-Gale, Gale, and Gilmore 1984; Gale et al. 1985), Cyprus (Stos-Gale and Gale 2003, 97), and the Levant (Stos-Gale and Gale 2003, 97-98).

This proposition is to a certain extent supported by other research teams, concerning western Anatolia (Pernicka et al. 1984, 580, 590, fig. 1; Seeliger et al. 1985, 649-51, Pernicka et al. 1990, 290-91; Begemann, Schmitt-Strecker, and E. Pernicka 2003, 191-99), and the Levant (Phillip, Clogg, and Dungworth 2003). Outside the Mediterranean basin, southeastern Arabia is another region, from which a large body of lead isotope data is available. Not surprisingly, Bronze Age communities in the region also appear to have used the rich copper deposits locally available (Weeks 2003, 155-63; Begemann et al. 2010, 149-57).

According to the results of the Oxford team, imported metal always constituted part of studied assemblages, but not to significant extents. As an example, the portion of samples from second millennium BC Crete (Stos-Gale 2001, 200-203, fig. 10.2) and third millennium BC Anatolia (Stos-Gale and Gale 2003, plate XVIIIa) that are attributed to Cypriot deposits do not exceed 18 percent of the total assemblages.

As discussed above, studies of oxhide ingots indicate that Cyprus was a major exporter of copper in the last centuries of the second millennium BC, which correlates with textual evidence. However, the isotope analysis of finished artifacts showed that Cyprus was not necessarily the only source of copper in interregional circulation. Instead, certain other source areas such as Sardinia, Wadi Arabah, the Taurus Mountains in southern Turkey and Kerman in Iran appear to have supplied the interregional market, generally however, to a lesser extent than Cyprus. The evidence further implies that the sources of imported copper attested in individual assemblages become more diverse during the Late Bronze Age (Stos-Gale 2001, 201-4; Stos-Gale and Gale 2003, 94-99).

As far as the comparison between distinct alloy types are concerned, in certain assemblages noticeable isotopic differences are observed between tin-bearing and tin-

free copper objects. This is a particularly common phenomenon at the late third millennium BC sites in the Aegean, such as Troy (Pernicka et al. 1984, 590, fig. 31; Seeliger et al. 1985, 649-51; Gale, Stos-Gale, and Gilmore 1985, 158, table 4), and Poliochni (Pernicka et al. 1990, 290-91, Fig. 3). A comparable distinction is also evident in the burial assemblages of southeastern Arabia from the same period (Weeks 2003, 150-52). However, in certain other studies, where isotopic differences between the alloy types are particularly examined, no notable differences are detected between tin-bronzes and non-tin-bearing copper objects. This is observed in assemblages from Bronze Age Crete (Stos-Gale 2001, 201-3), and in the study of Luristan Bronzes (Begemann, Schmitt-Strecker, and Pernicka 1989, 272).

Ingots and Artifacts of Tin

A total of ninety-nine tin ingots are examined from the Uluburun assemblage. Their isotopic distribution pattern demonstrated that the samples form two distinct clusters (Stos-Gale et al. 1998, 119-20, fig. 5; Pulak 2000, 153, fig. 23). The two groups are also observed to be distinct in terms of their chemical composition. The first group, which consists of sixty-eight samples, was determined to contain about 1 percent lead. In contrast, the other group had lead contents only below 0.02 percent and also differs from the first group by its lower $^{208}\text{Pb}/^{206}\text{Pb}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ ratios (Pulak 2000, 155).

Neither group, however, displays any isotopic similarity to Cornwall and Erzgebirge, two major tin source areas in Europe. Interestingly, the group with the higher lead content displays correlation with the Bolkardağ ore field in the Taurus Mountains. The possibility of a third millennium BC tin mine and smelting site in the

central Taurus has been discussed previously in this chapter. However, a Late Bronze Age tin working in Anatolia has not been evidenced archaeologically or textually. Hence, the isotopic overlap between the Taurus fields and the Uluburun ingots is difficult to interpret (Pulak 2000, 153-55). On the other hand, a striking overlap was observed between the group with the lower lead content and the tin ingots recovered from a Late Bronze Age shipwreck off the coast of Hishuley Carmel near Haifa (Stos-Gale et al. 1998, fig. 6; Pulak 2000, 155).

As tin was used almost exclusively as an additive to copper, finished artifacts of metallic tin are extremely rare in Bronze Age contexts. The earliest example is a bangle from the mid-third millennium BC Thermi in the northern Aegean. The only other item from the third millennium BC is a ring from Tell Abraq in southeastern Arabia, which dates to the end of the millennium. The Thermi bangle has an isotopic composition, which does not overlap with any known source areas of Europe or the Near East. The isotopic characteristics of this object are also different from those of the Late Bronze Age tin ingots (Stos-Gale et al. 1998, 119). Interestingly, the Tell Abraq ring is found to have compatible isotope ratios with the local copper-based artifacts. As the copper objects must have been made of local (Omani) copper, and the ring was most likely an import, it has been concluded that distant sources of tin could be isotopically indistinguishable from Omani copper deposits (Weeks 2003, 163).

3.5. SUMMARY AND CONCLUSIONS

Copper deposits occur in several locales in southwest Asia and the eastern Mediterranean, the exploitation of which started several millennia before the period studied in this thesis. Likewise, the production of copper alloys constituted a full-fledged industry fifteen centuries before the second millennium BC. However, what makes the second millennium BC special in the history of metallurgy is the dramatic expansion of copper-based metal industries during this period. Source areas, which had already been supplying copper to prehistoric communities in the preceding millennia, were now being exploited at more extensive scales. This intensification of copper production is complemented by a more consistent and wide-spread use of tin-bronze. Enabling an excellent degree of control over the mechanical and color properties of the product, this alloy managed to gradually replace arsenical copper through the second millennium BC, even though tin had to be imported largely or exclusively from distant source areas. However, the absolute provenance of Bronze Age tin remains as an unsolved problem.

The intensification of copper production, as well as the use of tin-bronze, became especially noticeable during the Late Bronze Age. This phenomenon is not surprising, as this was the period, when inter-state correspondence and interregional flow of commodities are documented more extensively than before. Therefore, during this period copper-based objects (among them tin-bronzes) are found in larger quantities than the preceding centuries. This phenomenon is in good accord with contemporary textual evidence for large scale mobilization of copper and tin.

Textual information, along with the provenance studies of ingots, points to Cyprus as a primary supplier of copper for interregional circulation, especially after

1400 BC. On the other hand, provenance studies by no means demonstrate a Cypriot domination of the copper trade. Instead, different regions appear to have made use of their local copper resources, while imported copper always constituted a relatively small portion of the metal assemblages. Moreover, as the isotope studies on artifacts implicate, other source areas in the Near East also contributed to copper in interregional circulation, particularly during the Late Bronze Age.

The mobilization of copper and tin took place through trade (that can be state or privately administered), reciprocal gift exchange, and state-imposed taxes and tribute. Thus, palaces, noble individuals and professional merchants were involved in the exchange of these metals. As the available textual sources have been overwhelmingly recovered from palatial contexts, royal involvement in the production and circulation of copper is relatively well documented. In some cases, the palaces even appear to have certain degree of control over the export (as in Cyprus) or import (as in Ugarit) of copper. As evidenced at Mycenaean Pylos and the Hittite Kingdom, palaces employed metal-smiths to operate their own copper industries, in which certain high-ranking state officials acted as overseers of production. However, the available textual information from any society of the second millennium BC fails to provide conclusive evidence for a palatial monopoly over the trade or industry of copper and tin.

Circulation and production of metals outside the palatial sphere are also inferred from textual sources, especially concerning the trade of tin. The use of weighed quantities of tin as a kind of currency in Late Bronze Age Assyria and Nuzi demonstrates the highly decentralized circulation of this metal. Likewise, the evidence from the Kaneš texts testifies that the Middle Bronze Age tin trade between Assur and Kaneš was carried out with minimal interference of the palaces.

The evidence from the studied region indicates that all aspects of copper industries known from the wider Near East and the Mediterranean are observed in this region. Archaeological excavations revealed production facilities in association with secular and religious public buildings, as well as in non-public contexts. The tablet archive from Tell Atchana/Alalakh testifies that the central authority taxed copper from provinces and entrusted it to hired bronze-smiths, sometimes along with tin or scrap metal. The amounts of copper allotments, as well as the quantity of intended products could be quite large, which implies that the state-administered copper industry at this site had a substantial scale and was an essential part of the total economy.

4. RESULTS OF COMPOSITIONAL ANALYSIS

4.1. INTRODUCTION

This chapter presents the results of the compositional analysis, which determined the concentrations of fourteen chemical elements that constitute the copper-based matrix in each sample. The results are tabulated in Appendix I. Since the examination of the patterns of alloy use is a major aim of this study, the discussion of the compositional data begins with the situation of tin and arsenic, the two primary alloy constituents (Section 4.2). Particular attention is paid to the frequency of tin usage, as it is considered in this study as a potential indicator of the extent of integration into long distance exchange networks. Therefore, the intensity of tin usage in the study region will be investigated in comparison with the evidence from the wider Near East and the eastern Mediterranean. An overview of the previous studies from the region will also be presented at the beginning of this section, so that the new results can be evaluated in comparison to earlier data.

In the proceeding section (4.3), the relationships between the concentrations of each chemical element will be examined, so as to delineate compositional variability between assemblages. These relationships will be investigated by means of multivariate (principal component) and bivariate (binary correlation) statistical analyses. In the next section (4.4), those chemical elements that occur, at least in some samples, in sufficiently high concentrations to imply intentional alloying and those that display notable features in correlation analyses will be dealt with in more detail.

The situation of each element will be demonstrated by means of frequency histograms and statistical summaries. The histograms are employed to display the

measure of dispersion in datasets. Statistical summaries, on the other hand, are expressed in median, lower limit and upper limit concentrations. These parameters, however, are susceptible to be significantly affected by the extreme values in the data. As a result, basing statistical analysis on the absolute range of data would lead to misleading and less informative median and limit values in non-normal datasets. Therefore, taking the non-normal characters of the compositional data into consideration, statistical summaries are generated in a tenth to ninetieth percentile range in this study⁵⁷. Thus, the median, upper limit and lower limit values are calculated without taking the lowest and highest 10 percent ranges of the data into consideration. These statistical parameters obtained for each element are then compared to those from previous studies, which are also computed in the same percentile range in this study.

4.2. TIN AND ARSENIC: DISCERNING THE PATTERNS OF ALLOY USE

4.2.1. Previous Archaeometallurgical Research

The first archaeometallurgical studies in Cilicia and the Amuq go back to the beginning of the twentieth century. Table 4.1 presents the list of these studies, displaying the number of samples examined in each study and from each site⁵⁸. In the earliest research programs that were carried out before the 1960's, the analyses involved relatively small numbers of samples. The number of analyzed objects

⁵⁷ Tenth to ninetieth percentile proved its effectiveness in the study of prehistoric copper objects from southeast Arabia (Weeks 2003).

⁵⁸ The numbers include only the copper-based artifacts analyzed. Such other categories of metallurgical samples as ores, slags, and non-cuprous objects are excluded.

Table 4.1. Previous archaeometallurgical studies from Cilicia and the Amuq.

Study	Period of Focus	Soloi Hoard	Mersin	Tarsus	Tell Atchana (Alalakh)	Amuq Various Sites
Von Luschan 1902, Bittel 1940, Deshayes 1960	Early Middle Bronze Age	13				
Braidwood, Burke, and Nachtrieb 1951, Braidwood and Braidwood 1960	Late Chalcolithic thru Early Bronze Age					121
Esin 1969	Chalcolithic thru Late Bronze Age		52	70		
Moorey and Schweizer 1972	Middle and Late Bronze Age				23	
Gale, Stos-Gale, and Gilmore 1985	Chalcolithic thru Late Bronze Age		9			
Yalçın 2000	Early Chalcolithic		9			
Kuruçayırılı and Özbal 2005 Özbal, Kuruçayırılı, and Mısırlı 2005	Early Bronze Age thru Hellenistic and Roman Periods		41	87		
Özbal 2006	Late Bronze Age				43	
Dardeniz 2007	Late Bronze Age thru Hellenistic and Roman Periods			75		
Selover 2010	Late Bronze Age				14	
Total		13	111	232	80	121

appears especially low, when only those that are subjected to full quantitative investigation are considered. It was only after 1960 that analytical programs started to incorporate more significant quantities of samples and provided statistically more informative results. More specialized archaeometallurgical investigations that focus on one single object category started to be performed in the last decade. The primary outcomes of these research programs will now be outlined.

Evidence from the Amuq

The first archaeometallurgical research on the material from the Amuq is carried out by Braidwood and colleagues, who conducted the semi-quantitative spectral analysis of 115 copper-based objects from the fourth and third millennium BC contexts (Braidwood and Braidwood 1960)⁵⁹. To complement this semi-quantitative investigation, thirteen of the objects were also subjected to wet chemical methods of full quantitative analysis (Braidwood, Burke, and Nachtrieb 1951)⁶⁰.

Fourteen objects from the Chalcolithic period constitute the earliest group of objects analyzed in this study⁶¹. The most notable observation from the semi-quantitative examination of this group is that nickel was determined to be a “major” constituent (with over 10 percent in weight) in twelve of these objects (Braidwood and Braidwood 1960, 119-20; Buchholz 1967, 245-46, table 12). The occurrence of nickel in such high concentrations in the majority of samples is not attested in later assemblages from the region.

⁵⁹ Predominantly from the sites of Tell Judeidah and Tell Ta'yinat.

⁶⁰ The results of the semi-quantitative analysis are published later than those of the full quantitative study. This work is included in Braidwood's general report of the fieldwork in the Amuq (Braidwood and Braidwood 1960). The results are later summarized in Buchholz 1967.

⁶¹ The samples in this group belong to the Amuq Phase F and the so-called “First Mixed Range” of the Amuq chronological phases and date prior to 3100 BC.

The succeeding Amuq Phase G (late fourth, early third millennium BC) provided conclusive evidence for the occurrence of tin-bronze. The studied assemblage from this period consisted of more than fifty copper-based samples, among which the cache of six anthropomorphic statuettes appears as the most interesting group (Buchholz 1967, 247-48, table 13). Semi-quantitative examination determined tin contents of over 10 percent in five of the statuettes and four of the remaining implements. Tin is also noted to display a “strong presence” (between 1 and 10 percent) in the sixth statuette and three other items. The semi-quantitative investigation is complemented by the full-quantitative analysis of two of the statuettes and five other artifacts (Braidwood, Burke, and Nachtrieb 1951, 91, table 4, 9, 12). Having detected tin contents between 7 and 11 percent in the statuettes and in one other item, this analysis verified the results of the semi-quantitative analysis.

Besides tin-bronze, the use of arsenical copper is evidenced by the observation of arsenic contents between 1 and 10 percent in four objects. Finally, some miniature items, which constituted the accessories of the statuettes, were found to be made of a copper-silver alloy. In some of these items, gold is detected along with copper and silver, which indicates the high degree of complexity achieved by the metallurgy of the period.

In the succeeding centuries of the third millennium BC, tin-bronze and arsenical copper continued to occur in some frequency in the Amuq. Twenty-four samples examined from Phase H (roughly the second quarter of the third millennium BC) yielded five tin-bronze and three arsenical copper objects. Of a total of sixteen items from Phases I and J (roughly the second half of the third millennium BC), five items were determined to have tin contents between 1 and 10 percent (Braidwood and

Braidwood 1960, 373-79; 420-22; 453-55; Buchholz 1967, 248-50, table 13)⁶². In sum, as its most significant outcome, this research program testified that tin-bronze was known in the Amuq as early as the first centuries of the third millennium BC and continued to be used in a modest frequency throughout this millennium.

Moorey and Schweizer's compositional study of metal artifacts from Iraq, Syria, and Palestine included twenty-three copper samples from Tell Atchana (Moorey and Schweizer 1972, 191-92). However, these items had no associated records, and hence, could not be precisely attributed to any chronological phase. As a result, the researchers assigned these objects only tentatively to either the Middle or Late Bronze Age by means of typological comparison with the published artifacts in Woolley's excavation report⁶³.

Of the twenty-three objects studied, fourteen are found to have tin contents above 2 percent, with an average concentration of 9.13 percent. In contrast, arsenic is observed to have a limited occurrence, as it is attested only in concentrations of around 1 percent and only in four samples⁶⁴. Even though these results demonstrated a frequent use of tin-bronze in the second millennium BC contexts of Tell Atchana, the authors particularly notice that a preferential use of this alloy in particular object categories is not evident. Instead, tin appears to have been used in artifacts of a diverse typology (Moorey and Schweizer 1972, 192).

⁶² Braidwood and colleagues also present the analysis results of six "reamers" (points) very tentatively dated to the broad timespan between Phases F and I (Braidwood, Burke, and Nachtrieb 1951, 89, table 3; Buchholz 1967, 250; table 13). The analysis determined more than 8 percent tin in one object, and between 1.35 and 2.05 percent arsenic in three others. Two of these arsenical copper items also contain 2.73 percent nickel each. There is also a sample that had a nickel content of 1.20 percent without any significant arsenic concentration.

⁶³ Twenty artifacts were assigned to the Late Bronze Age (Levels III-I), while six were thought to belong either to the Middle Bronze Age (Level VII) or the Late Bronze Age levels (Moorey and Schweizer 1972, 191).

⁶⁴ Of the chemical elements examined, the concentrations of only arsenic and tin were expressed in precise percentages by weight. Only in the case of one single object, antimony content was also recorded precisely.

The first archaeometallurgical investigation of the copper objects recovered by the recent fieldwork at Tell Atchana was carried out by Özbal (2006). The studied set of artifacts consisted of forty-three items, all of which belong to the Late Bronze Age. As one would expect from any assemblage from this period, tin-bronzes are quite common, comprising about half of the samples (twenty of a total of forty-three). The remaining half of the assemblage predominantly consisted of unalloyed copper objects, while arsenic is found only in four samples, with the highest concentration being only 1.65 percent. Hence, by demonstrating the consistent use of tin and the scarcity of arsenic at second millennium BC Tell Atchana, this research verified the earlier study by Moorey and Schweizer.

Selover's investigation of clothing pins from Tell Atchana is the first study from the Amuq that focuses on the metallurgy of one particular artifact category (Selover 2010). This study involved the semi-quantitative compositional analysis of fourteen copper pins from the Late Bronze Age levels of Tell Atchana that are recovered in recent fieldwork. Interestingly, a high content of arsenic is detected in all fourteen samples examined. The consistent utilization of arsenical copper in clothing pins led the author draw the conclusion that the reason behind this choice could be the desire for the silver-like color of the alloy. The use of tin-bronze, on the other hand, would have resulted in a gold-like color, which the author thinks was not a demanded property in these implements. Selover bases her argument on the discovery of some silver pins at this site and the total absence of those made of gold. She concluded then that the pins made of arsenical copper appear to have been manufactured as an imitation of silver pins (Selover 2010, 152).

We should, however, note that the analytical results of this study seriously contradict those from the earlier research on the Late Bronze Age material from Tell

Atchana. As noted above, Moorey and Schweizer (1972) identified only four items (of a total of twenty) with somewhat significant arsenic contents. Likewise, only three of a total of twenty-one pins analyzed in Özbal's study (2006) turned out to be made of arsenical copper. Against this backdrop, it is quite surprising for an investigation to detect significant arsenic contents in all fourteen samples from this site and this time period.

Evidence from Cilicia

Archaeometallurgical studies in Cilicia began with the compositional analysis of copper artifacts from a Bronze Age hoard recovered near the ancient site of Soloi, eleven kilometers southwest of Mersin. The discovery of the hoard was first publicized at the beginning of the twentieth century by von Luschan, whose study included the compositional analysis of two objects from this hoard (von Luschan 1902)⁶⁵. This early work was succeeded about four decades later by the analysis of ten more items from the hoard (Bittel 1940). Finally, the analysis of one last artifact was published two decades after Bittel's study (Deshayes 1960).

The group of thirteen items analyzed primarily consists of weapons and heavy tools such as daggers, spearheads and flat axes. Nine of the objects were identified as tin-bronzes with an average tin content of 7.81 percent, while one stamp seal was found to be made of arsenical copper. Even though the precise dating of the hoard is equivocal, the dating suggested by Bittel to the early centuries of the twentieth century BC is generally accepted (Bittel 1940, 201-5). As a result, these preliminary

⁶⁵ This hoard of seventy-seven metal objects had originally been discovered by a shepherd in 1889 but remained unpublished until von Luschan's report in 1902.

studies of modest scale demonstrated the use of tin-bronze in Cilicia, possibly as early as the beginning of the second millennium BC.

In 1969, Esin published the outcome of her research on the copper-based metallurgy of prehistoric Anatolia prior to the second millennium BC. This large scale analytical study involved the investigation of several hundred samples from all parts of Anatolia, among which the Cilician sites of Tarsus and Mersin are represented by seventy and fifty-two samples respectively. The earliest Cilician artifacts included in this research program are fifteen items from the Chalcolithic levels of Mersin (Mersin Levels XVII-XIII). The analyses of these early items detected arsenic contents of about 1 percent in five samples⁶⁶.

The third millennium BC assemblage from Cilicia exclusively consists of samples from Tarsus, whose examination demonstrated a modest use of tin-bronze during this period. From a total of fifty-six samples analyzed, nine and twenty-four have been identified respectively as tin-bronze and arsenical copper⁶⁷. In the Middle Bronze Age assemblage, which comprises a total of twelve items from the two sites, eight arsenical copper objects and no single example of tin-bronze is detected. Overall, during the Early and Middle Bronze Ages, Cilician copper metallurgy is characterized by an abundant use of unalloyed and arsenical copper and an insignificant presence of tin-bronze.

With respect to the Late Bronze Age, a somewhat more significant occurrence of tin-bronze becomes visible in its earlier phase, namely the Late Bronze Age I period. In a total of twenty-eight samples, tin is detected in eight items. With fifteen representatives in this assemblage, arsenical copper still enjoys a more frequent use

⁶⁶ Respective tin contents of 2.6, 2.1, and 1.3 percent were observed in a stamp seal, an awl and a pin from the Chalcolithic levels (Levels XVII-XIII). However, these artifacts are more likely to be intrusions from later levels (Yakar 1984, 60-61; Gale, Stos-Gale, and Gilmore 1985, 168; Yener 2000, 66).

⁶⁷ Eight of these objects contain significant levels of both tin and arsenic, and thus are counted in both groups.

than tin-bronze. More noticeable changes occur during the Late Bronze Age II period, from which thirteen tin-bronze and six arsenical copper objects are identified among a total of thirty-four samples. In sum, Esin's study showed that it was not until the Late Bronze Age, that tin-bronze started to constitute a significant part of Cilician copper metallurgy.

In 1985, Gale and his colleagues carried out the first lead isotopic study of samples from the region of interest (Gale, Stos-Gale, and Gilmore 1985, 167-71). Their analysis incorporated twenty-five copper-based samples from Mersin, the compositional analysis of which had already been performed by Esin. To complement the isotopic investigation and to test the accuracy of the earlier analysis by Esin, the research team subjected nine of the samples to geochemical analysis. The comparison between the new and the previous research demonstrated a high degree of agreement for concentrations below about 0.8 percent. Particularly important was the high degree of coherence between the two research programs in terms of arsenic and tin concentrations. Only in one tin-bronze item a considerable discrepancy was detected, as Esin's analysis has been noted to have underestimated the concentration by about 45 percent⁶⁸. As far as the other elements are concerned, the exceptionally high lead content of a bracelet, which Esin's study had tentatively reported to be significantly higher than 5 percent, was now precisely measured as 17.75 percent (Gale, Stos-Gale, and Gilmore 1985, table 7, sample 17917).

Insight into the very early metallurgy of the region is provided by Yalçın, when he published the chemical and metallographic examination of seven copper pins and two axes from early Chalcolithic Mersin (Level XVI, early fifth millennium BC) (Yalçın 2000). The metallography and the trace element characteristics of the studied

⁶⁸ Gale and colleagues, however, note a general underestimation of tin concentrations in Esin's study in the assemblage from Troy (Gale, Stos-Gale, and Gilmore 1985, 168).

artifacts demonstrated that they had been manufactured by casting and subsequent hammering from smelted and not native copper. Hence, this research testified the practices of casting and smelting in early fifth millennium BC Cilicia and rendered the Mersin objects as some of the earliest items made of smelted copper.

The study of copper objects from Tarsus and Mersin by Kuruçayırılı and Özbal incorporates samples from a considerably long timespan from the Early Bronze Age thru the Hellenistic and Roman periods. In the assemblage from the Early Bronze Age, only nine samples of a total of thirty-two are identified as tin-bronze. However, tin was also detected in the single sample from the Early Bronze Age I period, testifying the use of tin-bronze in Cilicia as early as the first centuries of the third millennium BC (Kuruçayırılı and Özbal 2005, table 4, sample T47.80). The relative abundance of this alloy remains modest during the Middle Bronze Age, from which only two items of a total of nine contain tin. By contrast, more than half (thirteen of a total of twenty-one) of the objects studied from the Late Bronze Age are made of tin-bronze. These results demonstrated that it was not until the Late Bronze Age that tin-bronze was a common alloy at Tarsus, verifying the earlier results of Esin's study (Kuruçayırılı and Özbal 2005, 185-86, figure 2a-h).

Unlike the situation of tin, there is some discrepancy between the two studies with respect to the abundance of arsenic. The more recent analysis detected arsenic in a larger number of samples, and thus, determined a greater relative abundance of arsenical copper. In Esin's study, arsenical copper constituted nearly half of the total assemblage (twenty-four of a total of fifty-six samples), while this portion rises to 65 percent (four of total sixty-two samples) in the more recent study by Kuruçayırılı and Özbal. With regard to the ternary alloy of copper arsenic and tin, the two studies are in good agreement as both noticed its frequent occurrence in Bronze Age Cilicia.

As far as the Mersin assemblage is concerned, half of the samples (twenty-two of a total of forty-one) are of uncertain context. Sixteen items datable to the Bronze Age are exclusively from the second millennium BC, the analyses of which identified three arsenical copper and four tin-bronze artifacts (Kuruçayırılı and Özbal 2005, 186, 189). The analysis of eleven samples from the Iron Age and Hellenistic-Roman levels of the two sites yielded seven tin-bronze and one arsenical copper artifacts, testifying the consistent use of tin-bronze during the first millennium BC.

Finally, antimony contents in excess of 10 percent are measured in two stamp seals from the Early Bronze II levels of Tarsus (Özbal, Kuruçayırılı, and Mısırlı 2005). These exceptionally high concentrations, along with the selective use of this alloy in a single object type, conclusively proves the intentionality of the production of copper-antimony alloy. Even though it is not possible to determine with certainty whether the copper-antimony seals from Tarsus had been locally made in Cilicia, they are most likely to have been produced within the boundaries of Anatolia⁶⁹.

As noted in Chapter 3, artifacts of this alloy are commonly attested in Chalcolithic Palestine (Shalev and Northover 1993; Tadmor et al. 1995) and the Middle Bronze Age Caucasus (Hauptmann and Gambashidze 2001; Pike, Cowell, and Curtis 1996). From Anatolia, three more prehistoric copper artifacts are reported to contain significant amounts of antimony. Two of these items are from Early Bronze Age central Anatolia. The third item is the most interesting because it is recovered from the Soloi Hoard, not far from the studied region⁷⁰. More significantly, this object is a stamp seal, just like its counterparts from nearby Tarsus (Özbal, Kuruçayırılı, and Mısırlı 2005, 201, table 3).

⁶⁹ One of the seals (T47-1) is of a typical Anatolian shape. The second seal (sample T47-87) is of an entirely unique shape, consisting of a perforated stalk branching into two identical ridged knobs (Goldman 1956, 232; 237; figure 392).

⁷⁰ As reviewed at the beginning of this section, the hoard is tentatively dated to the beginning of the second millennium BC.

When Dardeniz performed the compositional study of forty-six copper arrowheads from Tarsus, she carried out the first archaeometallurgical study from Cilicia that exclusively focuses on one particular artifact category (Dardeniz 2007). Eleven arrowheads from the Late Bronze Age constitute the earliest set of samples in the studied assemblage. The analysis of this group revealed a predominance of unalloyed copper, as arsenic and tin are detected in four samples only. The use of alloys in the manufacture of arrowheads increases in the Iron Age assemblage of twenty-seven samples. Eight of these are tin-bronzes, four are arsenical coppers and two are ternary alloys. As far as the Hellenistic and Roman periods are concerned, of the nine samples examined, six turned out to be tin-bronzes, whereas arsenical copper was not detected (Dardeniz 2007, table 6.1). In sum, this study demonstrated a gradual increase in the use of tin in arrowheads from the late second into the late first millennium BC.

A notable observation of this research was that all arrowheads with hollow sockets, a characteristic type of the Iron Age, Hellenistic and Roman Periods, were found to contain high levels of lead. Lead is detected in all twenty-five representatives of this type, with 32.3 and 14.33 percent being the highest and median concentrations respectively. Apparently, lead was being added to such arrowheads in order to compensate the weight deficiency caused by the hollow interior, which would otherwise diminish the arrow's mass and hence, its piercing capacity upon impact.

Summary of Previous Studies

The studies summarized above provided certain results that are not only significant for an understanding of the metallurgical trends in the region, but also with

respect to the prehistoric copper metallurgy of the entire Near East and the eastern Mediterranean. Most notably, some of the earliest evidences for copper smelting (Yalçın 2000), as well as the use of tin-bronze (Braidwood, Burke, and Nachtrieb 1951) are attested in this region. Another find of great interest was the evidence for the use of copper-antimony alloy during the third millennium BC (Özbal, Kuruçayırılı, and Mısırlı 2005). As far as the situation of tin-bronze and arsenical copper are concerned their relative abundance with respect to sites and time periods are shown in figure 4.1⁷¹. As noted above, archaeometallurgical research has clearly testified the use of tin-bronze in the region as far back as the early third millennium BC⁷². However, despite its early occurrence, the utilization of this alloy remained infrequent throughout the third millennium BC in both Cilicia and the Amuq, which draws a contrasting picture with contemporary central Anatolia, northeastern Aegean, and Mesopotamia.

Cilicia and the Amuq display similar relative abundances of tin-bronze during the Early Bronze Age, as respectively twenty-one and twenty-seven percent of their assemblages are constituted by tin-bronze objects⁷³ (figure 4.1). The two regions, however, significantly differ in terms of their tendencies towards arsenical copper. In Cilicia, a very significant presence of this alloy has been observed, as it comprises more than half of the objects from this period⁷⁴.

⁷¹ In this statistical summary, not every sample analyzed in the above-mentioned studies are considered. Instead, only those samples that can be ascribed with certainty to any specific chronological phase of the Bronze Age are included. In order to render the statistics more trustworthy, samples from insecure analytical data (mostly semi-quantitative) are excluded.

⁷² Human figurines and other artifacts from Amuq G Levels of Tell Judeidah (Braidwood and Braidwood 1960, Braidwood, Burke, and Nachtrieb 1951) and the EB I needle (sample T47.80) from Tarsus (Kuruçayırılı and Özbal 2005) are the earliest tin-bronzes from the region.

⁷³ Tin-bronze objects without any arsenic, as well as objects of copper-tin-arsenic ternary alloy are included.

⁷⁴ Again, arsenical copper objects without tin and objects of copper-tin-arsenic ternary alloy are counted in this group.

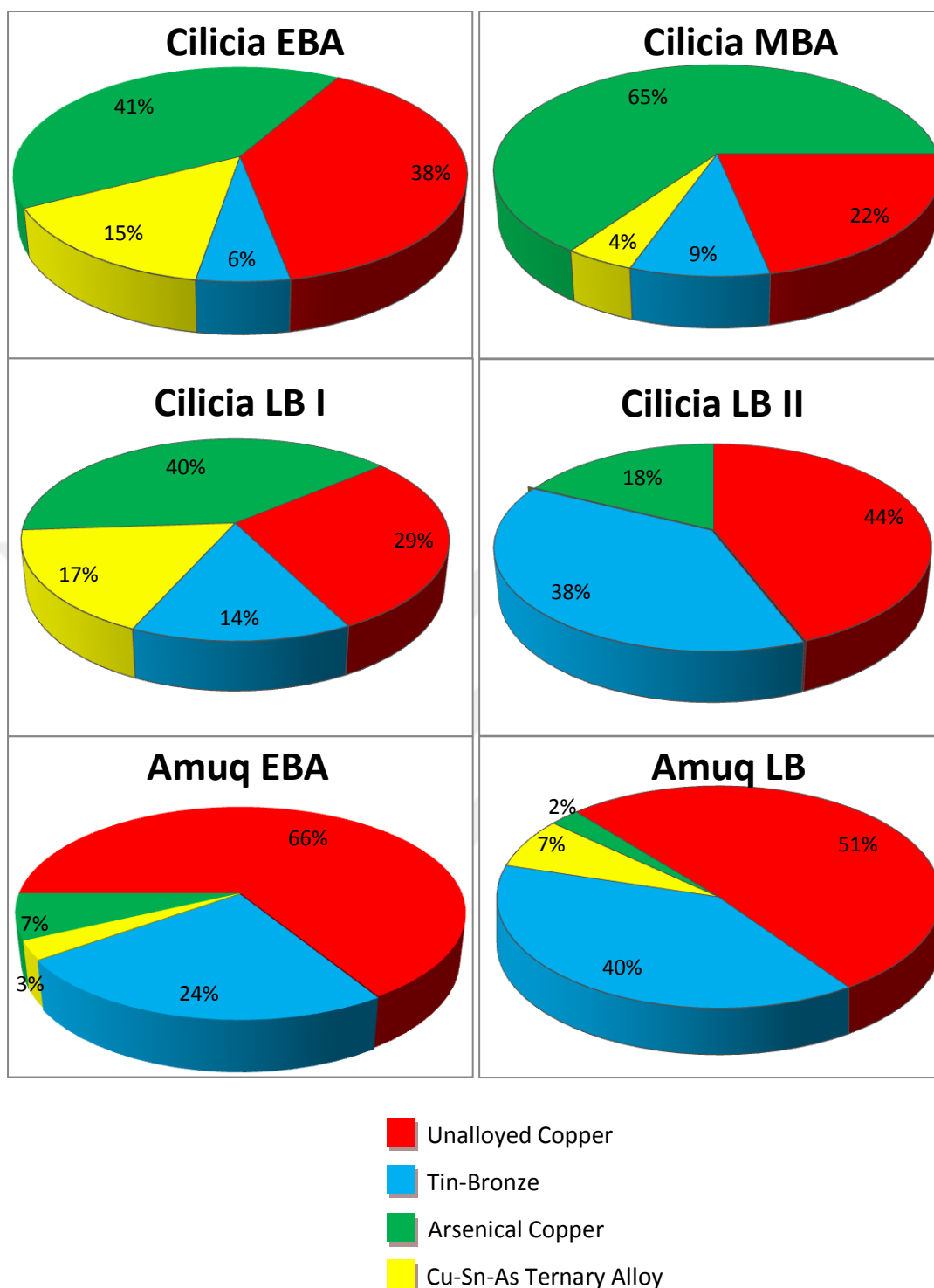


Figure 4.1. Alloy use in Cilicia and the Amuq in the Bronze Age (previous studies).

In contrast, arsenical copper was quite scarce in the Early Bronze Age Amuq, constituting not more than 10 percent of the assemblage.

If we move on to the Middle Bronze Age, the current data from the Amuq does not include any sample that is securely datable to this period. In Cilicia, which remains the only source of information on the metallurgy of this period, alloying patterns appear to be carried unaltered from the preceding Early Bronze Age. The use of tin-bronze is still infrequent, while arsenical copper remains the most widely used alloy, now constituting 65 percent (fifteen of a total of twenty-three samples) of the assemblage.

With regard to the Late Bronze Age, a significant use of tin-bronze is now apparent in both Cilicia and the Amuq for the first time. In the Amuq, where the Late Bronze Age had been treated as a single entity, tin-bronzes constitute nearly half of the studied assemblage. Arsenic still displays a very limited usage, detected in only less than 10 percent of the analyzed objects.

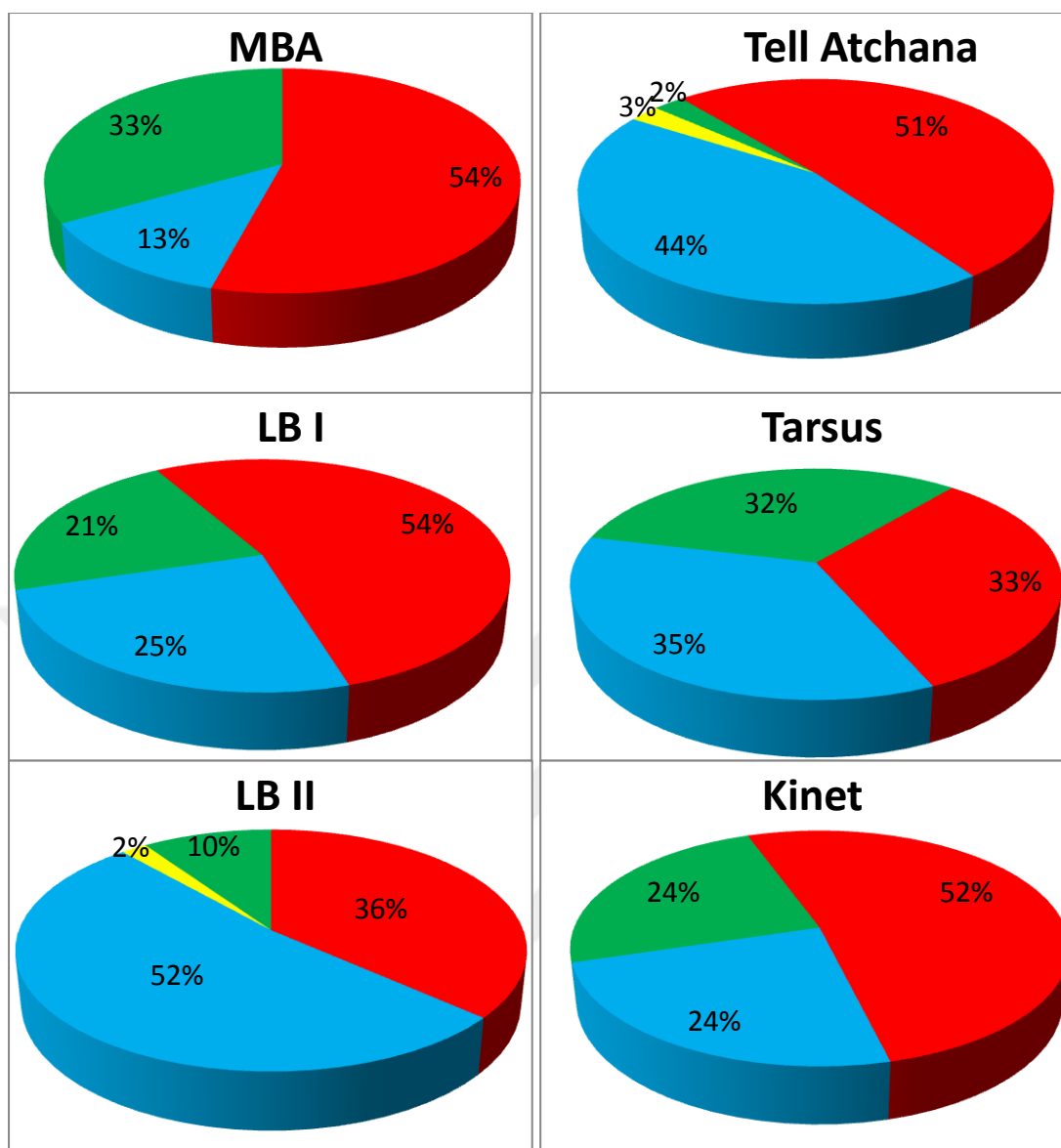
It is only in Cilicia that we gain insight into the patterns of alloy use in two distinct phases of the Late Bronze Age. The Late Bronze Age I period demonstrates the ongoing abundance of arsenic along with an increased importance of tin-bronze, as the two alloys respectively constitute 54 and 31 percent of the total assemblage. Major changes appear to have occurred in the Late Bronze Age II period, when the relative abundance of arsenical copper drops to 18 percent, while that of tin-bronze rises to 38 percent. Accordingly, the evidence indicates a gradual, but not a drastic increase in the use of tin throughout the Late Bronze Age.

4.2.2. New Results: Tin Concentrations and Tin-Bronze

Having summarized the evidence from previous research, let us now examine how the results of the current study will contribute to our existing knowledge on the Bronze Age metallurgy of the study region. The relative abundances of unalloyed copper, arsenical copper and tin-bronze, as demonstrated by the current analyses, are displayed in figure 4.2. The use of tin-bronze shows a noticeable increase from the Middle Bronze to the Late Bronze Age I and subsequently to the Late Bronze Age II period (figure 4.2a). From the Middle Bronze Age, only three of a total of twenty-four samples (13 percent) have been determined to be tin-bronzes⁷⁵. The relative abundance of the alloy increases to 25 percent (seven of total of twenty-eight samples) in the Late Bronze Age I and to 52 percent (twenty-seven of total fifty-two samples) in the Late Bronze Age II periods. Thus, it was not until 1400 BC that objects of tin-bronze constituted half of the total assemblage of copper-based artifacts. Moreover, this increase is observed at all three sites as demonstrated in figure 4.3.

The gradual increase in the use of tin is also well reflected in frequency histograms (figure 4.4). Prior to the Late Bronze Age II, pure copper and arsenical copper objects, which contain tin only in trace quantities, constitute the vast majority of assemblages. Accordingly, the histograms of the Middle Bronze Age and Late Bronze Age I show an accumulation of tin concentrations predominantly below 1 percent. In contrast, the extensive use of tin during the Late Bronze Age II period results in an abundance of samples in the 1 to 10 percent range.

⁷⁵ In this study, tin concentrations higher than 2 percent are considered to indicate intentional alloying.



a. Periods.

b. Sites.

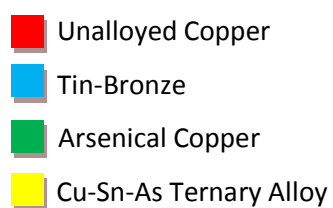


Figure 4.2. Relative abundance of copper alloys (new results).

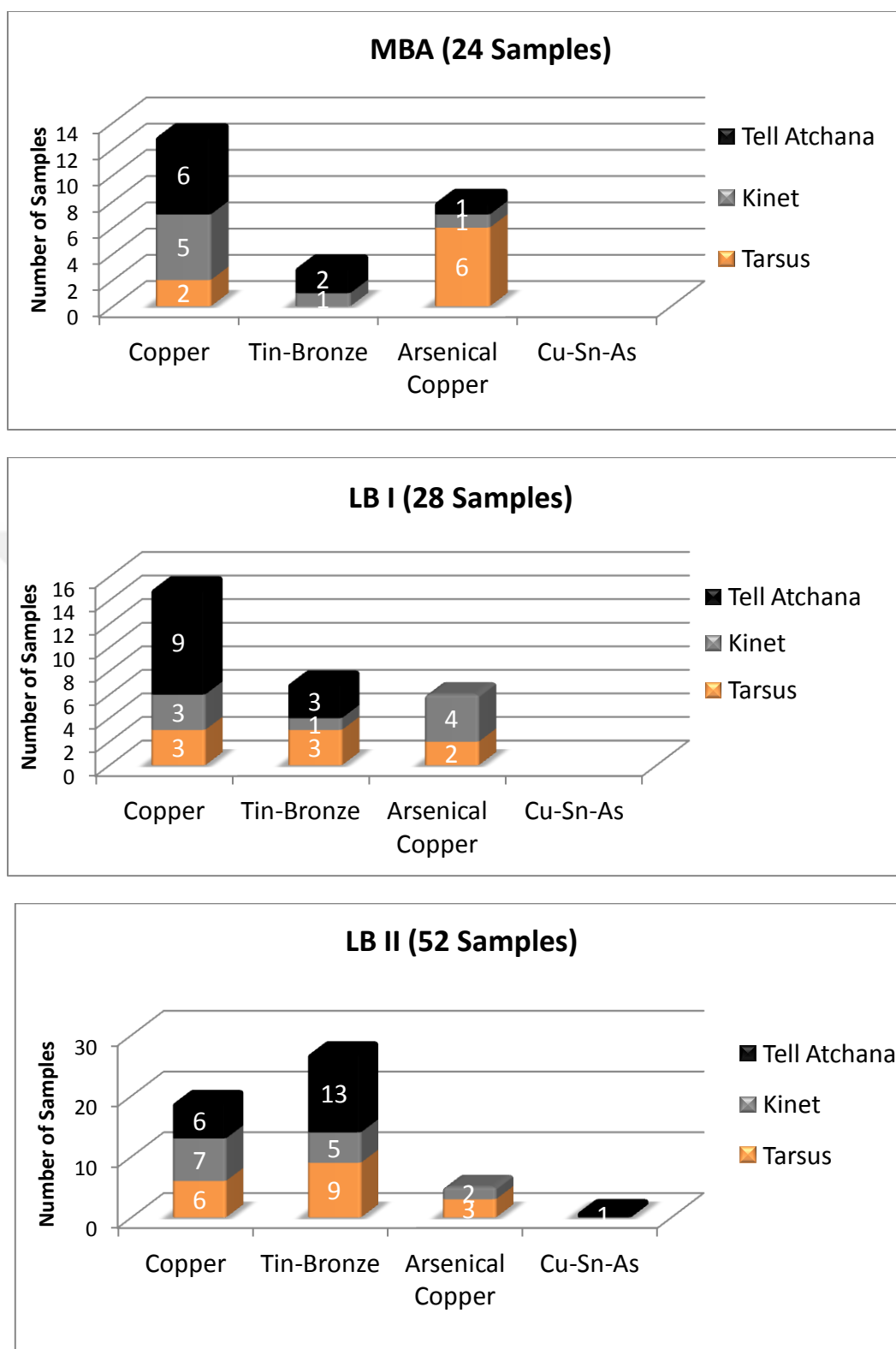


Figure 4.3. Relative abundance of copper alloys (sites and periods).

More than half of tin-bronze objects have tin contents above 5 percent, with two samples containing in excess of 10 percent tin. These are two Late Bronze Age II samples from Kinet, a blade (sample KT 25447) and a spearhead (sample KNH 1041) with respective tin concentrations of 10.16 and 11.55 percent. Objects that are not tin-bronzes have their tin contents predominantly in the 0.01-0.1 percent range in all periods.

As far as the statistical parameters are concerned, the progressive intensification of tin-bronze usage through the millennium is also demonstrated by the median values, as they depict a clear increase from 0.04 in the Middle Bronze Age to 0.11 in the Late Bronze Age I and to 2.54 in the Late Bronze Age II periods (table 4.2). Even though there is a significant difference between the three periods in terms of the frequency of tin usage, tin-bronze objects with high tin concentrations (above 5 percent) occur in each period. As a result, the median tin concentrations in the tin-bronze assemblage are similar for each period, calculated around 5 or 6 percent.

A comparison between the three sites reveals that tin was most regularly used at Tell Atchana, where tin-bronze objects constitute 47 percent of the total assemblage. This is particularly evident during the Late Bronze Age II period, from which tin is detected in more than half (fourteen of a total of twenty) of the samples (figure 4.2b). Tell Atchana is followed by Tarsus, where about 35 percent of the samples are determined to be tin-bronzes. It is important to note that Tarsus is the only site that does not yield any tin-bronze item from the Middle Bronze Age (figure 4.3). Kinet, where the portion of tin-bronzes in the total assemblage is below 25 percent, is the site where tin was used least extensively. Even during the Late Bronze Age II period, when the frequency of tin-bronzes dramatically increased at all sites,

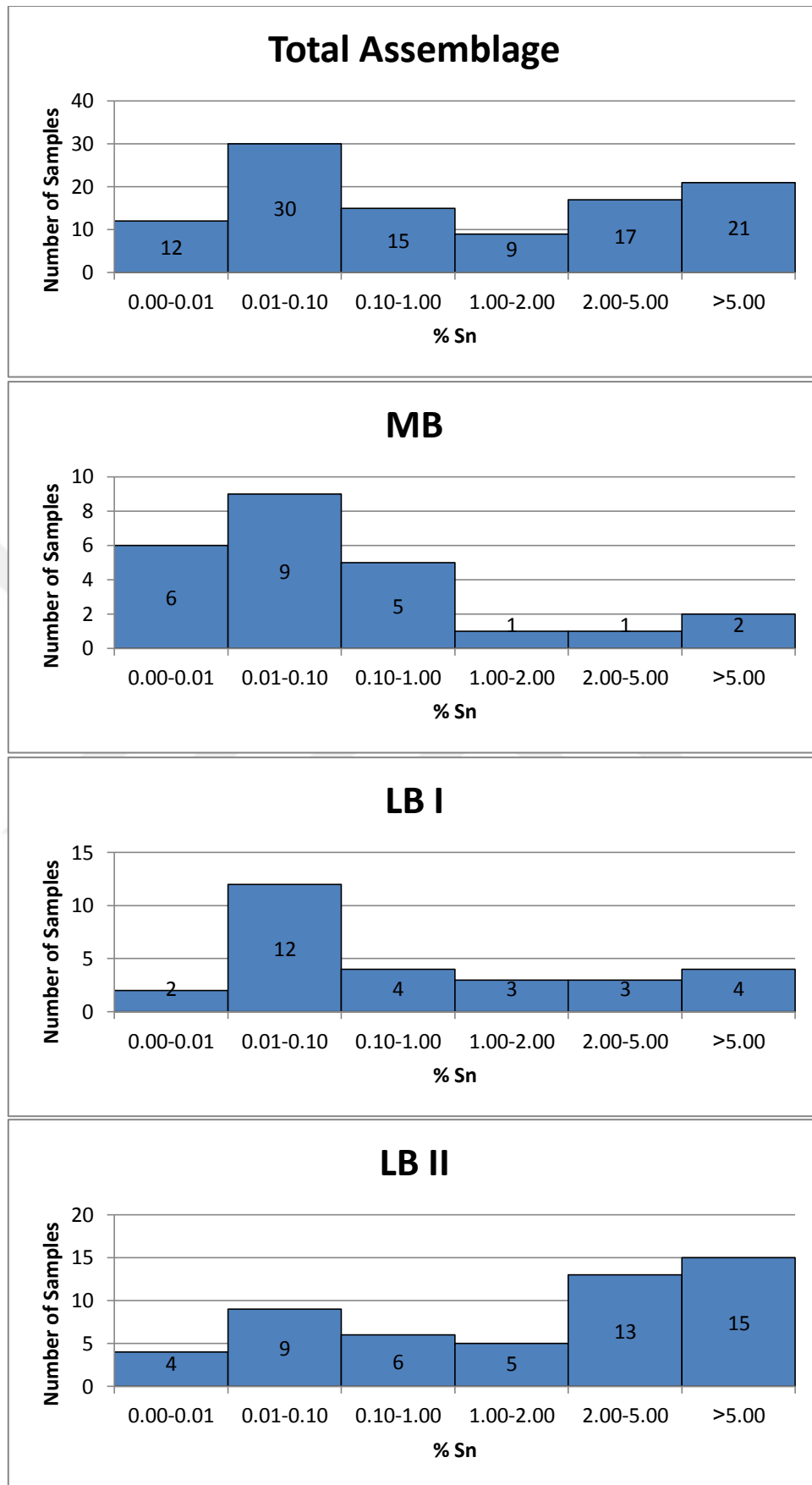


Figure 4.4. Frequency histograms for Sn (periods).

Table 4.2. Statistical summary for Sn concentrations.

	Overall	Unalloyed Copper	Arsenical Copper	Tin-bronze	Overall		Unalloyed Copper		Arsenical Copper		Tin-bronze	
	Median				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Tell Atchana	1.491	0.045	0.099	5.071	0.018	7.661	0.009	1.379	0.099	0.099	2.467	8.307
Tarsus	0.486	0.018	0.043	5.115	0.012	6.163	0.009	1.639	0.014	0.387	3.916	6.700
Kinet	0.060	0.012	0.120	6.232	0.003	6.329	0.003	0.950	0.037	0.508	4.081	10.712
MB	0.041	0.014	0.071	6.232	0.003	1.917	0.002	0.540	0.014	0.783	3.094	7.390
LB I	0.106	0.031	0.079	5.266	0.016	5.335	0.011	1.446	0.025	0.172	3.119	6.680
LB II	2.537	0.046	0.322	5.367	0.012	7.655	0.009	1.506	0.045	0.387	2.655	9.208
Overall	0.525	0.031	0.099	5.381	0.009	6.695	0.005	1.417	0.017	0.448	2.549	8.398

Table 4.3. Statistical summary for Sn concentrations (previous studies).

	Median	Lower Limit	Upper Limit
EB	0.280	0.000	4.470
MB	0.310	0.000	4.750
LB	1.260	0.000	7.800
IA	1.000	0.000	4.925

Kinet shows a lower intensity of tin usage compared to the other two sites. Moreover, an increase in tin usage from the Middle Bronze to the Late Bronze Age I period is not as obvious at Kinet as the other two sites, since only one single tin-bronze item is detected from both periods.

These differences among the sites are ascertained by the frequency histograms (figure 4.5) and the overall median values, which demonstrate a fall-off from Tell Atchana to Tarsus and from Tarsus to Kinet (table 4.2). Tin-bronze objects with relatively high tin contents (above 5 percent) are attested at all three sites. Therefore, the upper limit values in the overall assemblages do not significantly differ between the sites, ranging from 6 to 7.6 percent. Even though Kinet is the site with the least intensity of tin usage, it displays the highest values of median, lower, and upper limit values in the tin-bronze assemblage. This is apparently because the site has the lowest number of tin-bronzes and the two objects with the highest tin concentration.

The comparison between the alloy types demonstrates that the assemblage of arsenical copper objects has a significantly higher median tin concentration than that of pure copper objects in all periods and at all sites. Various explanations can be proposed for this phenomenon. One possible cause could be that unalloyed copper and arsenical copper had different sources with significantly different trace quantities of tin. This possibility will be checked in the next chapter by lead isotope analysis, which will examine whether there are notable isotopic differences between the unalloyed and arsenical copper assemblages. It is also known that minerals of tin and arsenic may co-occur in certain ore bodies of polymetallic character, such as those found at Hisarcık in central Anatolia (Yalçın and Özbal 2009, 119). Thus, when arsenic-bearing ores, which co-occur with tin minerals, are added to molten copper in

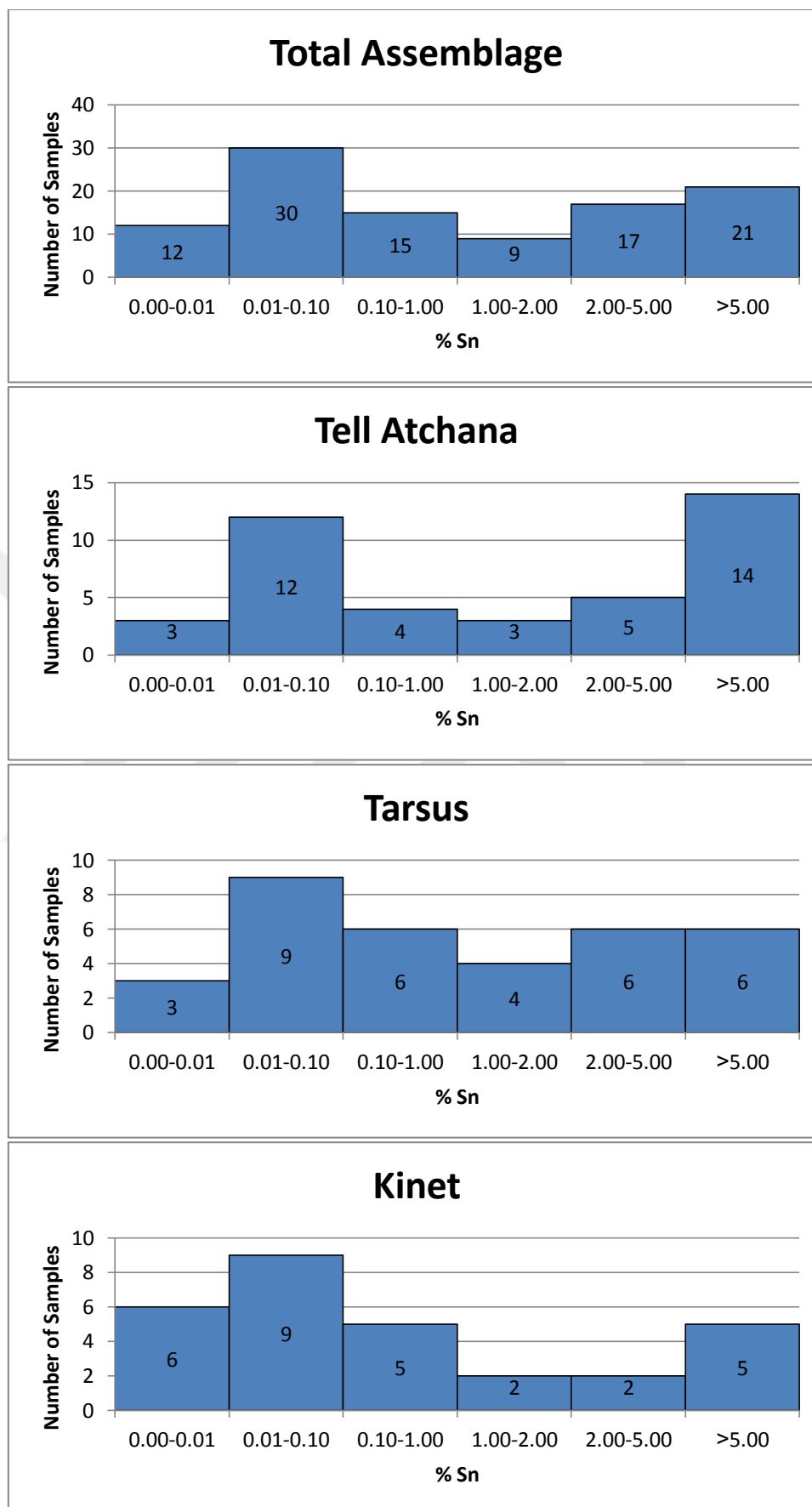


Figure 4.5. Frequency histograms for Sn (sites).

order to produce arsenical copper, the manufactured alloy would be expected to have a relatively high tin content.

If we turn to the comparison between the new data and those obtained in previous studies, it becomes evident that the earlier data also reveals a sharp increase in the median and upper limit concentrations from the Middle Bronze to the Late Bronze Age (table 4.3). In this respect, the new results are in accord with the earlier research. However, more close inspection of the individual time periods reveals certain differences. As discussed above, previous research indicated similar frequencies of tin-bronze utilization in the Early and Middle Bronze Ages. This similarity is visible in the comparable median values obtained for these two periods, computed as 0.280 and 0.310 respectively. These values are, however, considerably higher than the Middle Bronze Age median concentration determined in the current study, which is calculated to be 0.041. This observed discrepancy must be due to the fact that analytical techniques employed in earlier research programs had significantly higher limits of detection compared to icp-mass spectroscopy applied in the current study. Moving on to the later periods, the single median value calculated for the Late Bronze Age in the previous analyses is one order of magnitude higher than the current Late Bronze Age I median, but is about half of the current Late Bronze Age II median. This is apparently the outcome of the fact that earlier data represents the combination of the more tin-using Late Bronze Age II, and the less tin-using Late Bronze Age I periods, contrary to the current study, in which these two periods are treated separately.

As far as the Iron Age is concerned, data from earlier work demonstrate that the consistent use of tin-bronze continued into this period, even though the median and upper limit values are now somewhat lower than those obtained for the Late

Bronze Age. The zero values calculated as the overall lower limits are due to the large number of samples, whose tin contents were below the detection limits of the utilized analytical techniques.

4.2.3. New Results: Arsenic Concentrations and Arsenical Copper

The pattern displayed by the relative abundance of arsenical copper is quite the opposite of what we observed regarding the tin-bronze. This opposition is evident with respect to the criteria of both chronology and geography. Firstly, as opposed to the situation of tin-bronze, arsenical copper becomes progressively less common through the second millennium BC, as its relative abundance drops from the 33 percent of the Middle Bronze Age to 21 percent in the Late Bronze Age I and to 14 percent in the Late Bronze Age II period⁷⁶ (figure 4.2a)⁷⁷. Secondly, Tell Atchana, where we observe the most intensive use of tin-bronze, now appears as the site, where arsenical copper was least frequently employed. Only two of the twenty arsenic-containing objects observed in the overall assemblage belong to this site (figure 4.3). Tarsus, from which eleven of a total of thirty-four samples (32 percent) are determined to be arsenical copper, appears as the most extensive user of this alloy. This is particularly visible in the Middle Bronze Age assemblage, from which the majority of samples (six of a total of eight) are identified as arsenical copper. Kinet also displays good evidence for the use of arsenic, however, not to the same extent as Tarsus, as objects of this alloy comprise 24 percent (seven of total twenty-nine) of the assemblage (figure 4.2b, 4.3).

⁷⁶ The single object of copper-arsenic-tin ternary alloy from the Late Bronze II period is included.

⁷⁷ In this study, arsenic concentrations above 1 percent are considered to indicate intentional alloying.

In general terms, these results are in accord with the previous studies, as they also demonstrated a quite intensive utilization of arsenical copper during the third and early second millennia BC in Cilicia, but not in the Amuq (figure 4.1). However, there is also a notable difference between the earlier data and the new results. The ternary alloy of copper, tin, and arsenic, which was commonly observed in the earlier studies, is represented in the current study only by a single sample. This is a bracelet (sample AT 8626) from Late Bronze Age II Tell Atchana.

The examination of frequency histograms reveals that the vast majority of arsenic concentrations are between 0.1 and 1 percent, with a mode situated in the 0.10-0.50 percent range for all periods (figure 4.6). The objects of arsenical copper have a median arsenic content of 1.46 percent (table 4.4). There are only two objects that are determined to incorporate more than 3 percent arsenic. These are two needles from Middle Bronze Age Tarsus, which have arsenic contents of 3.82 (sample TGK 38.55) and 3.68 (sample TGK 37.813) percent. Thus, the two objects with the highest arsenic contents belong to a period and site where the alloy displayed its most common use.

The progressive decrease in the use of arsenic is clearly observed in histograms and median concentrations, as they demonstrate a shift towards lower values from the Middle Bronze Age thru the Late Bronze Age II period (figure 4.6, table 4.4). Besides, this gradual diminishing in arsenic concentrations is visible at all three sites (figure 4.7). Interestingly, arsenical copper objects display their highest median value in the Late Bronze Age II period, when this alloy was employed least intensively. This is apparently the outcome of the fact that three out of six arsenical copper objects from this period have relatively high arsenic contents that are in excess of 1.8 percent (samples TGK 37.826, TGK 38.1618, TGK 36.935). The ranking of

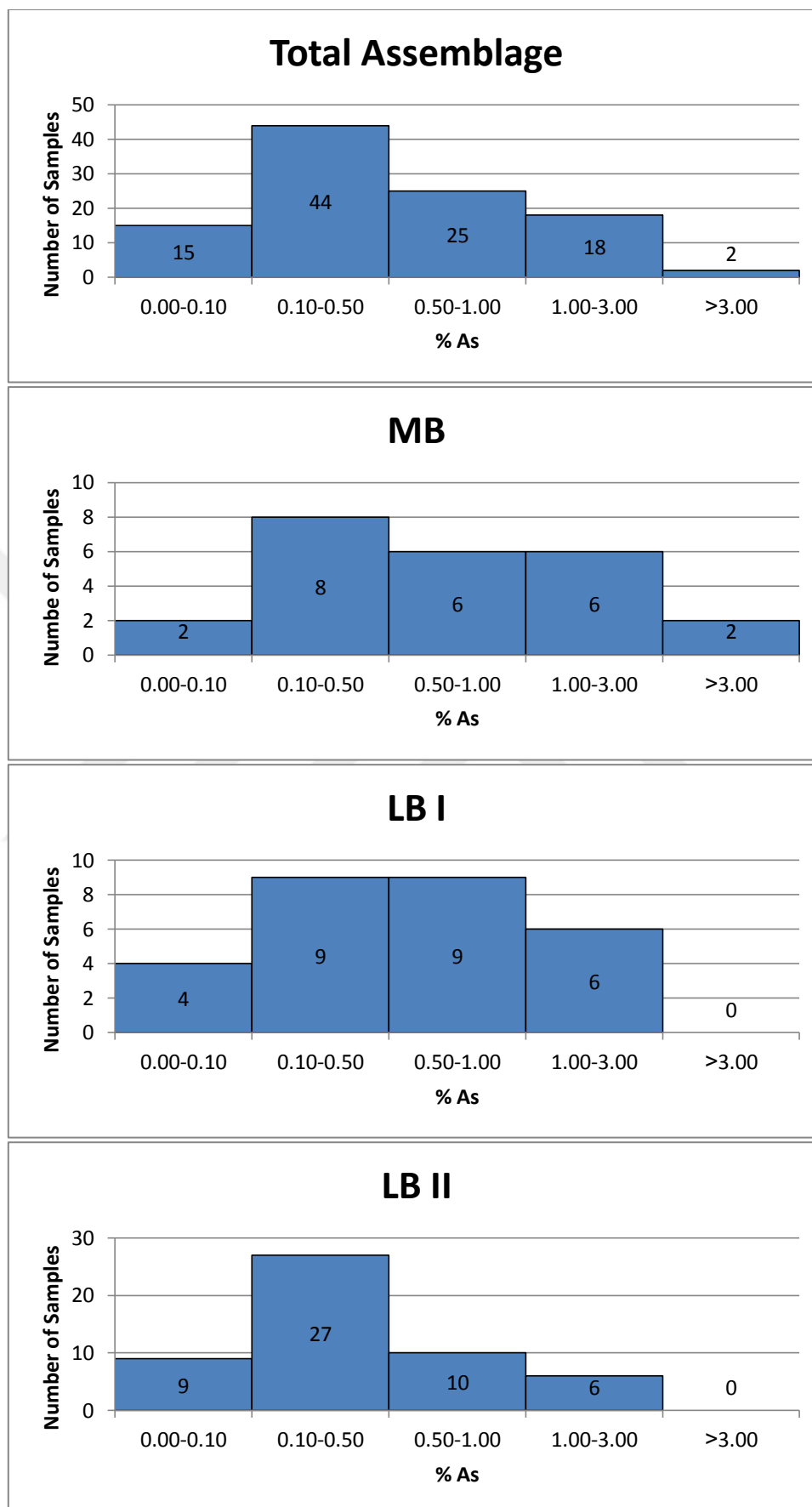


Figure 4.6. Frequency histograms for As (periods).

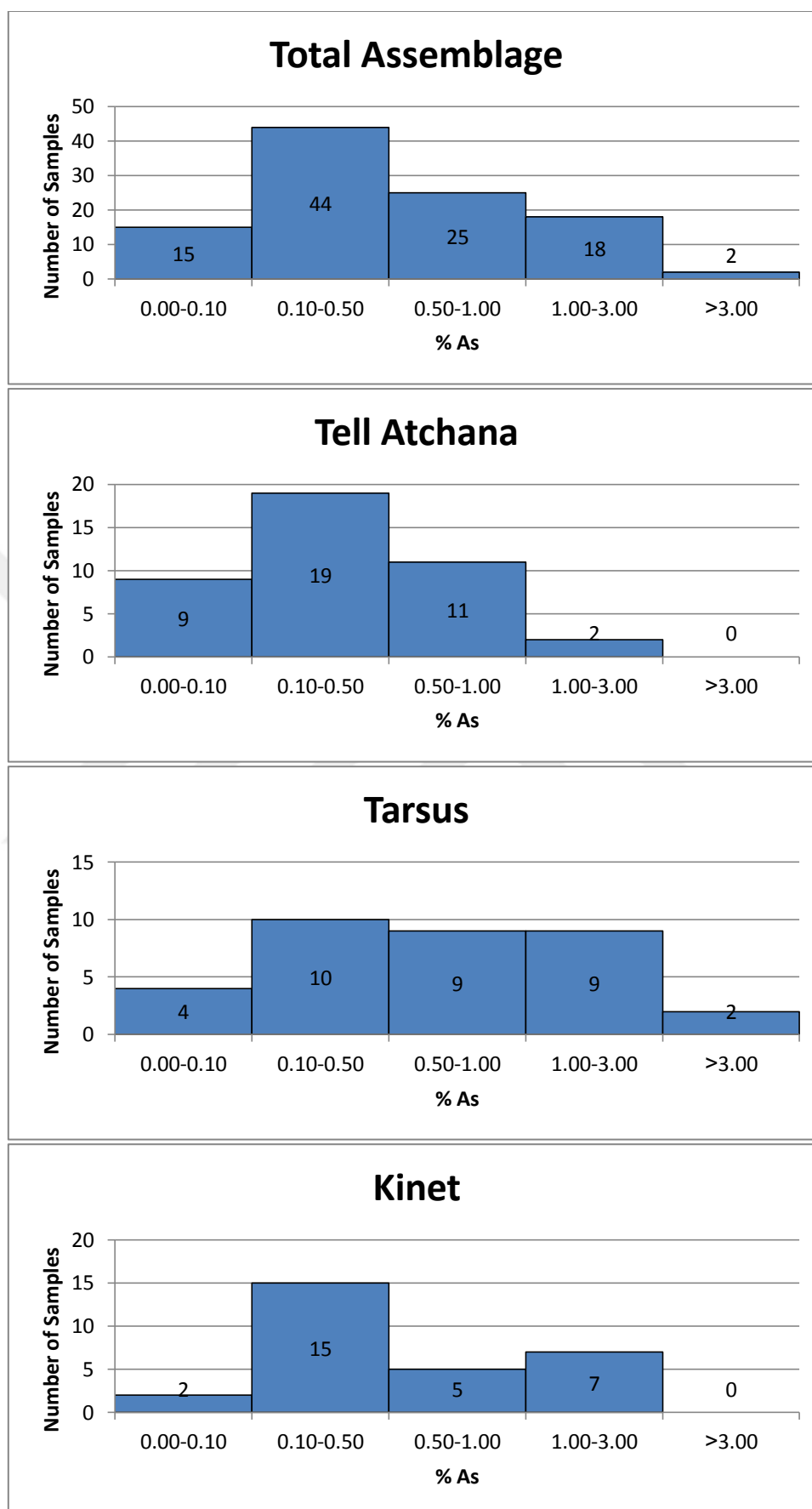


Figure 4.7. Frequency histograms for As (sites).

Table 4.4. Statistical summary for As concentrations.

	Overall	Unalloyed Copper	Arsenical Copper	Tin-bronze	Overall		Unalloyed Copper		Arsenical Copper		Tin-bronze	
	Median				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Tell Atchana	0.314	0.278	1.127	0.456	0.077	0.861	0.076	0.716	1.127	1.127	0.083	0.809
Tarsus	0.662	0.375	1.880	0.472	0.099	2.288	0.066	0.895	1.246	3.678	0.106	0.808
Kinet	0.463	0.367	1.239	0.421	0.119	1.250	0.091	0.666	1.133	1.568	0.216	0.577
MB	0.711	0.353	1.560	0.459	0.127	2.155	0.094	0.841	1.112	3.719	0.424	0.483
LB I	0.594	0.374	1.279	0.662	0.093	1.266	0.271	0.819	1.128	1.812	0.056	0.790
LB II	0.374	0.171	1.880	0.437	0.067	1.128	0.035	0.417	1.211	2.464	0.158	0.762
Overall	0.454	0.309	1.461	0.454	0.084	1.308	0.072	0.801	1.121	2.897	0.091	0.784

Table 4.5. Statistical summary for As concentrations (previous studies).

	Median	Lower Limit	Upper Limit
EB	1.110	0.192	2.010
MB	1.150	0.196	2.204
LB	0.569	0.038	1.645
IA	0.250	0.000	2.608

the three sites in terms of arsenical copper usage is well reflected by the median and upper limit values for the overall and arsenical copper assemblages (table 4.4).

Likewise, frequency histograms reveal that a shift towards higher concentrations is most pronounced at Tarsus, which is followed by Kinet (figure 4.7).

The comparison between the alloy types evidences that tin-bronzes have higher median arsenic concentrations than unalloyed copper objects in all periods and at all sites (table 4.4). This situation is interesting as we also observed higher arsenic concentrations in tin-bronze objects than in the unalloyed copper assemblage. This finding perhaps indicates that unalloyed copper and tin-bronzes might have been made of copper from different origins and distinct trace quantities of arsenic. Lead isotope analysis, to be presented in the next chapter, will examine this possibility. Another explanation could be the introduction of arsenic to the copper from tin, if it contains arsenic. This could be theoretically possible if tin was smelted from a polymetallic ore that also incorporates arsenic minerals, such as the ores from the recently discovered site of Hisarcık in central Anatolia (Yalçın and Özbal 2009, 119). On the other hand, it should also be noted that the principle component and binary correlation analyses have not indicated a significant correlation between tin and arsenic. For the moment, the situation cannot be readily explained.

An inspection of the data from previous research displays that the Early and Middle Bronze Age assemblages are pretty similar in terms of median, lower and upper limit concentrations (table 4.5). These median values are somewhat higher than the Middle Bronze Age median calculated in this study. In the data from previous studies, the median concentration drops to its half after the Middle Bronze Age, which is a comparable value to the Late Bronze Age I median of the current study. The Iron Age data demonstrates that objects with more than 2 percent arsenic continued to be

produced during this period. However, the significantly low median concentration in this period indicates that the overall usage of arsenical copper continued to diminish after the Bronze Age.

4.2.4. Alloy Use and Object Categories

The frequency of the occurrence of different alloys in different object categories is presented in figure 4.8. Four major artifact groups have been determined within the studied assemblage, and these incorporate statistically meaningful numbers of samples. Such rare items as hooks or rods, and such objects of uncertain functions as sheet and plaque fragments are excluded as they could not be grouped under any of these categories. Of the defined categories, the group of pins and needles incorporates the largest number of artifacts and hence forms statistically the most significant group. The artifacts of this category are mostly found to be made of unalloyed copper. However, it is also noticeable that arsenical copper displays its most significant presence in this category.

Blades, chisels, points, and awls are grouped under the category of tools, which are found to be made predominantly of tin-bronze. The hardness and mechanical strength necessary in such objects seems to be the obvious reason for this preference. For the same reason, spearheads and arrowheads are also expected to be made mostly of tin-bronze. However, the results show that unalloyed copper is used in this category to the same extent as tin-bronze. Demonstrating that small weapons such as arrowheads were not necessarily required alloyed copper, our situation is

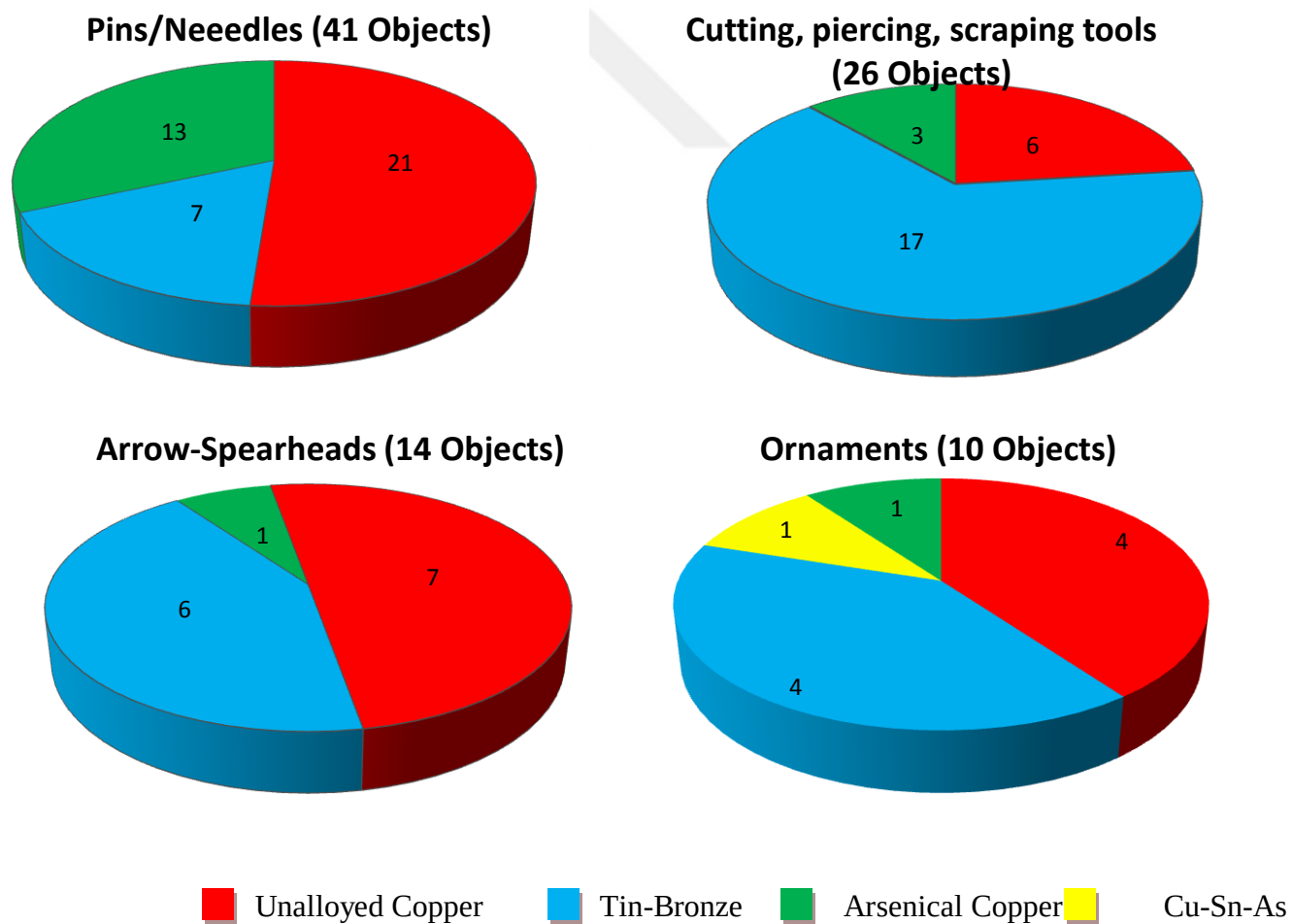


Figure 4.8. Alloy use in different object categories.

to the results of Phillip and colleagues, who found out that in a Late bronze Age hoard from Pella in the Levant arrowheads constitute the only group of artifacts that does not contain tin (Philip, Clogg, and Dungworth 2003, 89-90).

In the manufacture of rings and bracelets, grouped together under the category of ornaments, the surface appearance of the artifact must have played a more important role in the choice of material. However, the results do not indicate a single desired color since the reddish colored unalloyed copper appears to have been preferred to the same extent as the gold-like colored tin-bronze. As observed in the category of tools and weapons, arsenical copper displays a relatively insignificant usage in weapons and ornaments.

4.3. RELATIONSHIP BETWEEN CHEMICAL ELEMENTS

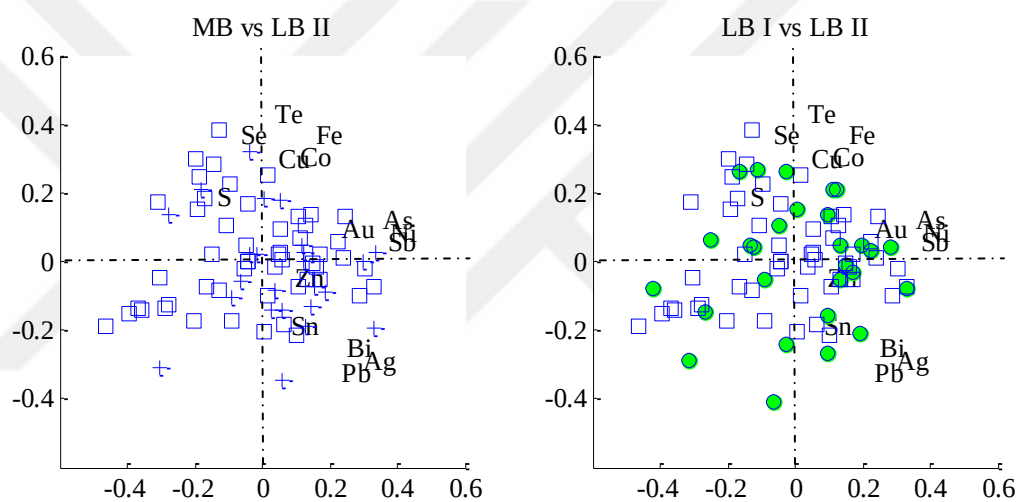
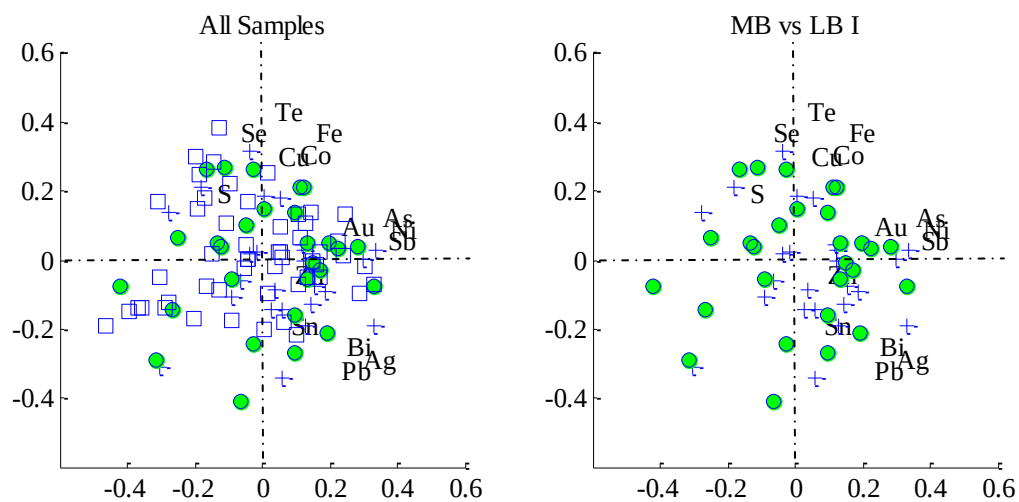
4.3.1. Principal Component Analysis

Principal component analysis is a common and effective method of investigating multivariate associations in a quantitative, multi-dimensional dataset. The analysis simplifies a large, multi-dimensional dataset by means of reducing it to a limited number of components, which encompass a significantly large part of the original data to describe its primary features. By means of graphical representation, the analysis attempts to define the relationships between variables (in our case the concentrations of chemical elements), as well as within and between the subsets of data (in our case the periods, sites and alloy types). In this study, principal component analysis is employed to represent the degree of correlation between individual elements by means of plotting samples and chemical elements on an x-y scatter, the

two axis of which are represented by the first two principal components (PC1 and PC2 henceforth). The relative proximity of two elements on this plot provides a measure for the degree of correlation between them. MATLAB version 7.11.0584 was employed to define the principal components and subsequently to generate the plots. A standard correlation principle component analysis is used as many researchers in the field consider it as the most effective means of describing multivariate data (Tangri and Wright 1993, Magee et al. 1998, 239; Weeks 2003, 99). In order to avoid potential inconsistencies caused by the non-linear correlations within the data, the data of element concentrations are converted to rank order.

General Patterns

The rank-ordered data of element concentrations appeared to be somewhat, but not highly structured as the first two principal components account for about 40 percent of the total variation. The scatter plots (figure 4.9-4.11) clearly demonstrate three clusters, into which a number of chemical elements can be grouped: Arsenic, antimony and nickel constitute one such cluster, with which gold also appears to be somewhat associated. Another group consists of silver, lead, and bismuth, from which tin is not largely separated. Finally, there is the cluster formed by copper, iron, and cobalt.



x-axis: PC1

y-axis: PC2

+ : Middle Bronze Age

● : Late Bronze Age I

□ : Late Bronze Age II

Figure 4.9. Object distribution with respect to PC1 and PC2 (periods).

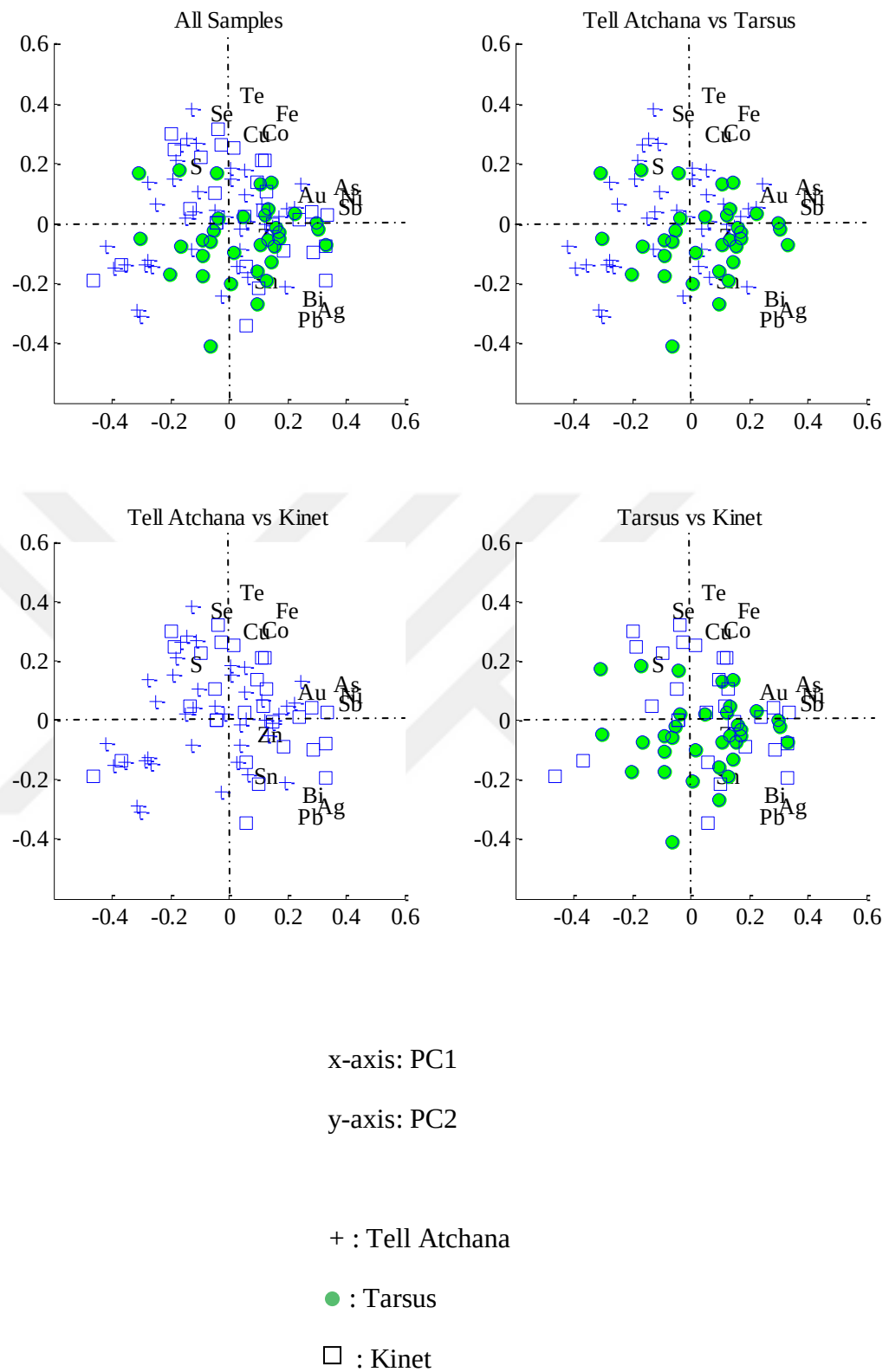
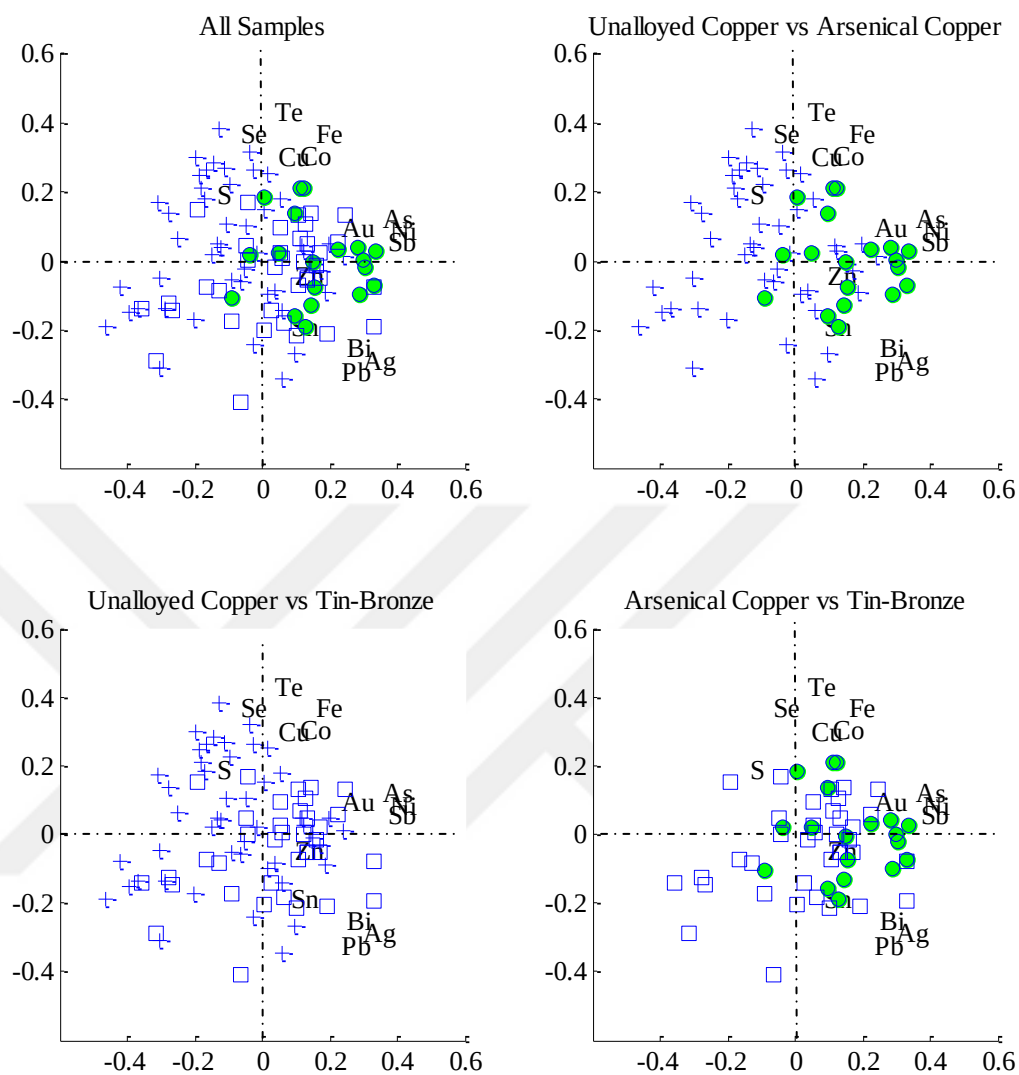


Figure 4.10. Object distribution with respect to PC1 and PC2 (sites).



x-axis: PC1

y-axis: PC2

+ : Unalloyed copper

● : Arsenical Copper

□ : Tin-Bronze

Figure 4.11. Object distribution with respect to PC1 and PC2 (alloy types).

Comparison Between Time Periods

The individual scattergrams for the three periods reveal that the Middle Bronze Age assemblage somewhat deviates from those of the later periods (figure 4.9). In this period, the majority of samples (fifteen of a total of twenty-four) are located in the right half of the plot area, where the PC 1 values are positive. In contrast, in both phases of the Late Bronze Age, the samples are more evenly distributed in the two halves of the plot area. The leftmost sector of the scattergram (where the PC1 values are smaller than -0.2) is almost entirely occupied by the Late Bronze Age I and Late Bronze Age II samples and devoid of those from the Middle Bronze Age. Such a distribution pattern is likely conditioned by the positioning of the element arsenic with respect to the two axes. Thus, it is in the Middle Bronze Age, when a significant number of samples have high arsenic contents, the distribution of samples displays a more prominent shift towards the right edge of the scattergram, close to this element.

Comparison between Sites

The scattergrams generated for individual sites demonstrate that Tell Atchana somewhat differs from the other two sites (figure 4.10). More than half of the samples from both Tarsus (twenty-one of a total of thirty-four) and Kinet (eighteen of a total of twenty-nine) are found in the right half of the scattergram, where the PC1 values are positive. Tell Atchana samples, on the other hand, are very evenly distributed, with twenty-one and twenty samples respectively situated in the left and right halves of the plot area. Furthermore, of the twelve samples found in the rightmost zone,

where the PC1 value is greater than 0.2, only two are from Tell Atchana. Thus, the Tell Atchana assemblage displays a more prominent shift towards the left sector of the chart. Once again, the different intensities of arsenical-copper usage may account for this pattern. It appears that Tell Atchana, which made use of this alloy least extensively, has more samples that are set apart from the element arsenic in the plot area.

The second major pattern is that those objects situated in proximity of the Cu-Fe-Co group are exclusively from Tell Atchana and Kinet. There is no single object from Tarsus found in the top section of the scattergram, where the PC2 values are higher than 0.2. This phenomenon cannot be readily explained by the differences between the sites with respect to the relative abundances of tin-bronze or arsenical copper. Rather, this situation may tentatively indicate that Tarsus might have used different sources of copper than those supplied the other two sites. This possibility will be tested by the lead isotope analysis presented in the next chapter.

Comparison between Alloy Types

The immediate feature to be noticed from the scattergrams is the relatively tight clustering of arsenical copper objects in contrast to the unalloyed copper and tin-bronze items that display a widely dispersed distribution pattern (figure 4.11). This tight concentration observed in the arsenical copper assemblage possibly points to the geochemical homogeneity of copper, out of which this alloy was produced. This relatively high degree of homogeneity tentatively implicates that arsenical copper was predominantly made of copper from a single source area. In contrast, the geochemical heterogeneity observed in the unalloyed copper and tin-bronze assemblages indicates

that they were produced of copper from relatively diverse source areas. Lead isotope analysis is expected to shed light on this issue in the next chapter.

4.3.2. Bivariate Correlation Analysis

The bivariate relationships between individual chemical elements are determined so as to further investigate the compositional variability between assemblages. To examine this, correlation analysis is employed, which expresses the relationship of each element with every other element as numerical coefficients. In this study, Microsoft Excel is used to compute these coefficients that have values between -1 and +1, which respectively express perfect negative and perfect positive correlations. Hence, the hypothetical correlation coefficient of a chemical element with itself would yield the value +1. Due to non-linear character of the data, the calculation of correlation coefficients directly on element concentrations would be inaccurate to express bivariate relationships. Therefore, the coefficients are calculated on ranked values by the conversion of the concentration data to ranked order. This conversion also allowed a more convenient comparison with the outcome of the principal component analysis, which was similarly based on rank-ordered data.

General Patterns

The correlation coefficients for each element pair are presented in tables 4.6-4.9, which displays that the majority of them are in the -0.2-0.3 range. The highest ten coefficients, and thus, the ten most significant correlations are displayed by the following element pairs (shown bold in table 4.26): As-Sb (0.70), Ni-Sb (0.57), Ni-Au

(0.56), As-Fe (0.55), As-Ni (0.53), As-Ag (0.50), Pb-Ag (0.50), and Pb-Bi (0.50), Ag-Bi (0.47), and Co-Te (0.46).

The strong positive correlations between arsenic, antimony, and nickel were already pointed out by the principal component analysis. Likewise, the principal component analysis clearly indicated the strong relationship between lead, silver, and bismuth. As for gold, it was tentatively implied to be moderately related to the arsenic-nickel-antimony group in the principal component analysis. This element, however, is now demonstrated to have a strong correlation with nickel only.

Accordingly, the binary correlation analysis is in good agreement with the principal component analysis in general terms. However, it is worth noting that the significant correlation between copper, iron, and cobalt, which was observed in the principal component analysis, is not verified by the binary correlation coefficients. Conversely, the strong correlations of arsenic with iron and silver that are demonstrated by the correlation analysis were not apparent in the principal component analysis.

The most notable negative correlations are detected for the element pairs Ag-Te (-0.37), Sn-Fe (-0.31), Cu-Sn (-0.28), Se-Sn (-0.22), Se-Bi (-0.21), and S-Bi (-0.21). All of these pairs display very low degrees of relationship in all periods and at all sites. At least in the case of the Cu-Sn pair, the significant negative correlation has an explanation. As a major alloying component, tin would replace some part of copper when the two metals are mixed. Hence, tin-bronze objects would normally bear a lower weight percentage of copper than those made of unalloyed copper. The correlation between tin and arsenic also displayed a negative coefficient (-0.09). As discussed in Section 4.2.2, of the more than one hundred specimens investigated in this study, only one item could be classified as a ternary alloy that contains both elements. This evidence indicates a tendency to alloy copper with either tin or arsenic,

Table 4.6. Element correlations (overall assemblage).

Cu	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	
1	-0.28	0.31	0.02	0.14	0.11	0.08	-0.08	0.12	0.22	-0.06	0.29	0.32	-0.08	-0.19	Cu
	1	-0.09	0.31	0.22	0.13	0.05	0.23	0.07	-0.31	0.20	0.06	-0.22	0.23	0.04	Sn
		1	0.53	0.05	0.70	0.01	0.27	0.50	0.55	0.17	0.05	0.06	0.19	-0.19	As
			1	0.43	0.57	0.06	0.22	0.35	0.23	0.21	0.22	-0.13	0.56	-0.13	Ni
				1	0.06	0.22	-0.04	-0.16	0.24	0.04	0.46	0.01	0.29	0.16	Co
					1	-0.01	0.28	0.38	0.33	0.29	0.08	0.05	0.38	-0.10	Sb
						1	0.37	0.35	0.09	0.23	-0.01	0.17	-0.01	0.16	Zn
							1	0.50	-0.07	0.50	-0.18	-0.16	0.04	-0.12	Pb
								1	0.06	0.47	-0.37	-0.16	0.13	-0.19	Ag
									1	-0.02	0.22	0.22	0.10	0.18	Fe
										1	0.05	-0.21	0.25	-0.21	Bi
											1	0.26	0.29	0.10	Te
												1	-0.09	0.22	Se
													1	0.03	Au
														1	S

Table 4.7. Element correlations (periods).

Cu	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	
1	-0.06	0.46	-0.35	-0.10	-0.30	-0.27	-0.23	0.05	0.41	-0.30	-0.04	0.42	-0.26	-0.06	Cu
	1	0.01	0.17	0.12	-0.05	0.28	0.31	0.24	-0.17	0.31	0.10	-0.15	0.21	-0.26	Sn
		1	0.18	-0.04	0.20	-0.60	-0.05	0.32	0.66	-0.09	-0.17	-0.17	-0.17	0.27	As
			1	0.57	0.47	-0.08	-0.02	0.09	0.13	0.35	0.46	-0.52	0.64	0.23	Ni
				1	0.05	0.13	-0.15	-0.21	0.11	0.12	0.53	-0.20	0.33	0.04	Co
					1	-0.14	0.11	0.18	0.18	0.51	-0.01	-0.18	0.41	0.36	Sb
MB						1	0.54	0.22	-0.55	0.41	-0.02	-0.08	0.17	-0.03	Zn
							1	0.28	-0.36	0.53	-0.24	-0.31	0.13	0.13	Pb
								1	-0.14	0.24	-0.40	-0.15	-0.03	0.35	Ag
									1	-0.09	0.22	-0.11	0.00	0.05	Fe
										1	0.16	-0.55	0.60	0.04	Bi
											1	-0.16	0.63	-0.13	Te
												1	-0.29	0.09	Se
													1	0.13	Au
														1	S

Cu	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	
1	-0.34	0.26	0.12	0.26	0.37	0.08	0.08	0.10	0.18	-0.04	0.32	0.29	0.08	-0.07	Cu
	1	0.06	0.23	0.17	0.04	0.21	0.43	0.39	-0.29	0.40	-0.22	-0.32	0.07	-0.07	Sn
		1	0.76	-0.03	0.86	0.33	0.12	0.49	0.61	-0.09	-0.14	0.29	0.57	0.05	As
			1	0.27	0.65	0.09	0.01	0.34	0.54	-0.05	0.05	0.20	0.71	0.11	Ni
				1	0.00	0.11	-0.24	-0.19	0.09	0.01	0.31	-0.10	0.28	-0.08	Co
					1	0.12	0.07	0.33	0.41	-0.07	0.08	0.41	0.46	-0.04	Sb
LB I						1	0.36	0.53	0.05	0.39	-0.25	-0.05	0.14	0.22	Zn
							1	0.53	-0.29	0.51	-0.22	-0.33	-0.26	-0.02	Pb
								1	-0.06	0.51	-0.54	-0.29	0.11	-0.20	Ag
									1	-0.27	0.26	0.33	0.57	0.29	Fe
										1	-0.14	-0.43	-0.09	-0.12	Bi
											1	0.49	0.12	0.19	Te
												1	0.28	0.14	Se
													1	0.09	Au
														1	S

Cu	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	
1	-0.22	0.16	0.05	0.25	0.01	0.14	-0.26	0.02	0.07	-0.11	0.50	0.32	-0.03	-0.17	Cu
	1	0.06	0.43	0.13	0.32	-0.10	0.20	0.12	-0.28	0.37	0.03	-0.08	0.23	-0.13	Sn
		1	0.57	0.28	0.84	-0.04	0.42	0.41	0.43	0.38	0.26	-0.04	0.30	-0.16	As
			1	0.54	0.51	0.04	0.51	0.46	0.04	0.47	0.16	-0.26	0.48	-0.34	Ni
				1	0.14	0.29	0.21	-0.01	0.37	0.28	0.47	0.13	0.30	0.14	Co
					1	-0.23	0.37	0.41	0.31	0.45	0.11	-0.17	0.46	-0.18	Sb
LB II						1	0.31	0.23	0.20	-0.05	0.05	0.44	-0.28	0.07	Zn
							1	0.56	0.09	0.42	-0.10	0.08	0.29	-0.07	Pb
								1	-0.01	0.42	-0.22	-0.16	0.29	-0.27	Ag
									1	0.01	0.22	0.24	-0.14	0.35	Fe
										1	0.17	-0.03	0.48	-0.10	Bi
											1	0.28	0.12	0.07	Te
												1	-0.33	0.17	Se
													1	-0.09	Au
														1	S

Table 4.8. Element correlations (sites).

Cu	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	
1	-0.32	0.48	0.20	0.45	0.35	0.43	-0.10	0.07	0.56	0.16	0.54	0.58	0.10	-0.10	Cu
	1	0.18	0.48	0.09	0.35	0.01	0.40	0.34	-0.25	0.18	-0.18	-0.37	0.31	0.07	Sn
		1	0.72	0.40	0.76	0.26	0.24	0.48	0.55	0.20	0.39	0.12	0.16	-0.36	As
			1	0.48	0.64	0.26	0.31	0.60	0.20	0.35	0.22	-0.10	0.43	-0.25	Ni
				1	0.19	0.33	-0.07	0.05	0.48	0.04	0.52	0.29	0.26	-0.04	Co
					1	0.19	0.31	0.52	0.33	0.26	0.21	0.16	0.38	-0.10	Sb
Tell Atchana						1	0.43	0.49	0.41	0.19	0.32	0.40	0.14	0.08	Zn
							1	0.34	-0.10	0.38	-0.05	-0.02	0.06	-0.11	Pb
								1	0.08	0.44	-0.14	-0.06	0.22	-0.11	Ag
									1	-0.14	0.53	0.43	-0.05	0.13	Fe
										1	0.14	0.19	0.12	-0.18	Bi
											1	0.54	0.09	-0.02	Te
												1	0.06	0.05	Se
													1	0.14	Au
														1	S
Cu	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	
1	-0.42	0.12	-0.13	-0.11	-0.03	-0.52	-0.33	0.14	-0.14	-0.52	0.00	0.04	-0.27	-0.56	Cu
	1	-0.36	0.49	0.50	-0.08	0.15	0.12	-0.30	-0.41	0.20	0.41	0.08	0.44	0.15	Sn
		1	0.19	-0.10	0.77	-0.30	0.14	0.41	0.63	0.18	-0.23	-0.13	-0.03	-0.17	As
			1	0.73	0.37	-0.08	-0.01	-0.20	0.09	0.24	0.50	-0.28	0.60	-0.12	Ni
				1	0.08	0.00	0.00	-0.44	-0.04	0.05	0.67	0.13	0.57	0.04	Co
					1	-0.32	0.08	0.06	0.44	0.31	0.04	-0.10	0.21	-0.19	Sb
Tarsus						1	0.27	-0.06	0.03	0.21	-0.01	0.04	0.11	0.52	Zn
							1	0.30	0.09	0.27	-0.10	0.02	-0.06	0.26	Pb
								1	0.13	0.21	-0.65	-0.34	-0.17	-0.17	Ag
									1	0.33	-0.13	-0.04	-0.08	0.10	Fe
										1	0.03	-0.32	0.44	-0.05	Bi
											1	0.11	0.51	-0.03	Te
												1	-0.21	0.30	Se
													1	-0.11	Au
														1	S
Cu	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	
1	-0.10	0.33	0.02	0.03	0.00	0.05	0.06	0.14	0.19	0.20	0.54	0.29	0.09	0.10	Cu
	1	0.12	0.10	0.06	0.26	-0.08	0.22	0.15	-0.12	0.22	0.07	-0.29	0.34	-0.07	Sn
		1	0.65	-0.08	0.62	-0.23	0.26	0.50	0.55	0.03	0.07	0.28	0.64	0.04	As
			1	0.22	0.59	-0.25	0.21	0.36	0.53	-0.12	-0.07	0.00	0.62	0.15	Ni
				1	-0.02	0.30	-0.03	-0.13	0.30	0.04	0.27	-0.25	0.26	0.48	Co
Kinet					1	-0.01	0.44	0.62	0.27	0.23	-0.17	0.14	0.40	0.11	Sb
						1	0.30	0.30	-0.10	0.38	-0.02	0.02	-0.05	0.03	Zn
							1	0.76	-0.19	0.79	-0.15	-0.45	0.44	-0.33	Pb
								1	-0.08	0.63	-0.15	-0.13	0.55	-0.25	Ag
									1	-0.40	0.21	0.28	0.42	0.31	Fe
										1	0.12	-0.46	0.30	-0.39	Bi
											1	0.03	0.17	0.34	Te
												1	-0.28	0.30	Se
													1	-0.11	Au
														1	S

Table 4.9. Element correlations (alloy types).

Cu	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	
1	-0.19	0.26	0.11	0.37	0.08	0.21	-0.09	0.05	0.25	0.00	0.41	0.38	0.01	-0.09	Cu
	1	-0.23	0.02	-0.05	-0.18	0.09	0.09	0.17	-0.22	0.11	-0.26	-0.29	0.20	0.13	Sn
		1	0.50	0.22	0.59	0.00	0.26	0.34	0.59	0.26	0.23	0.08	0.15	0.00	As
			1	0.38	0.53	0.07	0.28	0.57	0.26	0.31	0.01	-0.24	0.51	-0.01	Ni
				1	0.12	0.10	-0.17	-0.11	0.49	0.03	0.42	0.12	0.29	0.30	Co
					1	0.02	0.26	0.40	0.33	0.41	0.02	0.09	0.32	0.01	Sb
Unalloyed Copper						1	0.39	0.36	0.09	0.35	-0.03	0.32	0.00	0.17	Zn
							1	0.51	-0.02	0.53	-0.31	-0.20	0.00	-0.23	Pb
								1	0.06	0.45	-0.31	-0.20	0.21	-0.03	Ag
									1	0.09	0.39	0.38	0.07	0.34	Fe
										1	0.15	-0.01	0.17	-0.16	Bi
											1	0.31	0.24	0.17	Te
												1	-0.13	0.25	Se
													1	0.16	Au
														1	S

Cu	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	
1	-0.19	0.20	-0.29	-0.27	0.16	-0.24	0.46	0.52	-0.47	0.16	-0.26	-0.08	-0.28	-0.07	Cu
	1	-0.15	0.55	0.55	-0.08	0.21	-0.06	-0.09	-0.16	0.42	0.46	-0.26	0.61	-0.26	Sn
		1	-0.23	-0.14	0.05	0.16	0.32	0.19	0.43	0.20	-0.47	-0.30	-0.31	-0.10	As
			1	0.42	0.20	-0.15	-0.39	-0.58	0.07	0.03	0.71	-0.09	0.55	-0.16	Ni
				1	-0.48	0.24	-0.15	-0.08	0.09	0.24	0.37	-0.50	0.42	-0.41	Co
					1	-0.24	0.13	-0.15	-0.14	0.19	0.15	0.01	0.15	0.06	Sb
Arsenical Copper						1	0.22	0.22	0.38	-0.09	-0.32	-0.13	0.07	0.19	Zn
							1	0.61	-0.29	0.19	-0.33	-0.15	-0.29	0.00	Pb
								1	-0.38	0.06	-0.55	-0.12	-0.41	-0.05	Ag
									1	-0.20	-0.19	-0.04	-0.01	-0.04	Fe
										1	0.25	-0.55	0.44	-0.54	Bi
											1	0.11	0.68	-0.04	Te
												1	0.05	0.58	Se
													1	-0.07	Au
														1	S

Cu	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	
1	0.03	0.47	0.27	0.19	0.30	0.09	-0.21	-0.02	0.20	-0.27	0.55	0.42	0.08	-0.31	Cu
	1	0.12	0.19	0.44	0.48	0.03	0.26	0.07	0.15	0.20	0.44	0.42	0.27	-0.14	Sn
		1	0.61	0.43	0.73	0.23	0.21	0.37	0.48	0.06	0.42	0.14	0.22	-0.16	As
			1	0.54	0.47	0.33	0.30	0.32	0.22	0.07	0.42	0.15	0.34	-0.31	Ni
				1	0.46	0.37	0.29	0.07	0.29	0.01	0.55	0.38	0.34	0.08	Co
					1	0.10	0.20	0.18	0.43	0.05	0.50	0.18	0.42	-0.11	Sb
Tin-Bronze						1	0.44	0.61	0.08	0.26	0.11	0.16	0.03	0.06	Zn
							1	0.41	0.02	0.46	0.12	0.06	0.13	0.18	Pb
								1	-0.07	0.62	-0.22	-0.02	0.13	-0.19	Ag
									1	-0.14	0.40	-0.15	0.17	0.26	Fe
										1	-0.29	-0.03	0.11	-0.07	Bi
											1	0.39	0.20	-0.14	Te
												1	0.06	-0.05	Se
													1	-0.05	Au
														1	S

but very scarcely with both metals. Hence, the negative correlation between these two major alloying elements is likely to be the result of this trend.

Significant Correlations

The close examination of significant correlations demonstrates the following patterns. The Ni-Sb, Ni-Au, As-Fe, As-Ag, Pb-Bi, and Co-Te pairs display significant correlations in all periods (table 4.7). The most notable differences between periods are attested in the As-Sb, As-Ni, and Pb-Ag pairs, as these yield high coefficients only in the Late Bronze Age. The As-Sb correlation, which is the most significant relationship overall, is not observed in the Middle Bronze Age. In this period, this correlation is expressed by the coefficient of 0.20, in contrast to the high values of 0.86 and 0.84 obtained respectively for the Late Bronze Age I and the Late Bronze Age II periods. Similarly, the As-Ni coefficient is very low (0.18) in the Middle Bronze Age assemblage, in contrast to high values displayed by the Late Bronze Age I (0.76) and Late Bronze Age II (0.57) assemblages. Finally, the Pb-Ag coefficient of the Middle Bronze Age assemblage is about half of those from the two Late Bronze Age assemblages.

If we turn to the comparison between sites, we observe that the As-Sb, Ni-Au, As-Fe, and As-Ag correlations are strong at all three sites (table 4.8). However, the Tarsus assemblage significantly deviates from the other two for its noticeably low coefficient (0.19) for the As-Ni correlation, which is less than 30 percent of the values obtained for the other two sites. Likewise, the Ni-Sb relationship, which appears quite strong at Tell Atchana and Kinet (0.64 and 0.59 respectively), is only moderately high at Tarsus (0.37). Another notable observation is the situation of the Pb-Ag and Pb-Bi

correlations, which appear significant only at Kinet. For both pairs, the Kinet coefficients are more than two times greater than those of the Tell Atchana and Tarsus assemblages. In contrast, Kinet is the only site, where the Co-Te relationship appears insignificant.

With regard to alloys, only three pairs, Ni-Au, As-Fe, As-Pb, and Co-Te display a high degree of correlation in all alloy types (table 4.9). In contrast, the As-Sb, As-Ni, Ni-Sb, As-Ag, and Pb-Bi relationships are high only in the unalloyed copper and tin-bronze assemblages. The arsenical copper assemblage yielded significantly low coefficients for all these pairs, which can be as low as 0.05 as in the case of As-Sb, or -0.23 as in the case of As-Ni correlations.

4.4. OTHER SIGNIFICANT ELEMENTS

The situation of the elements Ni, Sb, Zn, Pb, Fe, Ag, and Bi deserve further discussion as they are either present in some samples in considerably high concentrations or because they displayed notable features in the principal component and bi-variate correlation analyses.

4.4.1. Nickel (Ni)

The frequency histograms demonstrate that the majority of samples have nickel concentrations in the 0.01-0.05 percent range in all periods and at all sites (figure 4.12, 4.13), with the overall median concentration of 0.031 percent (table 4.10). There are three samples with nickel contents above 1 percent. As discussed in Chapter 3, nickel is an element that is occasionally found in high concentrations in

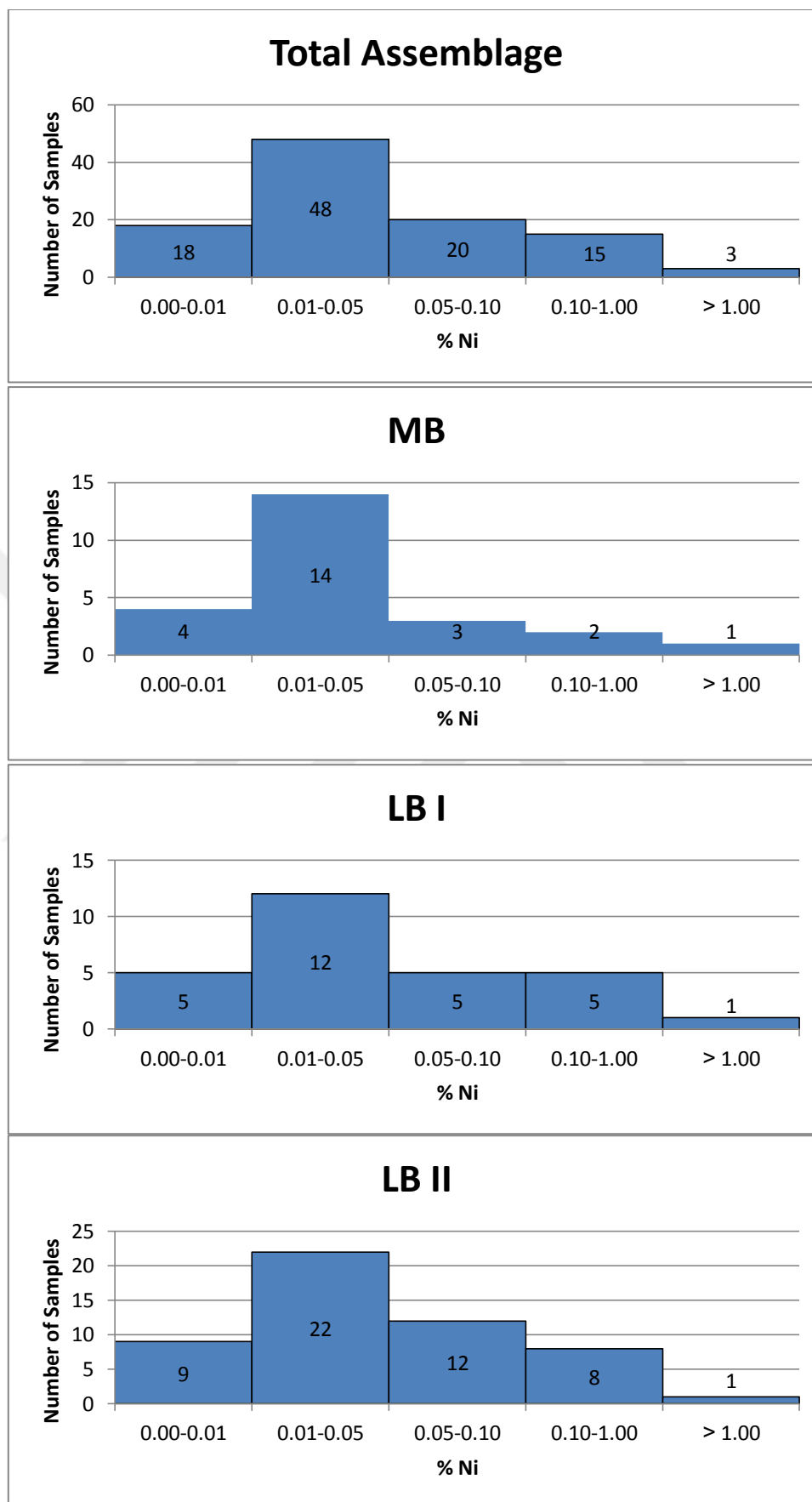


Figure 4.12. Frequency histograms for Ni (periods).

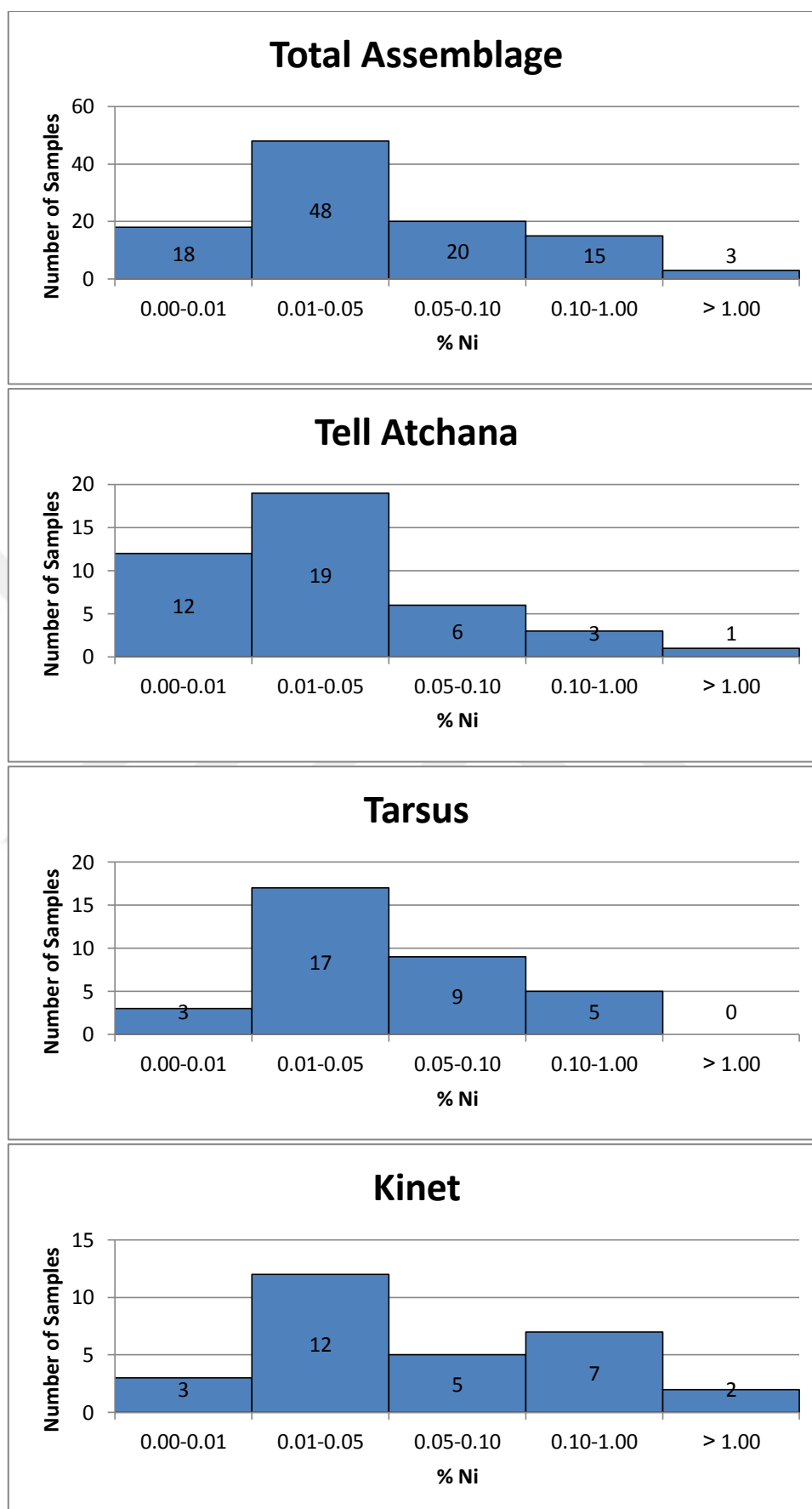


Figure 4.13. Frequency histograms for Ni (sites).

Table 4.10. Statistical summary for Ni concentrations.

	Overall	Unalloyed Copper	Arsenical Copper	Tin-bronze	Overall		Unalloyed Copper		Arsenical Copper		Tin-bronze	
	Median				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Tell Atchana	0.023	0.015	7.711	0.040	0.006	0.092	0.004	0.047	7.711	7.711	0.009	0.121
Tarsus	0.032	0.026	0.031	0.080	0.011	0.144	0.009	0.035	0.014	0.154	0.012	0.147
Kinet	0.050	0.031	0.186	0.068	0.010	0.302	0.006	3.009	0.036	0.323	0.032	0.129
MB	0.031	0.026	0.041	0.048	0.007	0.125	0.007	0.048	0.011	2.443	0.029	0.074
LB I	0.026	0.022	0.201	0.060	0.008	0.257	0.009	0.080	0.031	0.333	0.006	0.111
LB II	0.032	0.011	0.060	0.054	0.009	0.166	0.004	0.072	0.017	0.159	0.014	0.158
Overall	0.031	0.019	0.060	0.054	0.008	0.181	0.006	0.074	0.014	0.302	0.011	0.158

Table 4.11. Statistical summaries for Ni concentrations (previous studies).

	Median	Lower Limit	Upper Limit
EB	0.100	0.020	0.610
MB	0.040	0.020	0.160
LB	0.047	0.013	0.456
IA	0.040	0.014	0.080

copper artifacts from the Bronze Age. In most cases, but not necessarily, high contents of nickel are attested in copper objects that also have significant arsenic concentrations. High concentrations of nickel were also detected in previous research from the study region. The earliest of these items is a pin with 1.05 percent nickel from early fifth millennium BC Mersin (Yalçın 2000, table 3, sample MY 1589). In the Amuq, three of the six chisels studied from the fourth and third millennium BC contexts contain between 1.20 and 2.73 percent nickel. (Braidwood, Burke, and Nachtrieb 1951, table 3). Two of these items also contain more than 1 percent arsenic, and should thus, be considered as ternary alloys.

Studies of material from the later third and second millennium BC contexts of Cilicia determined nine samples from Mersin and seven from Tarsus to have nickel contents above 1 percent (Esin 1969, Kuruçayırılı and Özbal 2005, table 4). Nine of these sixteen artifacts also have high arsenic contents. Among these examples, four bracelets from Late Bronze Age I Mersin constitute a noticeable group, perhaps implying that high nickel copper was preferred in this particular object category. Two of these bracelets also incorporate high arsenic contents. The highest nickel concentration, which was determined as 8.15 percent, was observed in a small open band, possibly a ring, from Late Bronze Age II Tarsus (Kuruçayırılı and Özbal 2005, sample 37.856). Also from the same site and period, is a pin with nearly 3 percent nickel.

The current study identified three samples with notably high nickel contents. The highest concentration is 15.04 percent, which is attested in sample KNH 1073 from Late Bronze Age I Kinet. This artifact, which consists of two curved, pin-like fragments, is tentatively defined by the excavators as a possible bracelet. The other objects are a small hook-shaped item from Middle Bronze Age Tell Atchana (sample

JH 223, tentatively defined as a fishhook), and a pin from Late Bronze Age II Kinet (sample KT 23630), with respective nickel contents of 7.71 and 4.88 percent. The hook from Tell Atchana also has an arsenic content above 1 percent and is thus, considered a ternary alloy.

In summary, eleven of the twenty high nickel copper objects from the earlier studies and two of a total of three in this study have high arsenic concentrations. As discussed in Chapter 3, the close geochemical association between nickel and arsenic could facilitate the insertion of nickel into the alloy matrix even if the intended product was arsenical copper. However, the absence of arsenic in some of the nickel-rich copper objects proves that high nickel contents are not always the result of copper-arsenic alloying. In such cases, the alloy should be considered as an intentionally produced alloy of copper and nickel. Similar to the case of arsenic, alloying copper with nickel is known to enhance its physical properties and change its appearance to a light silvery color (Weeks 2003, 113). The employment of high-nickel copper (along with arsenic or not) in bracelets and rings in Cilicia was possibly because of its color.

With regard to alloys, a positive correlation between nickel and arsenic is implicated by the median concentration of the arsenical copper assemblage, as it is significantly higher than those of the two other assemblages (table 4.10). Hence, the performed statistical analysis supports the evidence from bi-variate element correlations, which has already indicated the strong relationship between these two elements. An immediate observation in the statistical summary is the extremely high median, lower limit, and upper limit values determined for the arsenical-copper assemblage of Tell Atchana. These considerably high values are caused by the fact that the nickel-rich sample JH 223 is the only arsenical copper artifact from this site.

As far as the data from previous studies are concerned, these display comparable median and upper limit concentrations for the Middle Bronze Age to those obtained in the current study (table 4.11). Concerning the Late Bronze Age, however, the median and upper limit values are higher in the earlier data. The lower limit concentrations in the earlier data are above 0.010 percent, and thus higher than those obtained in this study. This is probably because the previous studies employed analytical methods with higher detection limits than the icp-mass spectrometry utilized in this research. As the Early Bronze median and upper limit concentrations demonstrate, nickel concentrations appear to have been higher before the second millennium BC. In the Iron Age, even though the median concentration was comparable to those of the Middle and Late Bronze Age, the significantly low upper limit implies that copper with relatively high nickel contents were no longer common.

4.4.2. Antimony (Sb)

The overall distribution of antimony concentrations exhibits that the majority of samples fall into the 0.01-0.05 percent range (figure 4.14), with a median value of 0.03 percent (table 4.12). The mode occurs in the 0.01-0.025 percent range in the Middle Bronze Age and Late Bronze I assemblages, whereas it shifts to the 0.025-0.05 percent range in the Late Bronze Age II assemblage. Of the three sites, only Kinet has a significant number of samples with antimony contents in excess of 0.05 percent (figure 4.15). Overall, there are eleven samples with antimony contents above 0.1 percent, six of which are from Kinet. Not surprisingly, the Kinet assemblage displays the highest median, lower limit and upper limit concentrations (table 4.12). As the highest antimony content in the overall assemblage is only 0.13 percent, no

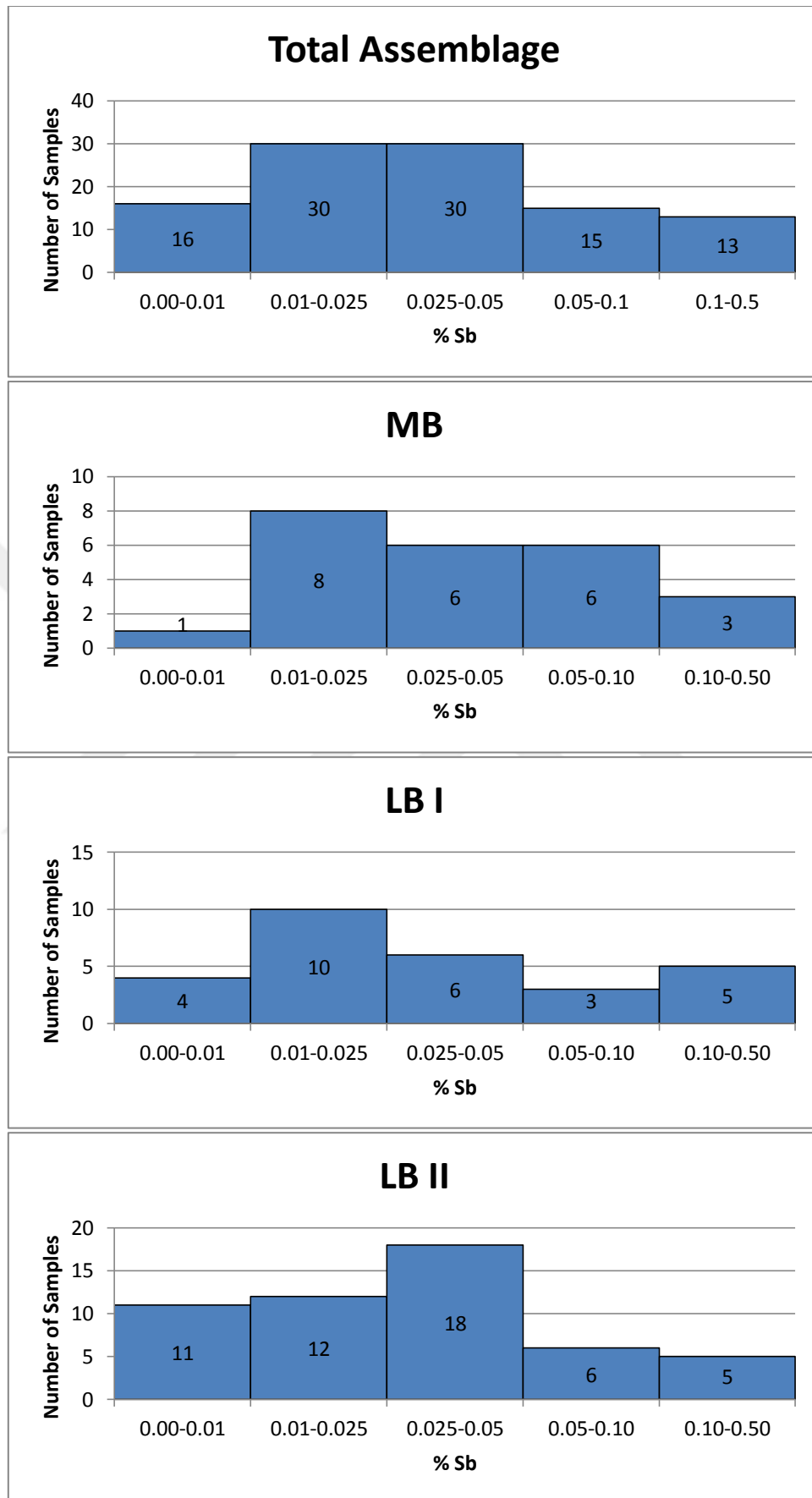


Figure 4.14. Frequency histograms for Sb (periods).

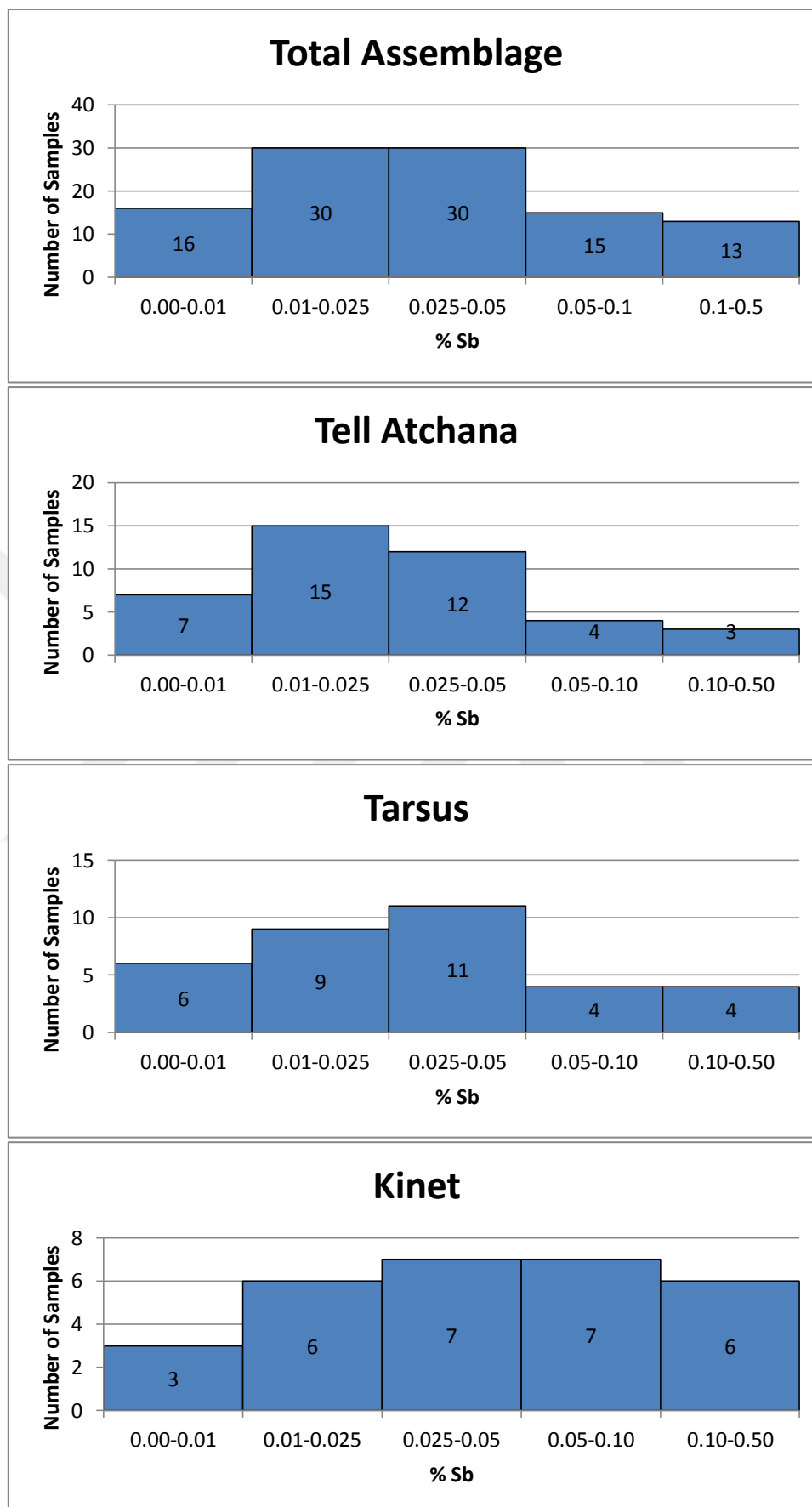


Figure 4.15. Frequency histograms for Sb (sites).

Table 4.12. Statistical summary for Sb concentrations.

	Overall	Unalloyed Copper	Arsenical Copper	Tin-bronze	Overall		Unalloyed Copper		Arsenical Copper		Tin-bronze	
	Median				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Tell Atchana	0.0241	0.0196	0.0203	0.0344	0.0060	0.0669	0.0041	0.0438	0.0203	0.0203	0.0094	0.1508
Tarsus	0.0319	0.0177	0.0567	0.0302	0.0068	0.1280	0.0050	0.0482	0.0229	0.3187	0.0107	0.0438
Kinet	0.0451	0.0212	0.0939	0.0451	0.0102	0.2126	0.0063	0.0835	0.0620	0.3627	0.0414	0.2361
MB	0.0433	0.0430	0.0546	0.0509	0.0109	0.2354	0.0114	0.0630	0.0172	0.3023	0.0202	0.3492
LB I	0.0256	0.0196	0.2589	0.0279	0.0060	0.2280	0.0088	0.0546	0.0484	0.4008	0.0048	0.0903
LB II	0.0319	0.0092	0.0630	0.0398	0.0063	0.0922	0.0034	0.0344	0.0525	0.0838	0.0123	0.1196
Overall	0.0333	0.0196	0.0686	0.0398	0.0068	0.1310	0.0046	0.0564	0.0224	0.3487	0.0104	0.1431

Table 4.13. Statistical summary for Sb concentrations (previous studies).

	Median	Lower Limit	Upper Limit
EB	0.1300	0.0000	0.4400
MB	0.0400	0.0000	0.3050
LB	0.0500	0.0000	0.1600
IA	0.1265	0.0482	0.7974

object can be classified as copper-antimony alloy. The comparison between the alloy types reveals that pure copper objects have significantly lower antimony contents than alloys (table 4.12). This observation may tentatively imply some correlation of antimony with both arsenic and tin. The As-Sb correlation has already been demonstrated by the principal component and binary correlation analyses, whereas the Sn-Sb relationship has not been indicated. The strong correlation of arsenic and antimony is further underscored by the arsenical copper assemblage as it has the highest median antimony concentrations in all three periods. It is also worth noting that the upper limit values are generally lower in the Late Bronze Age II period than the two earlier periods. This is apparently the outcome of the relative scarcity of arsenical copper during this period.

As for the data from previous research, the Middle Bronze Age median concentration of the earlier data is not significantly different from the one calculated in this study. However, the Late Bronze Age median value of the earlier research is higher than those of the Late Bronze Age I and II periods from the current study. The previous data demonstrate a dramatic fall in the median concentrations from the Early to the Middle Bronze Age (table 4.13), whereas there is no significant difference between the median values of the Middle and Late Bronze Ages. Interestingly, during the Iron Age, the median value rises back to the same level as in the Early Bronze Age. The securely detectable lowest limit concentrations are observed only in the Iron Age samples. This situation is the outcome of the fact that all Iron Age items from this region are investigated in the two recent studies (Kuruçayırılı and Özbal 2005, Dardeniz 2007), which employed techniques with better detection limits than earlier researches.

4.4.3. Zinc (Zn)

The overall distribution of zinc concentrations displays a concentration of samples below 0.005 percent (figure 4.16), with an overall medium of 0.0039 percent (table 4.14). The Middle Bronze Age assemblage exhibits a mode in the range of 0.0025-0.005 percent, whereas in the two Late Bronze Age assemblages there are more samples with Zn contents below 0.0025 percent. Significantly high zinc contents of 1.34-16.76 percent have been detected in eight items. Half of these are from the Late Bronze Age I period, and lead to the considerably high upper limit values observed in this assemblage (table 4.14).

The exceptionally high median and upper limit concentrations observed at Tarsus are also not surprising, as six high zinc objects of a total of eight are from this site (figure 4.17, table 4.14). The Tarsus assemblage also has a relatively large number of samples with Zn contents between 0.01 and 1 percent. However, as I will discuss below, these exceptionally high zinc contents recorded at Tarsus could be the outcome of sample contamination.

The earliest of the high zinc items are the two Middle Bronze Age artifacts from Kinet. The first of these items is the pin KNH 1042 with a zinc content of 2.12 percent. This object was made of tin-bronze with more than 6 percent tin; and also stands out with its 16.76 percent lead content, the highest detected in this study. The second object from Middle Bronze Age Kinet is sample KNH 1020, which has been defined as a wire, and has a zinc content of 9.02 percent, the highest in the overall assemblage.

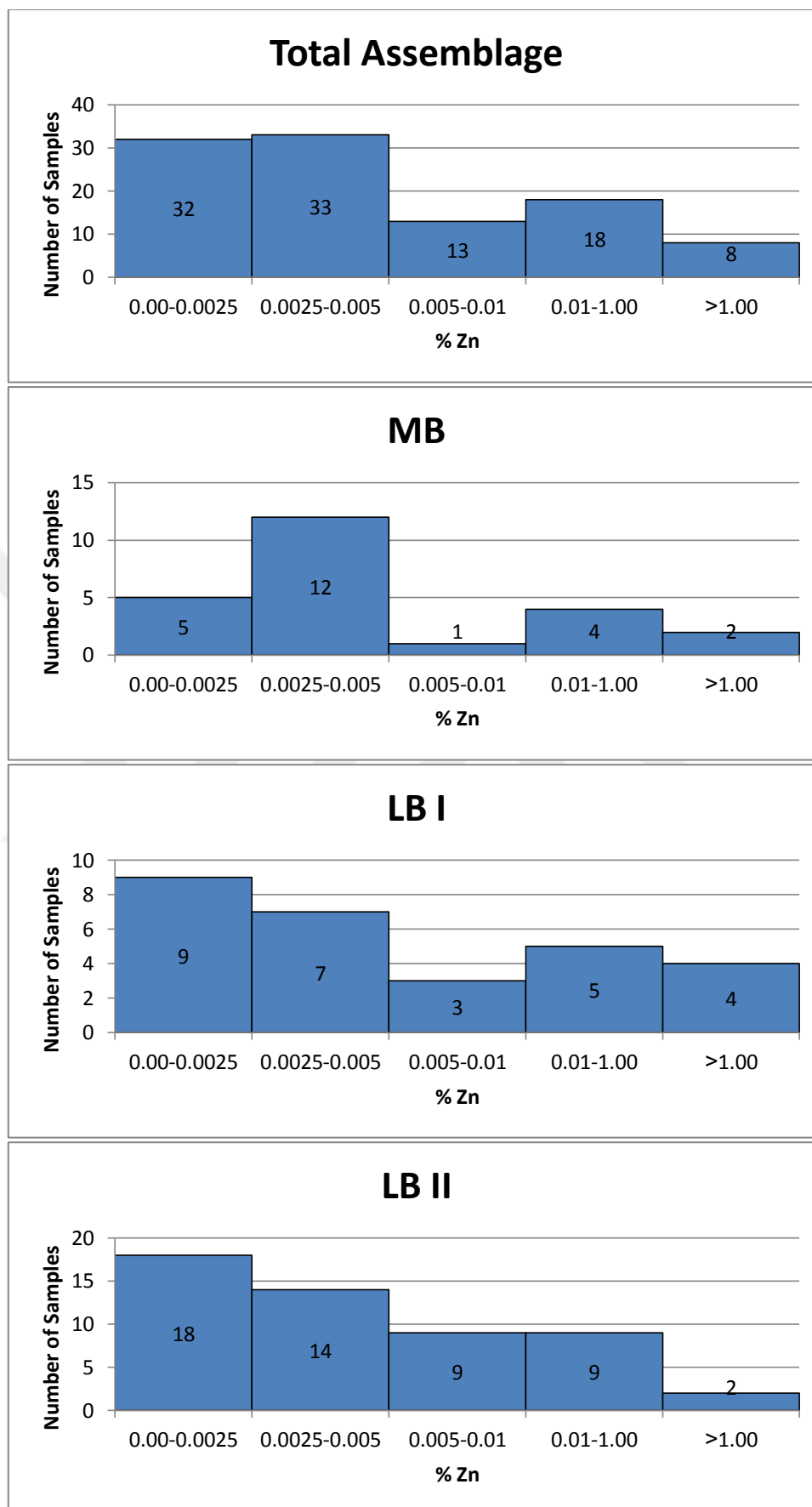


Figure 4.16. Frequency histograms for Zn (periods).

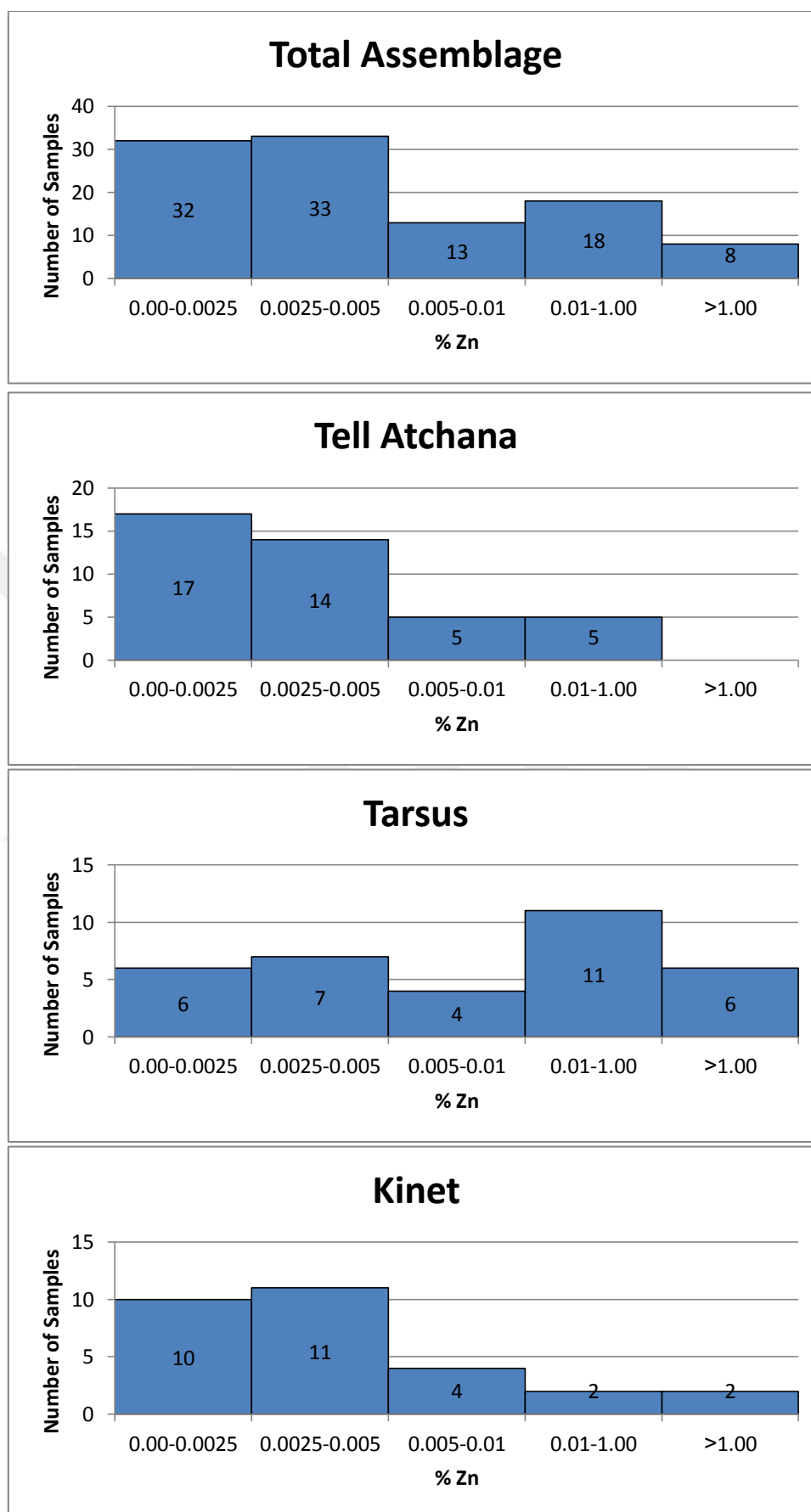


Figure 4.17. Frequency histograms for Zn (periods).

Table 4.14. Statistical summary for Zn concentrations.

	Overall	Unalloyed Copper	Arsenical Copper	Tin-bronze	Overall		Unalloyed Copper		Arsenical Copper		Tin-bronze	
	Median				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Tell Atchana	0.0028	0.0028	0.0017	0.0025	0.0016	0.0105	0.0016	0.0105	0.0017	0.0017	0.0016	0.0128
Tarsus	0.0110	0.0091	0.0027	0.0128	0.0022	3.0874	0.0049	4.0672	0.0019	0.4674	0.0034	1.2864
Kinet	0.0035	0.0045	0.0027	0.0035	0.0014	0.0120	0.0017	0.0136	0.0014	0.0061	0.0021	0.8550
MB	0.0037	0.0045	0.0024	0.1453	0.0019	0.2602	0.0027	0.2511	0.0018	0.0273	0.0327	1.7265
LB I	0.0042	0.0034	0.0056	0.0104	0.0015	1.6919	0.0016	0.5489	0.0018	1.2053	0.0017	2.6494
LB II	0.0041	0.0049	0.0046	0.0036	0.0017	0.0453	0.0019	0.6980	0.0017	0.2995	0.0017	0.0243
Overall	0.0039	0.0049	0.0027	0.0039	0.0017	0.2867	0.0018	0.5328	0.0017	0.1610	0.0017	0.1718

Table 4.15. Statistical summary for Zn concentrations (previous studies).

	Median	Lower Limit	Upper Limit
EB	0.0000	0.0000	0.0190
MB	0.0000	0.0000	0.0550
LB	0.0000	0.0000	0.0700
IA	0.0390	0.0004	1.0128

There are four samples with high zinc contents from Late Bronze Age I Tarsus. This group consists of a needle (TGK 36.861) with 4.07 percent zinc, a toggle pin (sample TGK 36.925) with 2.37 percent zinc, and two chisels (samples TGK 36.668 and TGK 36.934) with respective zinc contents of 4.52 and 1.34 percent. The two chisels are tin bronzes, whereas the toggle pin and the needle are respectively made of arsenical and unalloyed copper. The latest high zinc objects also belong to the Tarsus assemblage and date to the Late Bronze Age II period. These items are the arrowhead (sample TGK 36.695) and the finger ring (sample TGK 38.15), which incorporate 3.40 and 8.88 percent zinc respectively. Neither artifact contains tin or arsenic.

Even though copper objects with high zinc contents are already known in the region from previous studies, the author suspects that the high zinc contents recorded in Tarsus object in this study could be the result of some sample contamination. Firstly, these objects were sampled at the same time, in the same session of sampling, and are the only examples from this site to contain high levels of zinc. Furthermore, one of these items, (sample TGK 36.934), had previously been analyzed by the author and was determined to contain zinc only in trace quantities (Kuruçayırılı and Özbal 2005). Accordingly, these high tin contents attested in the Tarsus samples are likely the outcome of contamination from some unknown source.

Previous studies determined six Bronze Age samples from Mersin and Tarsus to contain between 1 and 6.8 percent zinc (Esin 1969; Kuruçayırılı and Özbal 2005, table 4 Dardeniz 2007, table 6.1)⁷⁸. Three of these items are unalloyed, while three are arsenical copper objects. More extreme levels of zinc are detected in an Early

⁷⁸ These studies also show that artifacts with high zinc contents become more common during the Iron Age and Hellenistic-Roman periods (Kuruçayırılı and Özbal 2005, table 4; Dardeniz 2007, table 6.1).

Chalcolithic bracelet (sample 17917) from Mersin (Esin 1969, Gale, Stos-Gale, and Gilmore 1985, table 6,7), and sample TGK 38.1623 from Late Bronze Age II Tarsus (Kuruçayırılı and Özbal 2005, table 4), which respectively contain 17.75 and 11.14 percent zinc. The latter item is an interesting object, defined by the excavators as the foot of a possibly small, animal-shaped vessel (Goldman 1956, 298). The artifact is made of tin bronze with 8.67 percent tin and also stands out for its exceptionally high lead content of 10.27 percent. Hence, the piece appears to have been made of an unusual alloy of copper, tin, zinc and lead. In accord with the current study, the data from earlier research does not record any sample from the Amuq that has a high zinc content.

Four high-zinc copper artifacts from the earlier studies and one from the current study (sample KNH 1042) also contain tin. The co-occurrence of the two elements in prehistoric copper objects has been underscored by Thornton (2007), who explains this phenomenon by arguing that tin-bronze and brass were used interchangeably as they both yield a similar gold-like color. Consequently, the mixing of the two alloys in the process of metal recycling must have been a common practice (Thornton 2007, 129-32).

More than half of the studied samples in earlier research had zinc contents below the detection limits of the available techniques (table 4.15). Furthermore, the very low but detectable zinc concentrations in earlier studies are represented only in the Iron Age assemblages, which are not focused on by the present study. Hence, a comparison between the statistical summaries of the current and previous research would not be meaningful.

4.4.4. Lead (Pb)

The overall distribution of lead concentrations exhibits a bimodal form, with the median value of 0.073 percent (figure 4.18, table 4.16). The two modes occur in the 0.01-0.05 and 0.1-1 percent concentration ranges. In the total assemblage, there are two items that stand out for their exceptionally high lead contents. These objects are a pin from Middle Bronze Age Kinet (sample KNH 1042) and a ring from Late Bronze Age I Tell Atchana (sample AT 7672), with respective lead contents of 16.76 and 1.87 percent. Both objects are tin bronzes. The pin from Kinet (sample KNH 1042), which has the highest lead concentration, also displayed an exceptionally high zinc content, as discussed above.

Copper objects with high lead contents were commonly attested in previous studies from the region. The evidence demonstrated that lead contents can be as high as 17.75 percent, as detected in a bracelet from Mersin (Gale, Stos-Gale, and Gilmore 1985, table 6.7). Also to note is the lead content of 10.24 percent, which co-occurs with 11.14 percent zinc in an object from Late Bronze Age Tarsus (Kuruçayırılı and Özbal 2005, table 4)⁷⁹. There are also ten objects from prehistoric Mersin and Tarsus that are recorded to contain between 1 and 2.1 percent lead (Esin 1969, Kuruçayırılı and Özbal 2005, table 4). The Tell Atchana ring AT 7672 analyzed in the current study is the only such example thus far attested in the Amuq. Alloying copper with lead is known to weaken the metal, and accordingly, it was most likely used so as to lower the melting point and enhance the casting properties of copper (Rosenfeld, Ilani, and Dvorachek 1997, 863).

⁷⁹ Sample TKG 38.1623, tentatively identified as the foot of a possibly small, animal-shaped vessel (Goldman 1956, 298).

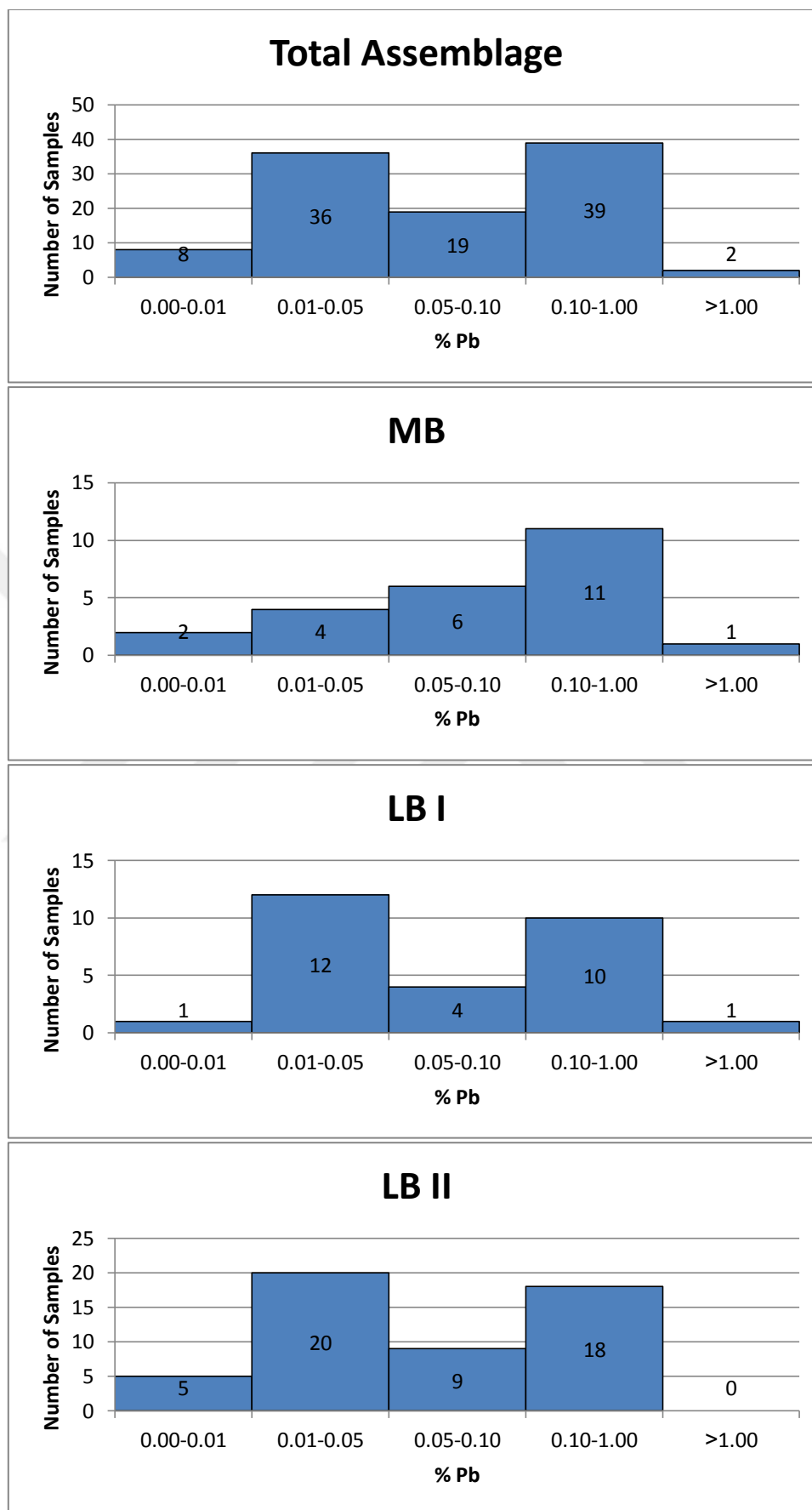


Figure 4.18. Frequency histograms for Pb (periods).

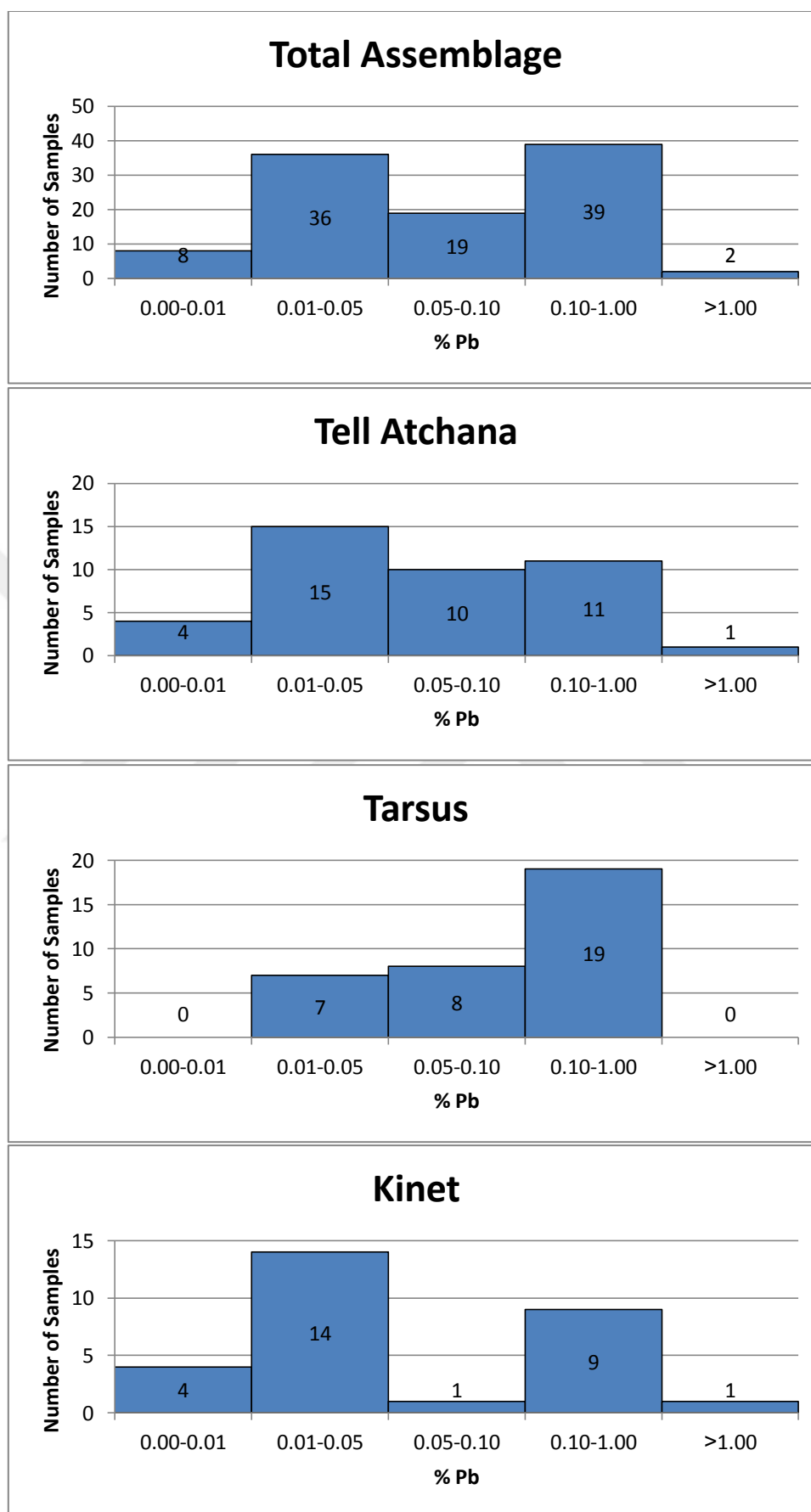


Figure 4.19. Frequency histograms for Pb (sites).

Table 4.16. Statistical summary for Pb concentrations.

	Overall	Unalloyed Copper	Arsenical Copper	Tin-bronze	Overall		Unalloyed Copper		Arsenical Copper		Tin-bronze	
	Median				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Tell Atchana	0.061	0.040	0.004	0.099	0.010	0.183	0.010	0.119	0.004	0.004	0.020	0.259
Tarsus	0.104	0.104	0.131	0.103	0.031	0.240	0.022	0.146	0.057	0.164	0.037	0.250
Kinet	0.045	0.022	0.126	0.046	0.009	0.360	0.006	0.452	0.018	0.153	0.025	6.887
MB	0.102	0.088	0.111	0.108	0.021	0.548	0.019	0.495	0.055	0.242	0.097	13.427
LB I	0.058	0.040	0.039	0.129	0.013	0.201	0.011	0.119	0.017	0.164	0.041	0.930
LB II	0.056	0.022	0.136	0.073	0.014	0.207	0.009	0.158	0.085	0.161	0.019	0.211
Overall	0.073	0.036	0.126	0.097	0.013	0.245	0.009	0.173	0.019	0.167	0.021	0.336

Table 4.17. Statistical summary for Pb concentrations (previous studies).

	Median	Lower Limit	Upper Limit
EB	0.090	0.000	0.549
MB	0.140	0.000	0.485
LB	0.110	0.004	0.388
IA	3.145	0.000	21.282

In the region, exceptionally high lead contents are commonly found in arrowheads with hollow sockets, a characteristic type of the Iron Age, Hellenistic, and Roman periods. The studied examples of this type were found to have an average lead content of 14.33 percent, while 32.3 percent is the highest content detected (Dardeniz 2007, table 6.1). Lead must have been added to these arrowheads so as to compensate the weight deficiency caused by the hollow interior, which would otherwise diminish arrow's piercing ability upon impact.

A comparison between the three periods demonstrates that the Middle Bronze Age has considerably higher overall median and upper limit values than those of the two later periods (table 4.16). It is also the only period that displays a unimodal distribution with the mode located in the 0.1-1 percent concentration range (figure 4.18). The second mode in the 0.01-0.05 percent range is observed only in the two Late Bronze Age assemblages. As far as the sites are concerned, Tarsus yields the highest median values, even though no sample with an exceptionally high lead content was detected at this site. Likewise, the site histograms demonstrate that the Tarsus assemblage has its single mode located in the 0.1-1 percent concentration range, in contrast to the other two sites, which also exhibit a second mode at a lower concentration range (figure 4.19). At Kinet, we observe an exceptionally high upper limit value for the tin-bronze assemblage, which is definitely caused by sample KNH 1042.

The median values obtained for individual alloy types indicate that lead concentrations were generally the highest in the arsenical copper assemblage. This observation tentatively indicates a possible positive correlation between arsenic and lead. This would also account for the high median values determined for the Tarsus and Middle Bronze Age assemblages, as these are the site and the period with the

most significant occurrence of arsenical copper. However, a strong correlation between As and Pb has not been detected in the principal component and binary correlation analyses.

The examination of the data from earlier research reveals a somewhat higher median value for the Middle Bronze Age than that calculated in this study (table 4.17). This difference becomes even more significant in the Late Bronze Age, as the median concentrations for the Late Bronze Age I and Late Bronze Age II periods of the current study are about half of that calculated in earlier research. The very high median and upper limit values determined for the Iron Age is obviously caused by the hollow-socket arrowheads, which constitute a major part of the studied assemblage, and always incorporate high contents of lead.

4.4.5. Iron (Fe)

The overall distribution pattern of iron concentrations demonstrates that the vast majority of samples have iron concentrations below 1 percent. The median concentration is 0.25 percent, which also divides the assemblage into nearly equal halves (figure 4.20, table 4.18). There are five samples with iron contents in excess of 2 percent and five in the 1 to 2 percent range. The highest concentration is 4.36 percent, which is attested in a pin from Kinet (sample KNH 1071). Previous studies have also detected several copper objects with high iron contents. There are eight items from Cilicia and the Amuq that have been determined to contain between one and 2.5 percent iron (Braidwood, Burke, and Nachtrieb, table 3; Kuruçayırılı and Özbal 2005, table 4; Özbal 2006, table 2; Dardeniz 2007, table 6.1), and two samples with exceptionally high iron contents of 10.5 and 32.7 percent. Both objects belong

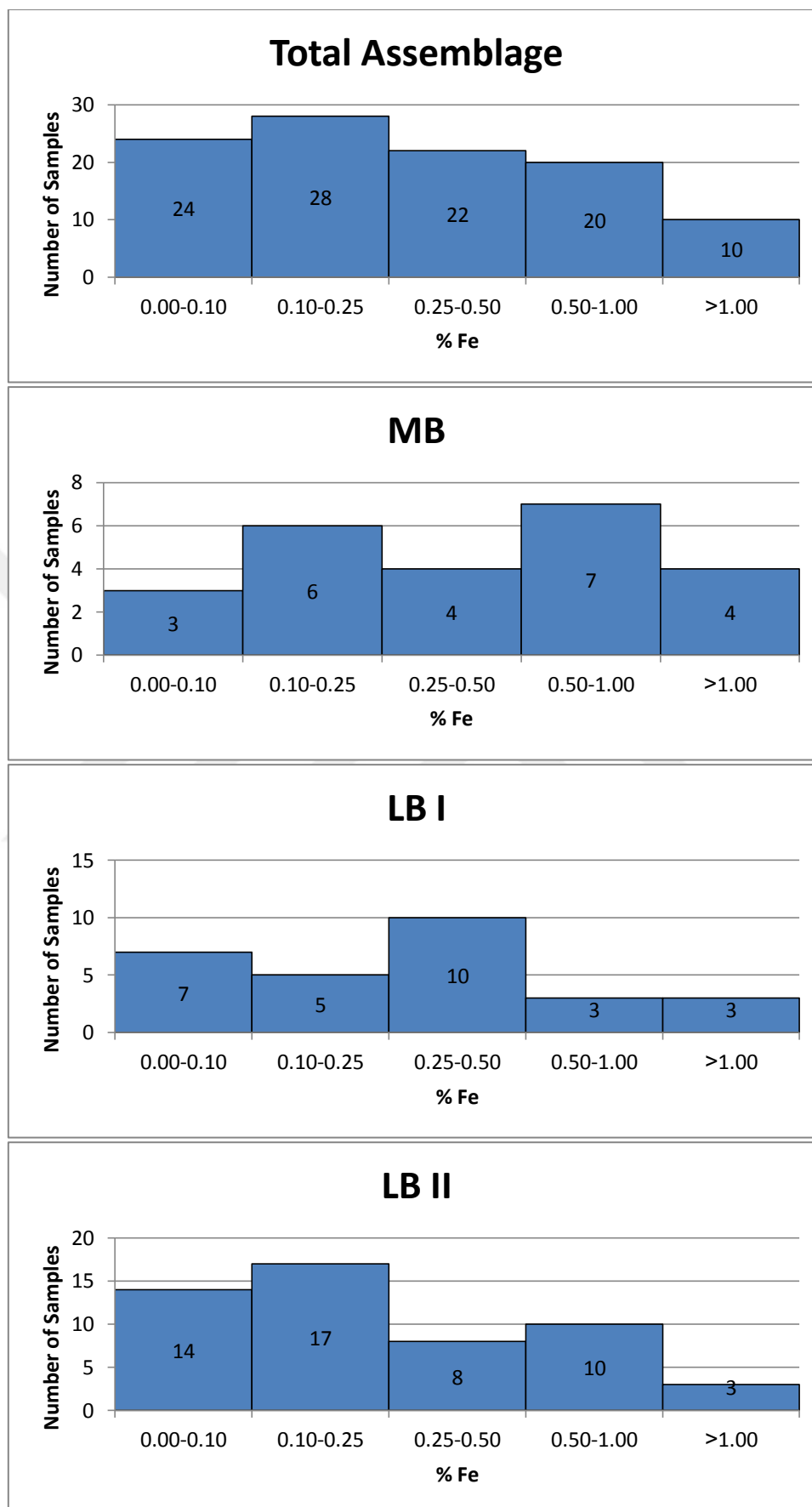


Figure 4.20. Frequency histograms for Fe (periods).

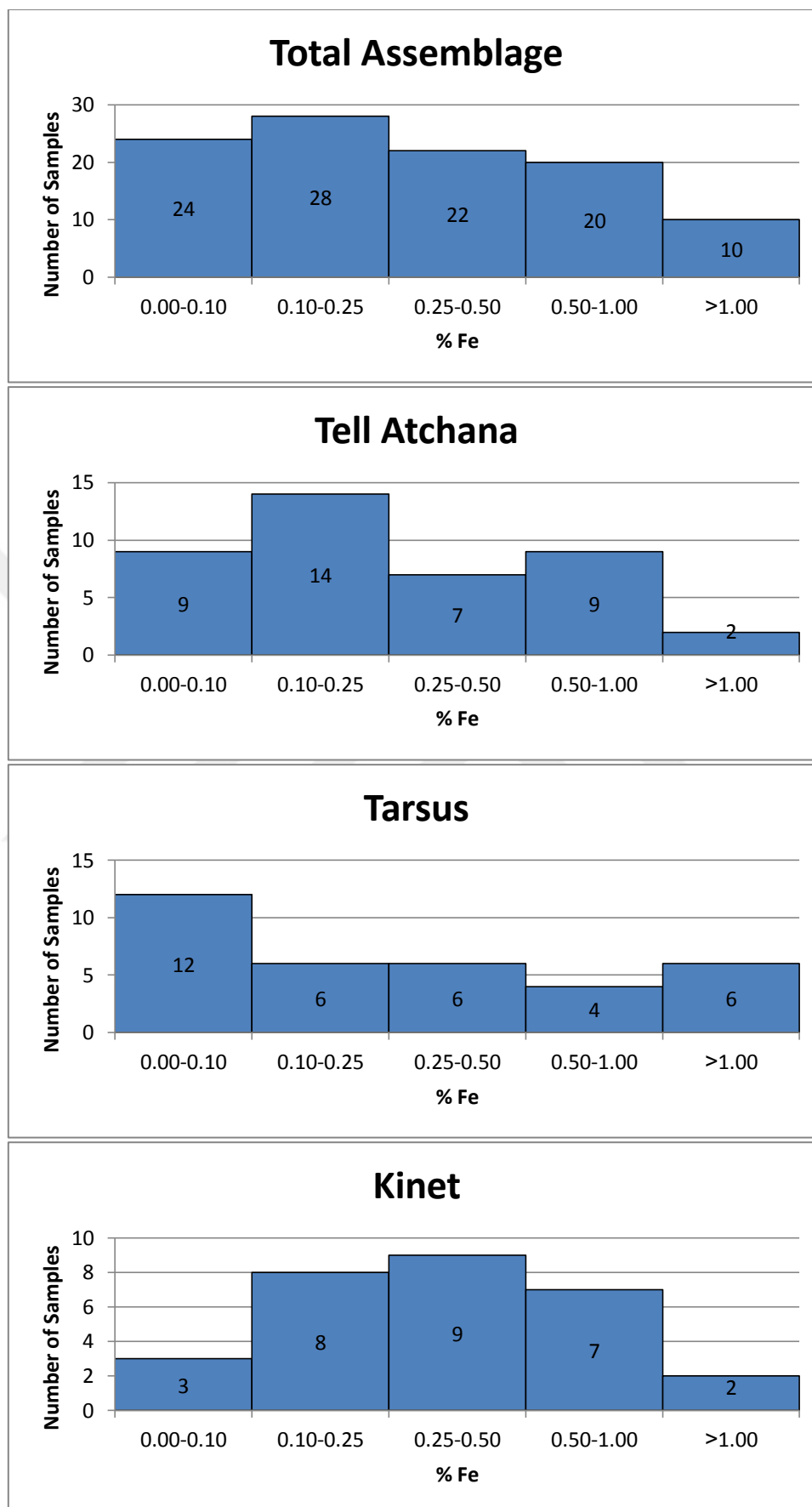


Figure 4.21. Frequency histograms for Fe (sites).

Table 4.18. Statistical summary for Fe concentrations.

	Overall	Unalloyed Copper	Arsenical Copper	Tin-bronze	Overall		Unalloyed Copper		Arsenical Copper		Tin-bronze	
	Median				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Tell Atchana	0.232	0.302	0.747	0.197	0.057	0.747	0.066	0.874	0.747	0.747	0.055	0.614
Tarsus	0.223	0.201	0.796	0.100	0.029	1.108	0.015	0.647	0.196	1.380	0.035	0.256
Kinet	0.361	0.404	0.556	0.219	0.095	0.798	0.080	0.810	0.150	2.206	0.099	0.462
MB	0.412	0.406	0.681	0.202	0.084	1.032	0.064	0.729	0.302	1.197	0.184	0.216
LB I	0.281	0.302	0.662	0.161	0.061	1.145	0.082	0.526	0.340	3.545	0.042	0.297
LB II	0.188	0.293	0.376	0.163	0.021	0.788	0.013	1.399	0.136	0.970	0.052	0.605
Overall	0.252	0.326	0.615	0.173	0.048	0.903	0.022	0.890	0.164	1.649	0.046	0.536

Table 4.19. Statistical summary for Fe concentrations (previous studies).

	Median	Lower Limit	Upper Limit
EB	0.325	0.120	0.757
MB	0.350	0.156	0.790
LB	0.330	0.148	0.939
IA	0.113	0.022	0.710

to the second millennium BC contexts of Tell Atchana and reported to be heavily oxidized fragments of copper (samples R03-1713 and A03-1409 in Özbal 2006).

In the present study, all items with iron contents higher than 2 percent are observed in the Late Bronze Age I and Late Bronze Age II periods. In contrast, four of the five samples with iron contents between one and two percent are from the Middle Bronze Age, which is apparently the reason why the highest median value is attested in this period (table 4.18). The comparison between the three sites does not reveal any significant pattern. With respect to alloys, the median values are the highest in the arsenical copper and the lowest in the tin-bronze assemblages in all periods (table 4.18). Hence, the evidence from statistical summaries appears to verify the significant As-Fe and the negative Sn-Fe correlations already demonstrated by the binary correlation analysis. In the data from previous studies, very close median values have been obtained for all three phases of the Bronze Age (table 4.19). These values are lower than the Middle Bronze Age median and higher than the Late Bronze Age I and Late Bronze Age II medians of the current study. There occurs a significant fall in the Iron Age.

4.4.6. Silver (Ag)

The overall distribution of silver concentrations displays a prominent mode in the 0.05-0.10 percent range, with an overall medium of 0.031 percent (figure 4.22, table 4.20). There are seven samples that have silver contents above 0.1 percent. These items belong either to the Middle Bronze Age or the Late Bronze Age I, but not to the Late Bronze Age II period. It is also during the Late Bronze Age II period that the mode shifts towards lower concentrations, to the 0.01-0.025 percent range. It is

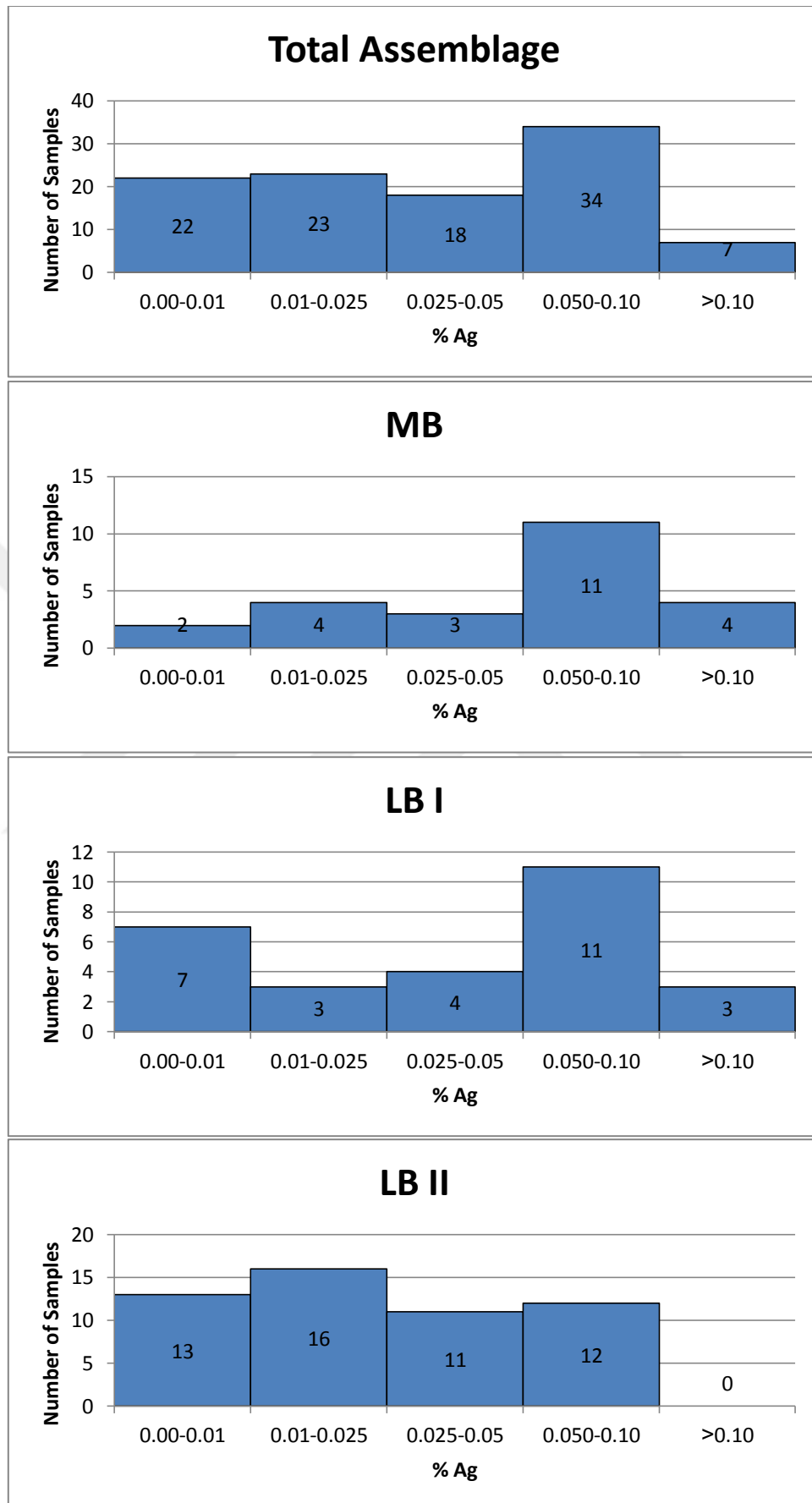


Figure 4.22. Frequency histograms for Ag (periods).

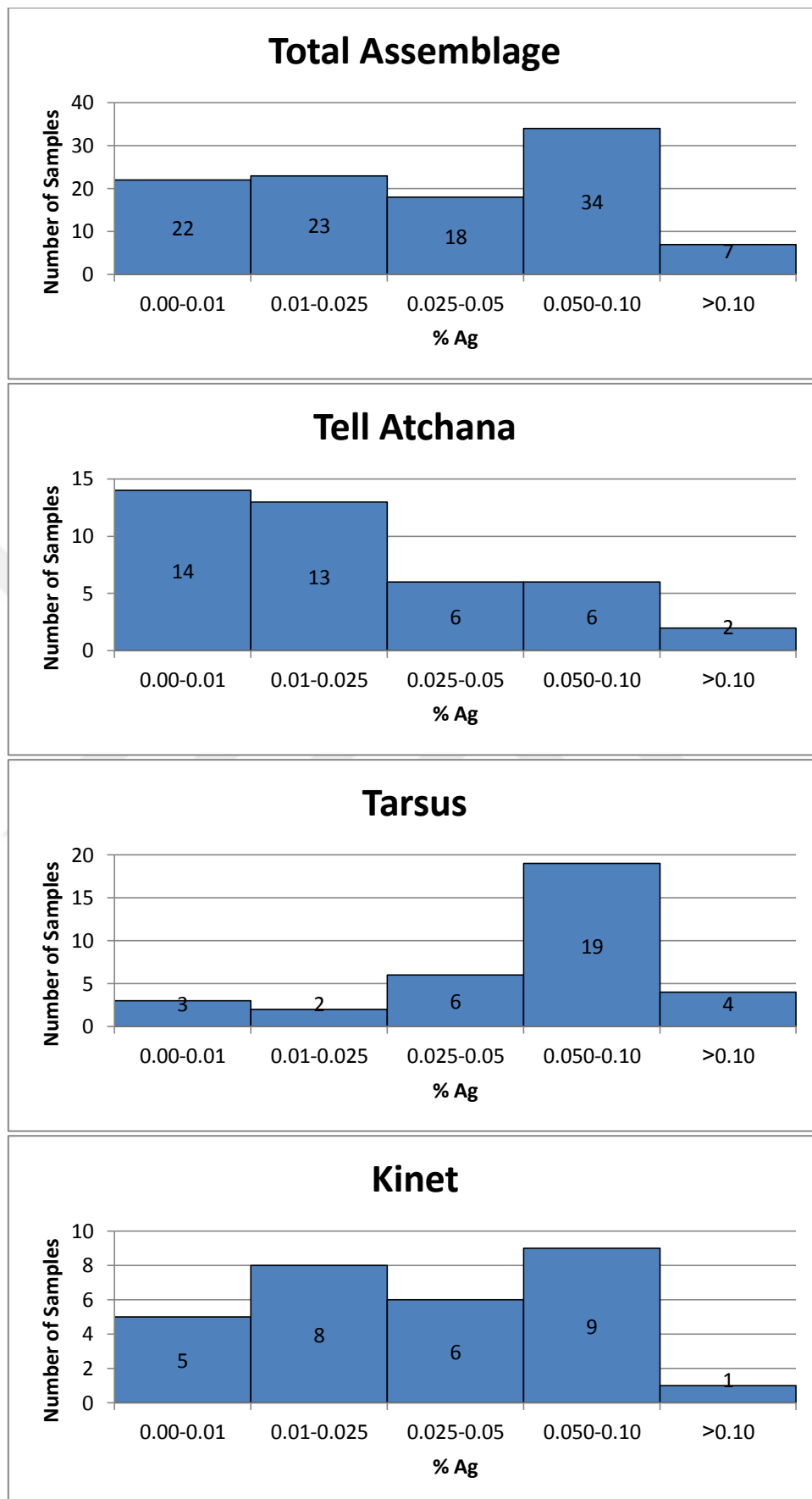


Figure 4.23. Frequency histograms for Ag (sites).

Table 4.20. Statistical summary for Ag concentrations.

	Overall	Unalloyed Copper	Arsenical Copper	Tin-bronze	Overall		Unalloyed Copper		Arsenical Copper		Tin-bronze	
	Median				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Tell Atchana	0.015	0.012	0.015	0.019	0.005	0.081	0.005	0.081	0.015	0.015	0.006	0.062
Tarsus	0.070	0.066	0.087	0.043	0.016	0.103	0.004	0.095	0.069	0.105	0.022	0.079
Kinet	0.031	0.022	0.057	0.025	0.007	0.084	0.006	0.053	0.029	0.079	0.013	0.122
MB	0.061	0.047	0.077	0.098	0.010	0.108	0.010	0.094	0.041	0.106	0.042	0.153
LB I	0.045	0.022	0.062	0.080	0.006	0.101	0.005	0.091	0.029	0.082	0.008	0.107
LB II	0.022	0.013	0.094	0.023	0.006	0.072	0.004	0.042	0.063	0.097	0.008	0.058
Overall	0.031	0.021	0.071	0.028	0.006	0.097	0.004	0.083	0.030	0.100	0.008	0.094

Table 4.21. Statistical summary for Ag concentrations (previous studies).

	Median	Lower Limit	Upper Limit
EB	0.040	0.000	0.120
MB	0.050	0.030	0.080
LB	0.020	0.000	0.091
IA	0.096	0.015	0.249

apparently because of these patterns that the lowest median and upper limit values are observed in the assemblage of this period (table 4.20). As for the sites, silver concentrations are the highest in the Tarsus assemblage and the lowest in the Tell Atchana assemblage, as demonstrated by frequency histograms and median values (figure 4.23, table 4.20). With respect to alloys, the highest median values are displayed either by the arsenical copper or tin-bronze assemblages, but never by unalloyed copper objects (table 4.20). The principal component and binary correlation analyses, however, demonstrated the strong correlation of silver with arsenic but not with tin. Hence, it is no wonder that the ranking of the three sites with respect to silver concentrations correlates with the relative intensity of arsenical copper usage.

The data from earlier studies determined comparable median values for the Early Bronze Age and Middle Bronze Age assemblages, which are also not significantly different from the Middle Bronze Age median of this study (table 4.21). The median drops significantly in the Late Bronze Age to a value, which is nearly identical to the Late Bronze Age II median of this study. This value is, however, nearly the half of that determined for the Late Bronze Age I period. Both median and upper limit concentrations significantly increase during the Iron Age.

4.4.7. Bismuth (Bi)

The overall distribution of bismuth concentrations demonstrates that the vast majority of samples have bismuth contents below 0.0005 percent, with an overall median of 0.0006 percent (figure 4.24, table 4.22). Nearly half of the samples in this range have bismuth concentrations less than 0.0005 percent. There are three items with bismuth contents in excess of 0.01 percent, all of which are found in the Kinet

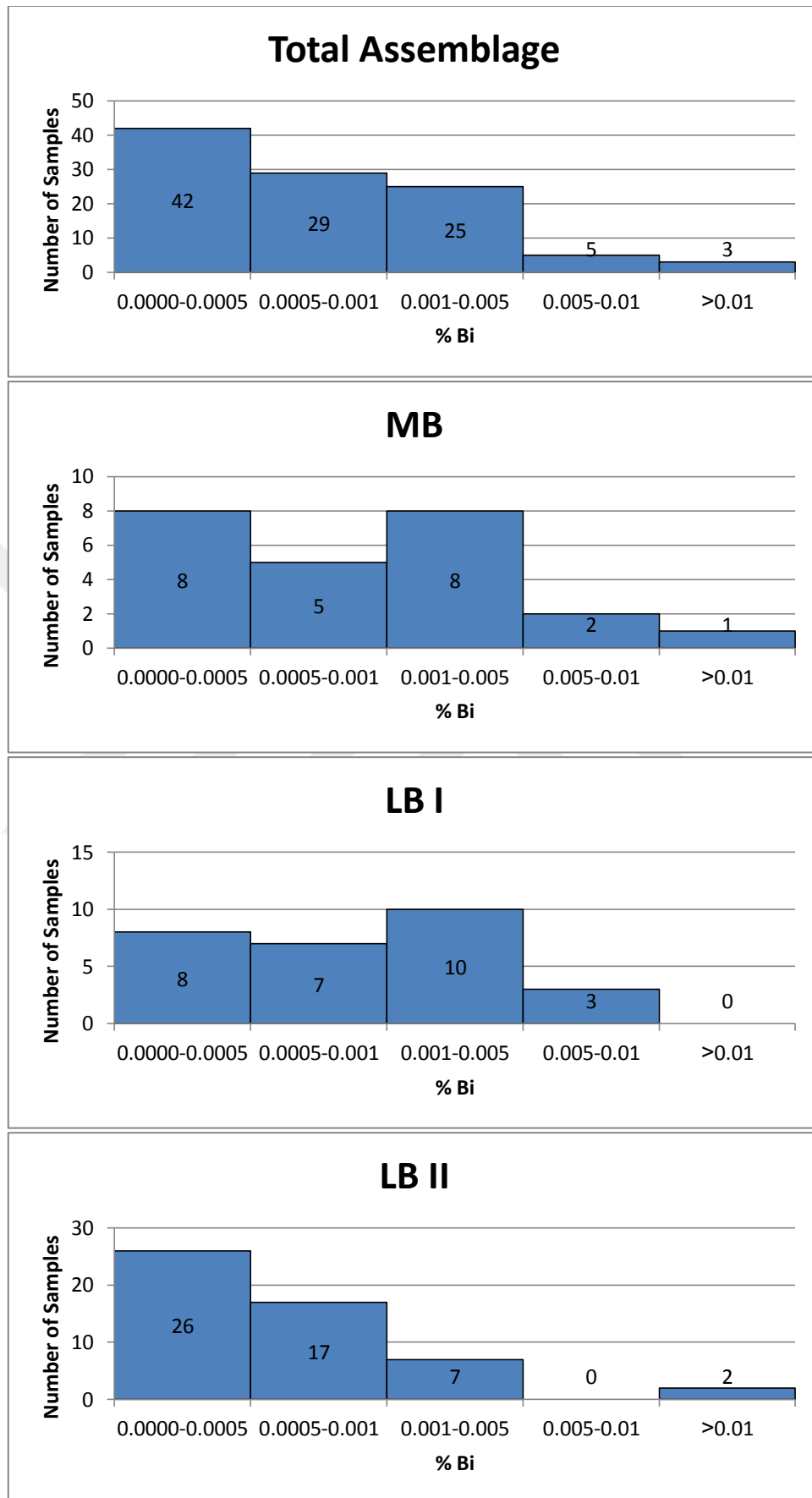


Figure 4.24. Frequency histograms for Bi (periods).

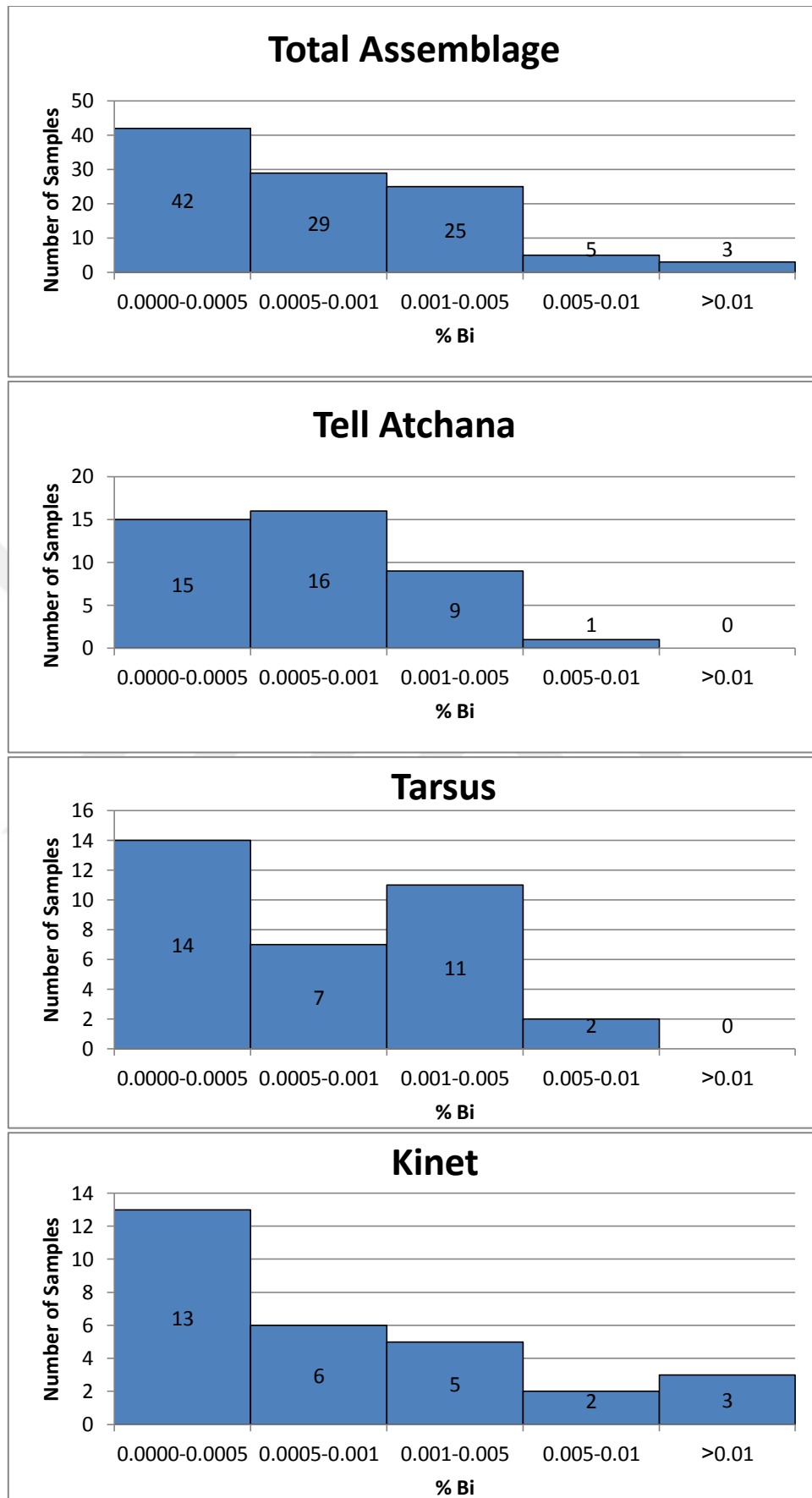


Figure 4.25. Frequency histograms for Bi (sites).

Table 4.22. Statistical summary for Bi concentrations.

	Overall	Unalloyed Copper	Arsenical Copper	Tin-bronze	Overall		Unalloyed Copper		Arsenical Copper		Tin-bronze	
	Median				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Tell Atchana	0.0006	0.0006	0.0002	0.0006	0.0003	0.0013	0.0002	0.0017	0.0002	0.0002	0.0004	0.0012
Tarsus	0.0008	0.0004	0.0010	0.0008	0.0003	0.0045	0.0003	0.0050	0.0002	0.0034	0.0004	0.0022
Kinet	0.0006	0.0005	0.0008	0.0007	0.0002	0.0096	0.0002	0.0050	0.0002	0.0149	0.0005	0.0083
MB	0.0009	0.0007	0.0013	0.0011	0.0002	0.0055	0.0003	0.0055	0.0002	0.0043	0.0010	0.0135
LB I	0.0010	0.0011	0.0005	0.0023	0.0002	0.0048	0.0003	0.0043	0.0002	0.0009	0.0006	0.0060
LB II	0.0005	0.0004	0.0034	0.0006	0.0003	0.0016	0.0002	0.0006	0.0011	0.0153	0.0004	0.0012
Overall	0.0006	0.0005	0.0008	0.0007	0.0002	0.0044	0.0002	0.0042	0.0002	0.0064	0.0004	0.0025

assemblage. One of these items is the tin-bronze pin KNH 1042 from the Middle Bronze Age period, which contains 0.0166 percent bismuth. As discussed above, this item also has the highest lead concentration, as well as a significant zinc content. The other two items are the toggle pin KNH 1039 and the possible bracelet KT 24589 with respective bismuth contents of 0.0142 and 0.0160 percent. Both objects are made of arsenical copper and belong to the Late Bronze Age II period. Of the three periods, the Late Bronze Age II has the highest median and upper limit concentrations (table 4.22). The two high bismuth objects from this period must have been at least partially responsible for this situation.

As for the sites, the Tell Atchana assemblage displays a more prominent shift towards lower concentrations, as about 75 percent of its samples have bismuth concentrations below 0.001 percent (figure 4.25). At the other two sites this portion is about two-thirds. Despite this pattern, the median values of the three sites are comparable. The overall median values obtained for individual alloy types also do not display any significant differences.

An examination of the data from earlier studies shows that 63 percent of the analyzed artifacts have bismuth contents below the detection limit permitted by the available analytical methods. The lowest detected bismuth percentage in these studies was 0.0005 percent, which is nearly equal to the median value calculated in this study. Thus, the comparison of the current and the earlier data would not be meaningful.

4.4.8. Copper Ingots

There are four artifacts, the investigation of which needs to be evaluated separately from the rest of the assemblage. This group consists of two copper ingots dated to the Late Bronze Age I period (sample KT 11421 from Kinet and sample AT 1675 from Tell Atchana) and two more possible ingots from the Late Bronze Age II period (samples AT 4073 and AT 4101 from Tell Atchana). Sample KT 11421 is a partially preserved bun-shaped ingot found in a heavily oxidized state. Sample AT 1675 is a fragment of what seems to be a curved ingot, while sample AT 4073 could be the fragment of a possible rectangular, slab-shaped ingot. Sample AT 4101 has a rounded shape of nearly five centimeters diameter and could be either a small ingot or a balance weight (Yener personal communication)⁸⁰. It contains 2.75 percent tin, and is the only item in this group that has a high concentration of tin or arsenic.

On the other hand, the bun ingot from Kinet (sample KT 11421) incorporates iron and nickel in respective contents of 3.10 and 1.31 percent. It is a quite common phenomenon that raw copper ingots from Bronze Age western Asia can incorporate such high contents of iron. It is also known from textual sources that metal-smiths had to refine raw copper before manufacturing it into finished artifacts (Moorey 1994, 243, 249; Weeks 2003, 106-7). Hence, the occurrence of such impurities as iron and nickel in high contents in a copper ingot is not an unexpected observation.

⁸⁰ Both samples AT 4073 and AT 4101 have initially been mistakenly categorized as slag in the excavation inventory.

4.5. SUMMARY AND CONCLUSIONS

4.5.1. Patterns of Alloy Use

Tin-bronze and Arsenical Copper

The results of the current study clearly testify to the gradual intensification of tin usage throughout the second millennium BC, and a parallel decrease in the frequency of unalloyed and arsenical copper. Even though this pattern correlates with the evidence from the wider Near East and the eastern Mediterranean, certain differences between the study region and its immediate neighbors can be discerned.

The data demonstrate that tin-bronze objects constitute 13, 25, and 54 percent of the study assemblage in the Middle Bronze Age, Late Bronze Age I and Late Bronze Age II periods respectively. In central Anatolia, the neighbor to the north, tin-bronze was extensively used already during the preceding millennium, notably in elite burial contexts (de Jesus 1980, graphs 2, 3, 5; Muhly 1993, 240). In Syria and the Levant to the south, the first examples of tin-bronze started to emerge towards the end of the third millennium BC (Philip, 1991, 93-98). However, compared to Cilicia and the Amuq, this region made a more significant use of tin in the Middle Bronze Age (ca. 2000-1600 BC), as tin-bronze objects constitute about half of the studied objects from this period (Philip 1991, 97-99; Rosenfeld, Ilani, and Dvorachek 1997, table 1 and 2; Philip, Clogg, and Dungworth 2003). Similarly, a consistent use of tin is evident on Cyprus by the end of the Middle Bronze Age (Balthazar 1990, 161, 431).

Even in the Late Bronze Age I period (ca. 1600-1400 BC), tin occurs infrequently in Cilicia and the Amuq; and tin-bronze becomes the predominant copper

alloy only during the Late Bronze Age II period (ca. 1400-1200 BC). The same phenomenon, however, occurs early in the Late Bronze Age in the Levant (Philip, Clogg, and Dungworth 2003, 89) and on Cyprus (Gale and Stos-Gale 1989, 252-54; Balthazar 1990, 161, 431).

This comparison might imply at the first sight that Cilicia and the Amuq had a relatively restricted access to networks of tin trade before 1400 BC. However, the observed difference between the study region and its neighbors may also be an outcome of the different nature of studied assemblages. Due to the scarcity of elite burials and luxury metal items from Bronze Age Cilicia and the Amuq, the studied samples from the region are almost exclusively of utilitarian character and have been recovered from domestic contexts. In contrast, the examined material from third millennium BC central Anatolia is almost entirely from elite burials. Likewise, ornamental or ceremonial objects, some of which are burial finds, constitute a major part of the studied assemblages from Syria and the Levant. The preference to use tin-bronze particularly in such objects and in elite contexts has been much discussed concerning different parts of the Near East (Stech 1999, 64-66; Weeks 2003, 188-91). Thus, the future discovery of Bronze Age elite burials, or luxury and prestige objects of copper in Cilicia and the Amuq may alter the current situation.

There are also obvious differences among the three sites in terms of relative intensities of tin and arsenic. Tell Atchana appears as the site, where tin-bronze is most commonly used, and constitute nearly half (47 percent) of the total assemblage (figure 4.2b). The portion of tin-bronzes in the assemblage drops to 35 percent at Tarsus, and to 24 percent at Kinet. These observed differences in the use of tin apparently reflect the different extent of access of individual sites to tin trade. Such an assumption finds its support in textual and archaeological evidence regarding the

politico-economic situation of the region. Regarding Kinet, even though it was a major harbor and apparently the most important settlement in eastern Cilicia, it was by no means as prominent as the other two sites. As for Tarsus, its larger size, its location close to the main gateway between central Anatolia and the Mediterranean coast, and finally its documented importance in Hittite records renders it a more imposing center. Finally, displaying the richest evidence for external contacts, Alalakh appears as the site most tightly connected to interregional trade networks. Hence the ranking of the three sites with respect to the intensity of tin usage seemingly reflects their ranking with respect to the intensity of external contacts.

On the other hand, the situation of arsenic draws the opposite picture. Tell Atchana, the most significant user of tin, appears as the locality, where arsenical copper is exceptionally rare, as only two samples in a total of forty-one from this site have been identified to be made of this alloy (figure 4.3). Arsenical copper demonstrates its most common use at Tarsus, where it constitutes 32 percent of the total assemblage. The use of the alloy at this site is particularly remarkable in the Middle Bronze Age, as six samples of a total of eight from this period contain arsenic. Having 24 percent share of the total assemblage, arsenical copper also displays a considerable use at Kinet. The frequency of arsenical copper at this site is especially significant during the Late Bronze Age I period, during which half of the samples contain arsenic.

Comparison with Earlier Work

In previous studies, a separation between the different phases of the second millennium BC was available for Cilicia only. The results of these researches

demonstrate a gradual increase in the extent of tin usage throughout the millennium, as the portion of tin-bronzes in the total assemblage rises from 13 percent in the Middle Bronze Age to 31 percent in the Late Bronze Age I and eventually to 38 percent in the Late Bronze Age II periods. Thus, the evidence indicates a dramatic increase from the Middle Bronze Age into the Late Bronze Age I period, whereas the increase from the earlier to the later phase of the Late Bronze Age had a more modest scale. In contrast, the current study indicates that the change from the Late Bronze Age I to the Late Bronze Age II period was also quite significant.

A clear separation between the different phases of the second millennium BC is not evident in earlier research programs from the Amuq. Thus, it was not possible to determine more precisely when tin-bronze became the predominant copper alloy in the region. We can now place this phenomenon into the Late Bronze Age II period, when the portion of tin-bronze objects at Tell Atchana increased to 65 percent from 25 percent of the Late Bronze Age I period.

With regard to the use of arsenic, the new results and the earlier data are in agreement as they both reveal the wide spread use of arsenical copper in Bronze Age Cilicia but not in the Amuq. However, with regard to the frequency of this alloy in Cilicia, earlier data evidence a more significant use throughout the second millennium BC. In previous studies, arsenical copper objects were found to constitute 69, 57, and 18 percent of the total assemblage respectively in the Middle Bronze Age, Late Bronze Age I and Late Bronze Age II periods (figure 4.1). In the current study, these portions drop to 46 percent (seven of a total of fifteen samples), 38 percent (six of a total of sixteen samples), and 16 percent (five of a total of thirty-two samples) for the three respective periods (figure 4.3).

The situation of copper-tin-arsenic ternary alloy constitutes another discrepancy between the current and earlier data. In earlier studies, copper artifacts with high tin and arsenic contents were determined to constitute some part of the metal repertoire in both Cilicia and the Amuq during all chronological phases of the Bronze Age (figure 4.1). This situation was particularly observed in Cilicia in the Middle Bronze Age and Late Bronze Age I periods, when the ternary alloy constituted respectively 15 and 17 percent of the studied assemblages. In contrast, only one single sample in a total of 104 in the present research could be determined to contain both elements in significant quantities (figure 4.3).

Other Alloys of Copper

The copper-nickel and copper-zinc alloys are represented in the study assemblage by three and two objects respectively. Twenty copper-based objects with high nickel contents were already identified in previous studies from the region; and five of these items were either rings or bracelets. Similarly, the sample, which yielded the highest nickel concentration in this study, was tentatively identified by the excavation team as the fragment of a bracelet. Hence, in this region there seems to have been a tendency to employ the copper-nickel alloy in these ornamental objects, apparently because of its light silver-like color.

Previous studies already detected high zinc contents in eight copper objects that also contain tin. Similarly, one of the two zinc-containing objects identified in the current study has a high tin content. The occurrence of zinc together with tin in the same object was a common phenomenon of the Bronze Age and appears to have been the outcome of metal recycling. As both tin-bronze and brass yielded the similar gold-

like color, metal-smiths should have mixed the two alloys freely when they recycled scrap metal (Thornton 2007, 129-32).

4.5.2. Trace Element Patterns

The most significant elemental relationship has been detected between arsenic and antimony. The evidence may tentatively indicate the production of arsenical copper by the direct smelting of fahlerz. These types of copper ores contain arsenic and antimony-bearing minerals in various relative quantities. As no item in our assemblage has a high antimony content, the ore was most probably rich in arsenic but relatively deficient in antimony. The second possible explanation is the presumed production of copper-arsenic alloy by the addition of arsenic-bearing minerals either to molten copper or to a co-smelting charge. If the arsenic-bearing ore in question is polymetallic and incorporates antimony minerals, the strong correlation between the two elements can be the result of such production processes.

Some of the significant element correlations, particularly those involving arsenic such as As-Sb, As-Ni, As-Ag relationships, are not observed in the assemblage of arsenical copper objects. Apparently, because arsenic contents are already high in all samples of this group, computing the correlations of arsenic with other elements in this assemblage is probably not meaningful and indicative.

Of the three periods, the Middle Bronze Age displays some unique geochemical characteristics, whereas the Late Bronze Age I and Late Bronze Age II periods are more similar to one another. This is particularly evident as some of the most significant element correlations overall, such as the As-Sb, As-Ni and Pb-Ag relationships, are not observed in the Middle Bronze Age assemblage. At least in the

case of As-Sb and As-Ni correlations, the situation can be explained by the possibility discussed above. In the Middle Bronze Age assemblage, a significant number of objects contain arsenic; and thus, computing the correlations of arsenic with other elements may not be indicative. This period, however, also stands out for its notably higher lead concentrations than the other two sites, as well as the total absence of samples with high iron contents.

The comparison between the three sites implicates that Tarsus is the only one that does not display the strong As-Ni and Ni-Sb correlations. The same site also stands out for its relatively high lead concentrations. The other site that demonstrates certain unique features is Kinet. The strong Pb-Ag and Pb-Bi correlations are attested only at this site. In contrast, the Co-Te relationship is very low at Kinet contrasting with the other two sites. Finally, this site yielded the objects with the highest bismuth concentrations and half of those with the highest antimony concentrations. Lead isotope analysis, to be presented in the next chapter, will hopefully determine whether these geochemical differences between assemblages actually account for distinct copper sources.

5. RESULTS OF LEAD ISOTOPE ANALYSIS

5.1. INTRODUCTION

Lead isotope analysis is a method widely employed in archaeometallurgy that can be applied to metal objects as well as ore samples. Even though the method was originally developed to investigate the origin of the metal used in an object, due to certain inherent limitations it is not always possible to assign a studied sample to one particular source. The method, however, always carries the capacity to provide significant information about the provenance of samples, especially when combined with other sources of evidence. Besides provenance studies, lead isotope analysis has proved itself as an invaluable means of inquiry in investigating the patterns of metal procurement and exchange in antiquity, primarily by means of comparisons among distinct assemblages.

Before the presentation and discussion of results, Section 5.2 will overview the principles and historical development of the method, as well as the means of data treatment. Subsequent to this, certain limitations of provenance studies and the scholarly debate about these issues will be reviewed in Section 5.3. Following this background information, the discussion will move on to the presentation of results, which is divided into two parts. The first of these, Section 5.4, will address the isotopic distribution patterns displayed by the studied assemblage, focusing on comparisons among distinct periods, sites and alloy types. In the succeeding Section 5.5, inferences on the provenance of copper will be developed through comparison of the current data with those from the ore fields in the Mediterranean and the Near East.

5.2. PRINCIPLES AND BACKGROUND

5.2.1. Principles of Lead Isotope Analysis

The lead isotopic composition of an ore deposit is expressed in the relative abundances of four isotopes of the chemical element lead, which is always part of the metallic matrix. In nature, lead is present in four different isotopes (atoms of the same chemical element with different masses), designated ^{204}Pb , ^{206}Pb , ^{207}Pb , and ^{208}Pb with respect to their atomic masses. In addition to their original amounts present in earth's crust, the three heaviest of these isotopes are also formed through radioactive decay of the heavier isotopes of uranium and thorium. It is in this manner that ^{206}Pb , ^{207}Pb , and ^{208}Pb are respectively formed by the radioactive decay of ^{238}U , ^{235}U , and ^{232}Th (Stos-Gale and Gale 1994, 99; Weeks 2003, 129-30). Thus, the lead content present in an ore body comprises lead that is originally present at the formation of the earth (primordial lead), and lead that is formed through the decay of radioactive thorium and uranium (radiogenic lead).

Since the minerals of lead are separated from the heavier radioactive elements during the formation process of an ore deposit, the isotopic composition of the deposit remains unchanged after this process is completed. Accordingly, different ore deposits on earth have distinct isotopic compositions that are also referred to as their “fingerprint”, and that are determined by the following parameters: (1) Local composition of primordial lead; (2) local compositions of radioactive isotopes of uranium and thorium, which determine the amount of radiogenic lead; (3) the age of the formation, which determines the time when radioactive decay stops to add to the amount of lead.

It is within the frame of this geological knowledge that lead isotope analysis was originally developed by geoscientists to investigate the age and geological history of ore deposits based on the half-lives of radioactive decay schemes (Stos-Gale and Gale 1994, 99-101; Weeks 2003, 130; Hauptmann 2007, 32).

5.2.2. Research in Archaeology

The method attracted the attention of archaeologists in the early 1960s when its potential was recognized for determining the provenance of archaeological specimens. It is the geographical variation in isotopic composition of distinct ore deposits that forms the basis for archaeological provenance studies. Consequently, when the isotopic composition of the metal in an artifact is determined, the origin of the utilized metal can be assigned to a specific ore deposit, or at least to a geographical locale, which displays a matching isotopic constitution.

At its preliminary stage, isotopic research in archaeology focused primarily on ancient lead objects. Also, non-metallic objects with high contents of lead, such as leaded glazes and glasses were included in lead isotope studies (Brill and Wampler 1967, Grögler et al. 1966). It was in the following decade that the method started to be applied to artifacts and ores of another metal, namely silver, which almost always contains significant levels of lead. The most prominent study on ancient silver was the research project developed to provenance the ancient Greek silver coins from the archaic and classical periods⁸¹. As its primary result, the project demonstrated the significance of the ore fields at Laurion on mainland Greece as a source for Athenian coins (Gale, Gentner, and Wagner 1980). At the same time, researchers also became

⁸¹ This project was a joint research administered by the Max Planck Institut für Kernphysik at Heidelberg University and the Department of Geology and Mineralogy at Oxford University.

interested in studying lead and silver samples from the earlier periods, such as those from the prehistoric Aegean (Gale and Stos-Gale 1981).

It was also during the early 1980s that the method started to be used in the provenance studies of copper-based artifacts, as these always incorporate at least trace amounts of lead. The framework of this application was the idea that no matter how minute the quantity of lead in a metal object, it must reflect the isotopic fingerprint of the ore deposit, where the metal originated (Gale and Stos-Gale 1982). This development is regarded a major breakthrough in lead isotope studies, due to the great abundance and strategic significance of copper and its alloys in antiquity. Subsequently, provenance research programs concerning the ancient Near East and the Mediterranean grew in number and scope⁸².

5.2.3. Representation and Treatment of Lead Isotope Data

The isotopic composition of any metallic sample (ore, slag or artifact) is determined by the relative abundance ratios of different lead isotopes to one another. In lead isotope research, the most commonly measured ratios are $^{208}\text{Pb}/^{206}\text{Pb}$, $^{207}\text{Pb}/^{206}\text{Pb}$, and $^{206}\text{Pb}/^{204}\text{Pb}$. Samples are represented as points plotted in a three dimensional space, where the three measured values determine the three Cartesian coordinates of each point (Stos-Gale and Gale 2009, 203). However, for convenience this three dimensional space is reproduced in two bi-variate mirror plots positioned at

⁸² These researches are primarily carried out by the Max Planck Institut für Kernphysik at Heidelberg University and the Isotrace Laboratory at Oxford. The Department of Archaeological Science at the University of Bradford, the Analytical Conservation Laboratory of the Smithsonian Institution, the Department of Earth Sciences at the University of Queensland, and more recently, the German Mining Museum at Bochum are other institutions that contribute to lead isotope data and the development of analytical methodology (Hauptmann 2007, 32).

a normal angle. Hence, each sample is represented by two symmetrical points, one on the upper, one on the lower scatterplot. The horizontal axis of both plots (the axis that joins the two plots) is the $^{207}\text{Pb}/^{206}\text{Pb}$ value. Most commonly, but not universally, the two vertical axis are the $^{208}\text{Pb}/^{206}\text{Pb}$ and $^{206}\text{Pb}/^{204}\text{Pb}$ values (Stos-Gale and Gale 2009, 203).

In the early stages of lead isotope research in archaeology in 1980's and 1990's, it was a common method to define “fields” to represent ore deposits graphically. It had been suggested that between thirty and fifty samples from a particular deposit would be necessary to define each field. These fields are then represented by ellipses enclosing the highest possible number of samples (datapoints in a graphical plot) from that deposit. It became a common practice for most research teams to enclose ellipses with 95 percent confidence (Stos-Gale and Gale 2009, 203).

In the last decade researches became more aware that drawing ellipses would be an accurate means of representing ore deposits only if the isotope data exhibit a normal distribution pattern. As lead isotope data are almost always far from displaying multivariate normality, defining ore fields by ellipses has gradually been abandoned. In rare cases, ellipses are still employed only to guide the eye while working with complex lead isotope diagrams⁸³ (Stos-Gale and Gale 2009, 203).

Complex statistical treatments such as multivariate statistical analysis (Sayre et al. 1992; Stos-Gale and Gale 1994), and kernel density estimation (Scaife et al. 1999) were once applied to lead isotope studies. However, once again due to the non-normal character of lead isotope data, these methods are now recognized to be misleading. Consequently, research teams consider the simple visual point-by-point comparisons between samples and deposits on the two bivariate scatterplots as the

⁸³ As an example, in L. Week's study of southeast Arabian metal artifacts (Weeks 2003) ellipses are used only in one of his nineteen lead isotope diagrams (figure 7.19).

most appropriate means of data analysis (Knapp 2000, 38; Weeks 2003, 142-43; Stos-Gale and Gale 2009, 203-4). The same approach is taken in the present study.

5.3. LIMITATIONS OF LEAD ISOTOPE ANALYSIS

Provenancing metals by means of lead isotopy is not without limitations, which became the subject of a major debate in scholarly discourse. There are several skeptical scholars who doubt the validity of lead isotope analysis in metal provenancing⁸⁴. This group of researchers has been opposed by those who defend the method. Not surprisingly, this second camp is constituted by the most prolific practitioners of lead isotopy in provenance studies⁸⁵. The skeptics raised several arguments against the method, which will now be addressed in detail.

5.3.1. Homogeneity of Ore Deposits

Provenancing of metallic specimens by lead isotopy is based on the fundamental assumption that, unlike their geochemical composition, isotopic characteristics of ore deposits do not display significant variations. This notion has been put to question by scholars, who are skeptical about provenance studies (Budd et al 1996, 170). However, various researches demonstrated that the isotopic composition within a deposit shows an insignificant degree of variation, mostly at the levels of a few tenths of a percent (Hauptmann 2007, 34, Begemann and Schmitt-Strecker 2008, 127). It has also been testified that the isotopic characteristics of an ore

⁸⁴ Their arguments are effectively summarized in Budd et al. 1996 and Knapp 2000.

⁸⁵ Their views are summarized in Begemann and Schmitt-Strecker 2008 and Stos-Gale and Gale 2009.

deposit can be traced in mineralogically different samples from the same deposit (Stos-Gale and Gale 2009, 202).

However, in certain deposits that contain uranium, lead continues to form until the present time due to radioactive decay, which leads to different isotopic compositions in past and present samples. Of the examined ore fields in southwest Asia, and southeast Europe, this phenomenon is observed only at Rudna Glava in Serbia. (Stos-Gale and Gale 1994, 102; Begemann and Schmitt-Strecker 2008, 127). It is, however, important to note that even in these areas, lead isotope research significantly contributed to the understanding of the aspects of prehistoric metallurgy (Begemann and Schmitt-Strecker 2008, 127-28; Stos-Gale and Gale 2009, 202).

5.3.2. Effects of Metallurgical Processes

It has been argued that metallurgical processes, which lead from the ore to the finished artifact, might significantly alter the original isotopic composition of metals (Budd et al. 1995). Experimental research, however, demonstrated that even though some part of the original lead content might be lost during smelting and refining, these operations do not cause any measurable discrepancy between the original ore and the final product in terms of isotope ratios (Stos-Gale and Gale 1994, 99; Weeks 2003, 131; Hauptmann 2007, 35; Stos-Gale and Gale 2009, 198-201). The practice of alloying, however, might theoretically alter the original isotopic characteristics of the base metal. In the case of ancient copper metallurgy, such an outcome is particularly likely when copper is alloyed with lead. In this case, the lead content of the final product primarily consists of the lead added to copper. Thus, in copper-lead alloys,

the measured isotope ratio would not imply the possible origin of the base copper (Begemann and Schmitt-Strecker 2008, 129).

As far as other copper alloys are concerned, it is very rare that they incorporate alloying agents in weight concentrations higher than 10 percent. With respect to tin-bronze, it is demonstrated that tin ores throughout the world contain less than thirty micrograms lead per gram of tin. Therefore, if a tin-bronze of 10 percent tin is produced, the added tin would contribute only three micrograms lead per gram of tin to the final product (Begemann and Schmitt-Strecker 2008, 129-30). Relatively high contents of lead are, however, observed in a number of tin ingots from the Bronze Age shipwrecks of Uluburun (Pulak 2000, 155), Hishuley Carmel, and Kefar Shamir (Galili, Shmueli, and Artzy, 1986). But, even in these instances, lead content never exceed one hundred micrograms per gram of tin. These concentrations are too low to imply a major contribution of lead from tin to the produced alloy (Begemann and Schmitt-Strecker 2008, 130). Moreover, the lack of any correlation between the tin contents and lead isotope characteristics in tested assemblages also speaks against the proposed contribution of lead from tin in tin-bronze objects (Begemann, Schmitt-Strecker, and Pernicka 1989, 270, figure 30.4.; Begemann and Schmitt-Strecker 2008, 130).

5.3.3. Metal Recycling

As far as metal recycling is concerned, there is unequivocal archaeological evidence from many parts of the Near East and the Mediterranean to indicate that this was a common practice in the Bronze Age. The common occurrence of the so-called ‘founder’s hoards’, large groups of hoarded scrapped artifacts, is considered a strong

indication for the frequent use of recycling. Particularly crucial for the discussion of metal recycling is the discovery of these hoards in association with metallurgical workshops. Evidence for this becomes especially abundant towards the end of the Late Bronze Age in the eastern Mediterranean where such hoards are known from Enkomi, Kition, Mathiati, Pyla, and Kalavassos on Cyprus (Knapp 2000, 45), Tell Nami in Israel, and the Gelidonya shipwreck (Sherratt 2000, 87-88).

Two of the most prolific scholars of lead isotope research, Gale and Stos-Gale, once strongly argued that metal recycling was not a common phenomenon during most of the Bronze Age. They base this argument on various propositions. First, they claim that metal recycling was an uncommon practice prior to the 13th century BC, given the scarcity of founder's hoards before this century (Gale and Stos-Gale 1985, 90). Also, they believe that during the Bronze Age there was a general preference to remove metals from circulation, rather than to recycle them as scrap. This was undertaken by means of deposition of bronzes in burials (Gale and Stos-Gale 1985, 90). Moreover, they argued that broken metal artifacts were being preferentially repaired rather than re-melted as scrap. They also suppose that whenever re-melting of old metal was carried out, it was more probable that a single object was melted in its entirety and cast into another single artifact. Therefore, the original isotopic fingerprint is expected to be carried into the new object unaltered (Stos-Gale and Gale 1994, 105).

However, all these propositions seem probable only in specific contexts, and are not very likely to reflect general aspects of Bronze Age metallurgical practices. As Muhly points out, metal was too expensive and smelting it from the ore required complex techniques. Consequently, old metal was preferentially stored as scrap rather than being readily discarded (Muhly 1985a, 80). There is also significant evidence to

indicate that recycling was frequent even before the 13th century BC. Examples of this practice are attested at several localities from 14th century BC Hattuša (Müller-Karpe 1994, 81-82), to Late Minoan IB (16th or 15th century BC) sites of Knossos (Popham 1984, 203-6, 218-20), Mochlos (Soles 1997), and Katsambas (Dimopoulou 1997, 435-37) on Crete. Even earlier evidence for recycling is found at Hassek Höyük in southeastern Anatolia and Khirbet Hamra Fidan in Jordan, respectively dated to the Chalcolithic and Early Bronze Age (Hauptmann 2007, 36).

Some researchers also argued that scrap metal could have been used in the manufacture of ingots (Knapp 2000, 43). However, the scarcity of common alloying elements, namely arsenic and tin, in ingots speaks against this possibility. These chemical elements would be expected to occur in significant quantities if the ingots incorporated re-melted scrap copper, any assemblage of which is likely to involve arsenical copper or tin-bronze objects (Stos-Gale et al. 1997, 108).

Recycling scrap metal, however, is not the only process through which copper lumps from different origins can get mixed. There is evidence for the processing of ores from different deposits at the same metallurgical facility. Such a phenomenon seems particularly likely at a site like Maysar 1 in Oman. This important copper producing site of the third millennium BC was in proximity to two copper deposits of distinct geological origins, and thus of distinct isotopic compositions. Moreover, the ingots produced at the site were found to be manufactured through agglomeration of smaller pieces of copper, which might come from these two different origins (Weeks 2003, 139). The use of copper from multiple sources in the same workshop has also been documented in earlier contexts, such as the Chalcolithic sites of Aslantepe and Hassek Höyük in Anatolia and Abu-Matar in Israel (Hauptmann 2007, 38)

Gale and Stos-Gale once argued that even the large oxhide ingots were most likely manufactured in a single cast, with copper smelted in a single large furnace. They base this argument on the discovery of exceptionally large furnaces at the Cypriot sites of Athieniou and Kition that are capable of smelting a sufficient volume of copper to cast a standard oxhide ingot (Stos-Gale et al. 1997, 108; Gale and Stos-Gale 1999a, 269). However, there is now unquestionable evidence that some oxhide ingots were produced in multiple casts (Pulak 2000, 141; Hauptmann 2007, 254). On the other hand, at least in the case of ingots from the Uluburun Ship, it has been demonstrated that the different casting batches of copper that constitute the ingot are indistinguishable in their isotopic compositions (Gale 2011, 214).

5.3.4. Overlapping Ore Fields

The final complication surrounding the provenance studies with lead isotopy progressively arose when researchers started to realize that the more isotope data became available from various ore deposits, the more overlap is observed between their isotopic fields. Consequently, it has become more problematic to assign a sample to one particular source (Discussed by Pernicka et al. 1990, Budd et al. 1996, 170; Weeks 2003, 133). Those researchers who are optimistic about the determination of absolute provenance champion the idea that it is still possible to attribute samples to particular deposits in those cases, where significant overlaps between the ore fields do not occur (Stos-Gale and Gale 1994, 102; Gale and Stos-Gale 1999, 268; Stos-Gale and Gale 2009, 202).

5.3.5. Capacity of Lead Isotope Analysis

Despite these limitations in the determination of absolute provenance, lead isotope analysis is capable of providing strong negative conclusions for provenance. This is due to the fundamental notion that if the isotopic composition of a sample does not match the field of a particular ore deposit, the sample cannot have its origin in this deposit. This capability of lead isotope analysis to eliminate certain deposits as unlikely candidates for provenance is its widely accepted strength, even by skeptical researchers (Budd et al. 1996, 169; Weeks 2003, 133). Lead Isotopy is also effectively used to investigate changes in trade patterns or technology, by means of comparisons between chronologically or spatially distinct assemblages (Pernicka et al. 1990, 263; Begemann, Pernicka, and Schmitt-Strecker 1995, 123, Weeks 2003, 163). Thus, even in those cases, where the evidence of absolute provenance can be elusive, the method has proven to be invaluable in delineating changes in the patterns of metal procurement, production, and exchange (Budd et al. 1996, 172-73, Weeks 2003, 133).

5.4. GENERAL PATTERNS IN THE ASSEMBLAGE

5.4.1. Outlying Samples

With the exception of five samples, the general distribution of the assemblage is located within the $^{208}\text{Pb}/^{206}\text{Pb}$ range of 2.035-2.085, $^{207}\text{Pb}/^{206}\text{Pb}$ range of 0.821-0.846, and $^{206}\text{Pb}/^{204}\text{Pb}$ range of 18,460-19,073 (figure 5.1). Before the discussion of patterns observed in this main body of samples, it is useful to examine the five outliers which fall outside these ranges. Four of these display the common

characteristics of having the highest ratios of $^{208}\text{Pb}/^{206}\text{Pb}$ and $^{207}\text{Pb}/^{206}\text{Pb}$, while their $^{206}\text{Pb}/^{204}\text{Pb}$ ratios are the lowest.

The two samples with the highest ratios of $^{208}\text{Pb}/^{206}\text{Pb}$ are two items from Late Bronze Age II Tarsus. The first of these is a pin made of unalloyed copper (sample TGK 36.928), while the second one is a tin-bronze chisel (sample TGK 38.1624). Isotopic similarity, along with chronological and geographical consistency, might imply a common origin of copper to which these artifacts could be attributed. Two Middle Bronze Age objects from Kinet stand out from the main group with their significantly high $^{207}\text{Pb}/^{206}\text{Pb}$ and low $^{206}\text{Pb}/^{204}\text{Pb}$ ratios, while their $^{208}\text{Pb}/^{206}\text{Pb}$ value is only slightly higher than those of the main group. The items in question are the needle (sample KNH 1074) and the pin (sample KNH 1375), both of which were made of unalloyed copper. These two objects have very similar $^{208}\text{Pb}/^{206}\text{Pb}$ ratios for a given $^{207}\text{Pb}/^{206}\text{Pb}$ ratio. Interestingly however, sample KNH 1074 has a more similar $^{206}\text{Pb}/^{204}\text{Pb}$ value with respect to $^{207}\text{Pb}/^{206}\text{Pb}$ ratio to the two outliers from Tarsus (samples TGK 36.928 and TGK 38.1624), which belong to a different site and period. The final outlier is a Late Bronze Age II ring from Tarsus (sample TGK 38.15), which is separated from the main group with its relatively high $^{208}\text{Pb}/^{206}\text{Pb}$ ratio, while the other isotopic ratios remain within the ranges of the main group. It is to note that this item does not correlate with the other four outliers, and thus, remains as a unique representative.

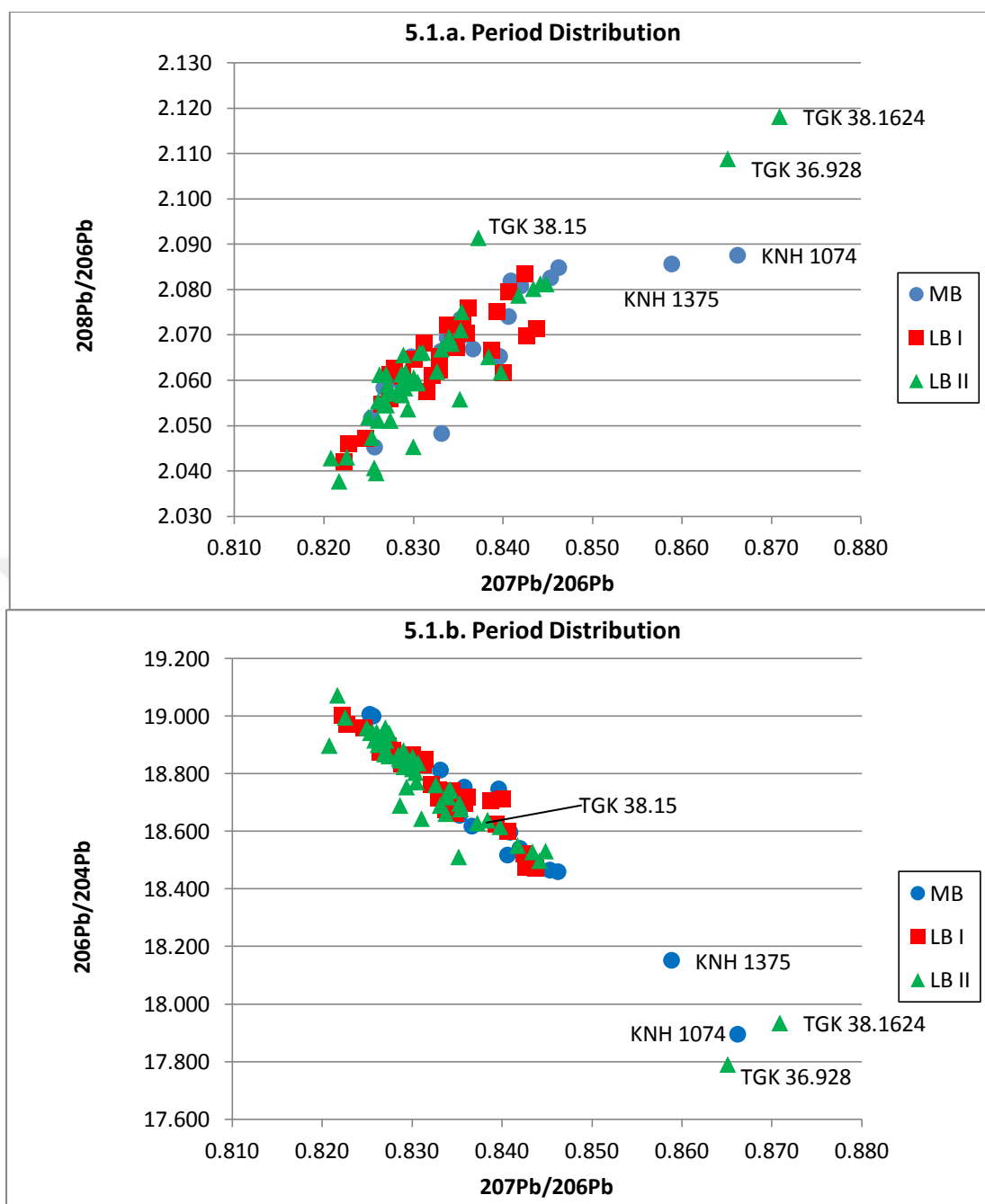


Figure 5.1. Lead isotope data of all objects by period.

5.4.2. Samples in Major Clusters

Focusing on the main group of samples, we observe that the overall assemblage can be grouped into three clusters, designated A, B, and C. Once again, some items can be distinguished as being separated from these tentatively defined clusters (figure 5.2).

Cluster A

Cluster A shows a clear separation from the two other clusters especially in the ratios of $^{206}\text{Pb}/^{204}\text{Pb}$ and the $^{207}\text{Pb}/^{206}\text{Pb}$, which fall between 18.80-19.00 and 0.823-0.831 respectively. Strikingly, the majority of the Late Bronze Age II samples (twenty-four of a total of forty-two) are located in this cluster. Conversely, only six (of a total of twenty-four) items of the Middle Bronze Age assemblage are found in this cluster. The Late Bronze Age I period is somewhat better represented with eleven (of a total of twenty-eight) samples. These numbers demonstrate that Cluster A reflects the isotopic characteristics of certain source areas, which had supplied the region throughout the period under study. However, the extensive use of these sources appears to have begun in the latest phase of the Bronze Age, namely during the Late Bronze Age II period.

Considering the site distribution of samples (figure 5.3), we can observe that the majority of items from Tell Atchana, namely twenty-six of a total of forty, is found in this cluster. On the contrary, Tarsus and Kinet have relatively few members, respectively represented by eight (of a total of thirty-three) and nine (of a total of twenty-nine) samples. The examination of alloy types shows that Cluster A hosts

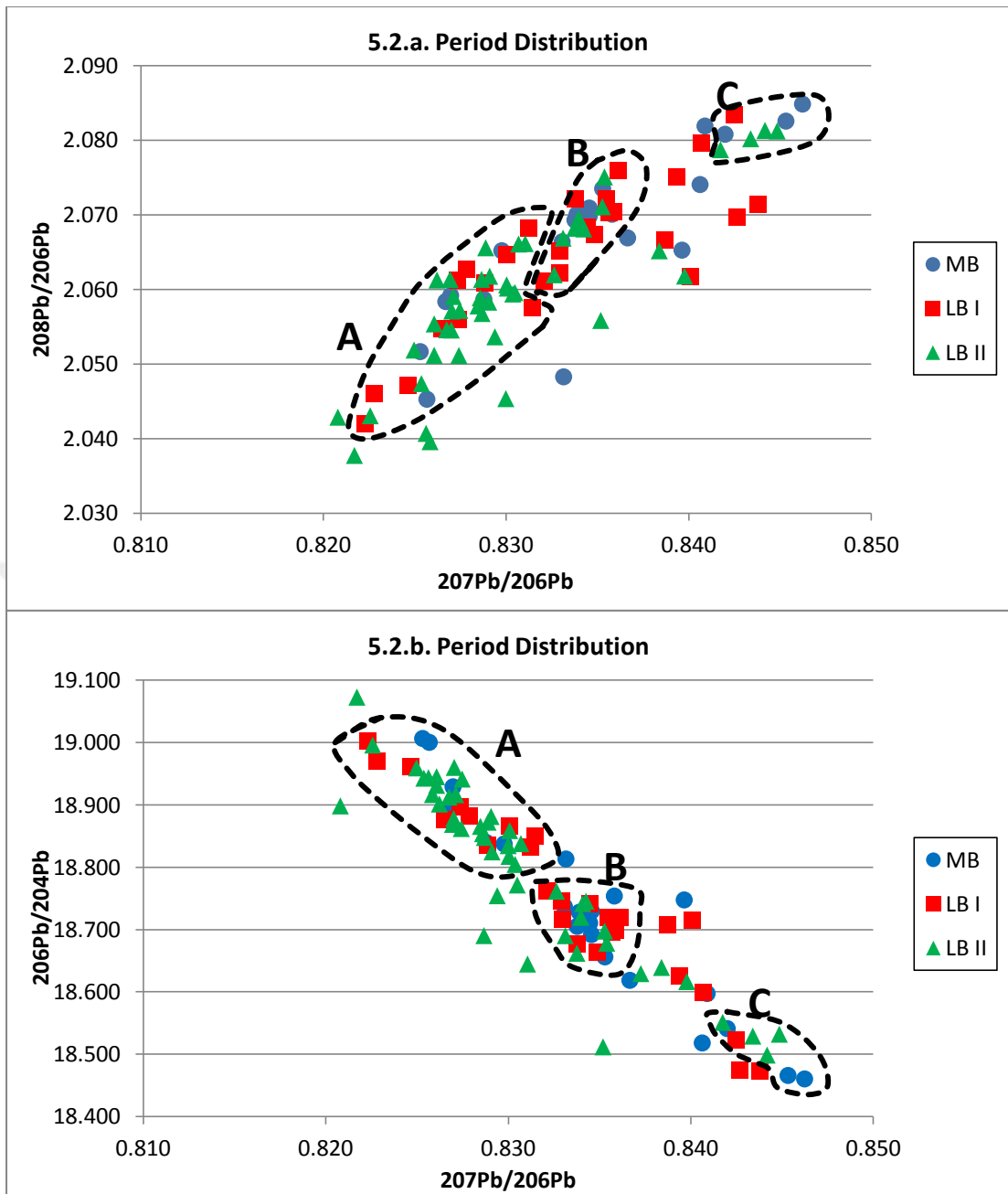


Figure 5.2. Lead isotope data of all objects (by period) with outliers omitted.

most of the tin-bronze samples (twenty of a total of thirty-seven) (figure 5.4). This is not an unexpected result, given that this cluster contains the majority of Late Bronze Age II samples, which is the period with the most frequent usage of tin.

We can inspect this cluster more closely using the isotope distribution plots, which display each period separately (figure 5.5, 5.6, 5.7). An immediate observation is that Kinet apparently started to utilize this source area in the later half of the second millennium BC, as no single Middle Bronze Age object from this site is found in this cluster. Conversely, nearly half of the Late Bronze Age I (three of a total of eight) and Late Bronze Age II (six of a total of fourteen) items from this site are concentrated in this cluster.

As far as Tell Atchana is concerned, this cluster hosts the majority of its samples in all three periods. This is particularly visible in the latest period, the Late Bronze Age II, where only two of a total of nineteen samples from the site fall outside this cluster. As for Tarsus, we have already noted that its samples are relatively few in Cluster A. Nevertheless, the small sample size still confirms the gain in importance of this cluster in the latest period. Expressed quantitatively, five out of eight Tarsus samples found in this cluster are from the Late Bronze Age II period.

In sum, before the Late Bronze Age the metal sources represented by Cluster A had been an important supplier of Tell Atchana only. Eventually, these sources became the major suppliers for all three sites during the Late Bronze Age II period.

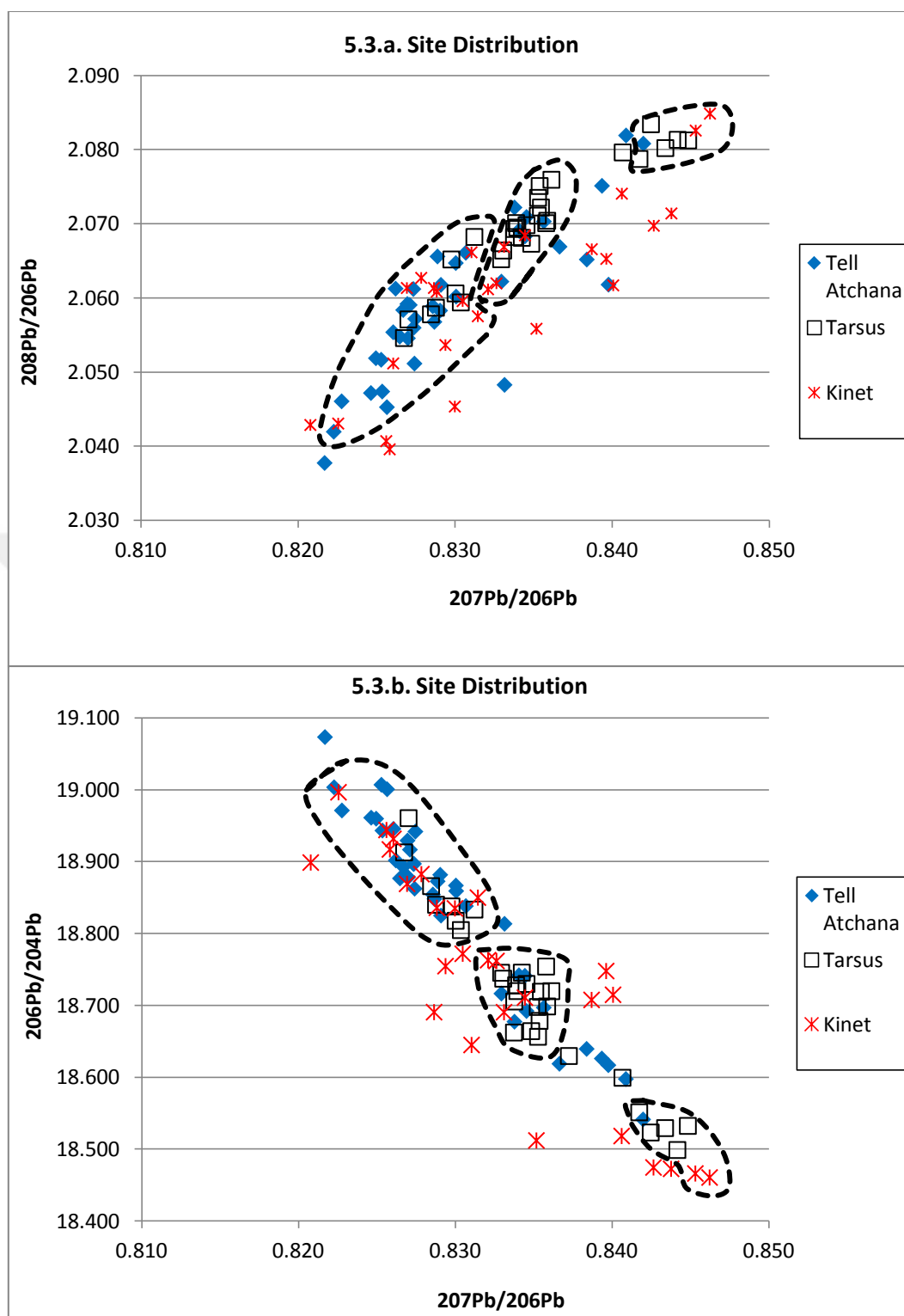


Figure 5.3. Lead isotope data of all objects (by site) with outliers omitted.

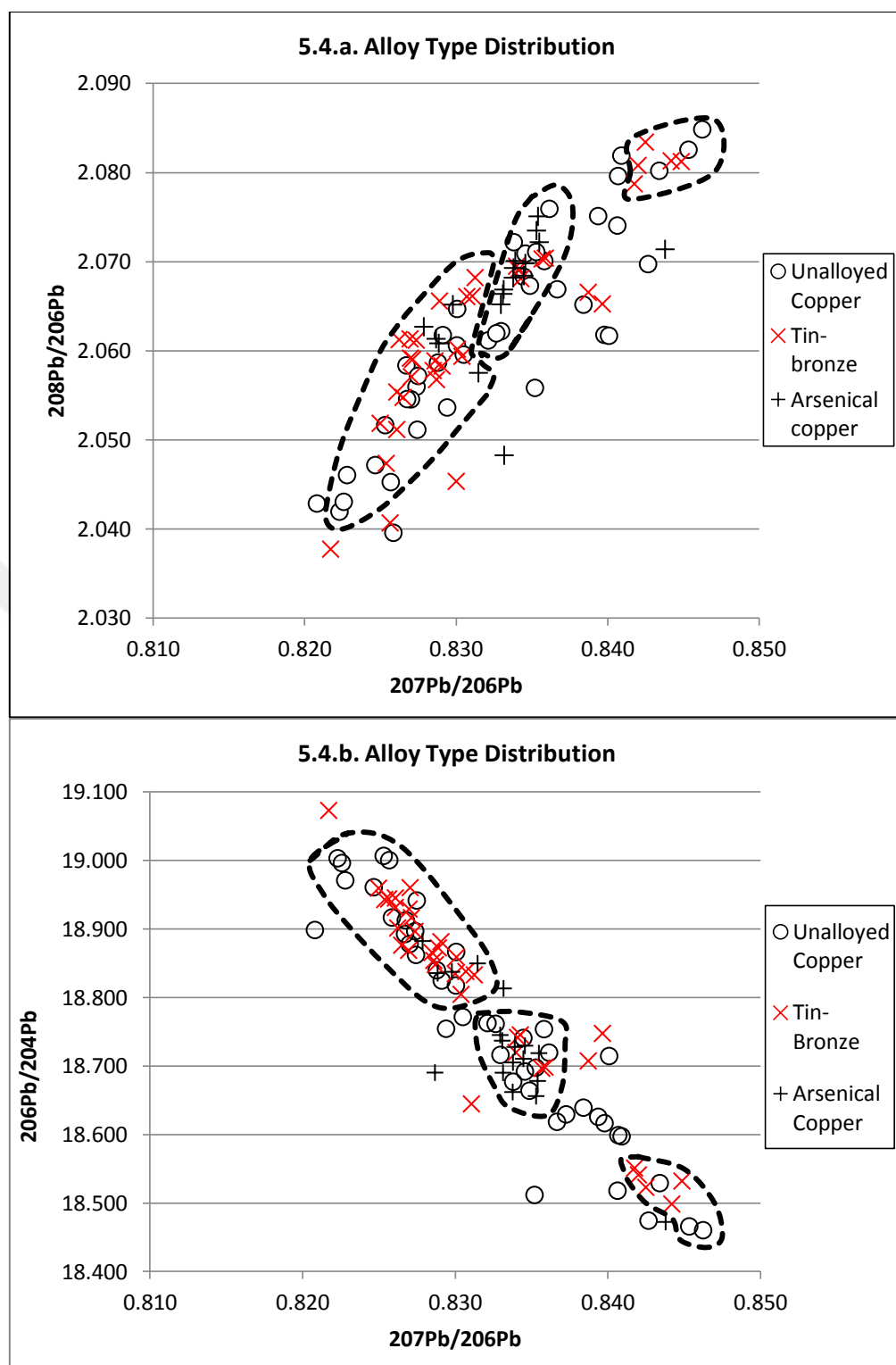


Figure 5.4. Lead isotope data of all objects (by alloy type) with outliers omitted.

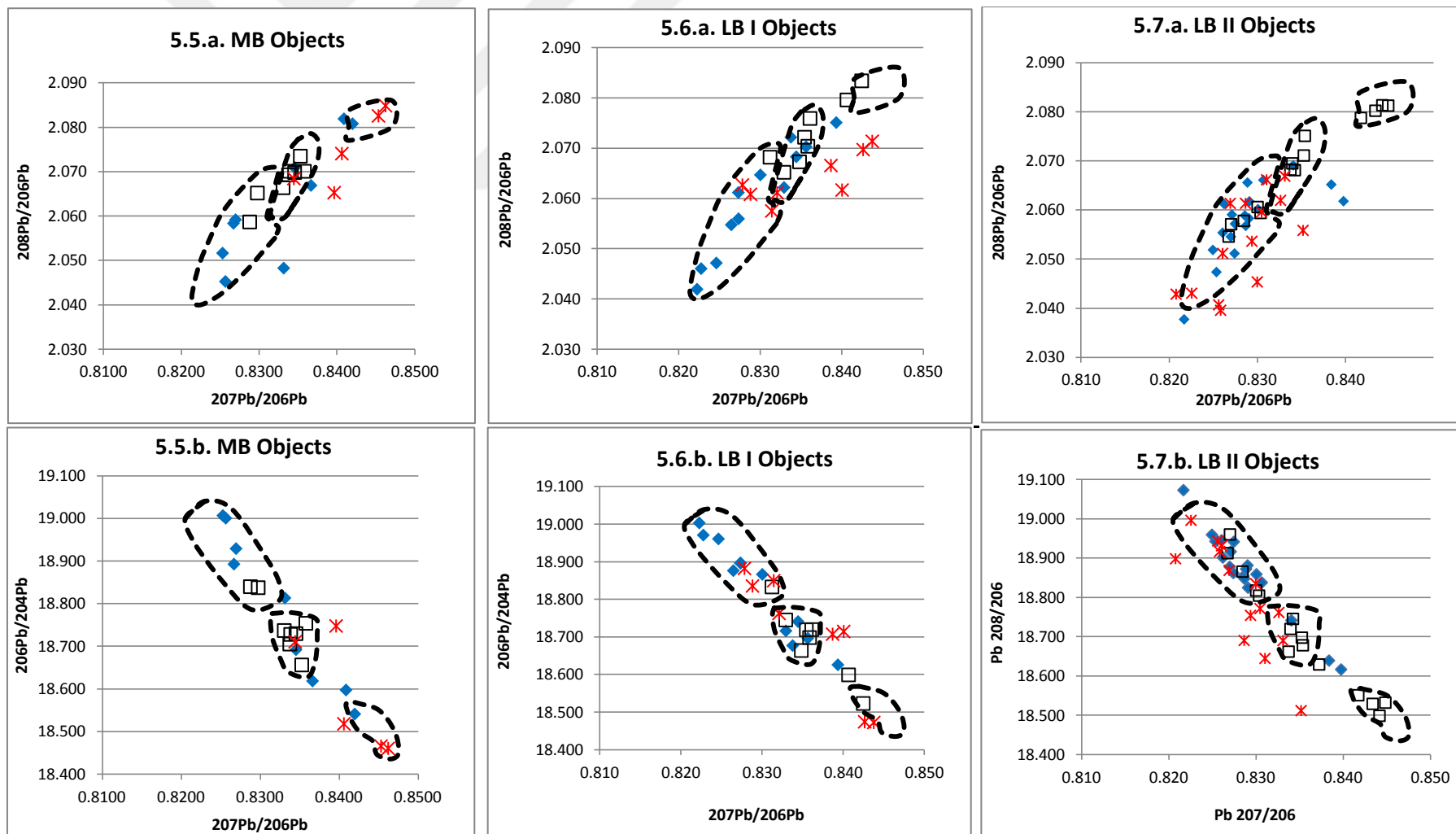


Figure 5.5. Middle Bronze Age samples (by site). Figure 5.6. Late Bronze Age I samples (by site). Figure 5.7. Late Bronze Age II samples (by site).

◆ ...Tell Atchana * ...Kinet □ ... Tarsus

Cluster B

Cluster B is likewise distinguished from the other clusters mainly by its $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ ratios, which have ranges between 18.66-18.76 and 0.832-0.836 respectively (figure 5.2). This cluster appears to have enjoyed its most extensive use before the Late Bronze Age II period, namely prior to ca. 1400 BC. The Middle Bronze Age and Late Bronze Age I periods respectively have eight (of a total of twenty-four) and ten (of a total of twenty-eight) samples in Cluster B (figure 5.5 and 5.6), whereas only eight (of a total of fifty) Late Bronze Age II items belong to this cluster (figure 5.7). In general terms, Cluster B exhibits an opposite chronological behavior to that displayed by Cluster A. Before the Late Bronze Age II period, it appears as a primary supplier, while during this period, the increased importance of Cluster A appears to have rendered Cluster B a secondary source.

With respect to individual sites, Cluster B seems to represent the most significant copper source for Tarsus, as half of its objects (sixteen of a total of thirty-three) is located in this cluster (figure 5.3). On the contrary, Kinet and Tell Atchana have very few representatives in this cluster, as only four (of a total of twenty-nine) objects from the former and six (of a total of forty) from the latter site are found in Cluster B. An examination of figures 5.5, 5.6, and 5.7 reveals that Cluster B remained an unimportant source for these two sites throughout the second millennium BC. As far as the alloy-types are concerned, we observe that the majority of arsenical copper objects (eleven of a total of eighteen) is concentrated within Cluster B. Such a concentration pattern is particularly valid for the arsenical copper items from Tarsus, as nine out of the total ten are located in this cluster. On the other hand, five of the seven arsenical copper objects from Kinet and the single representative from Tell

Atchana lie outside this cluster (figure 5.4). In sum, cluster B corresponds to certain source areas, which appear as a primary supplier of Tarsus in all three periods, particularly before the Late Bronze Age II period. Consequently, since arsenical-copper was most frequently used during the earlier phases of the second millennium BC and Tarsus was its most significant user, the majority of arsenical copper objects are concentrated in this cluster.

Cluster C

Cluster C is characterized by the highest $^{208}\text{Pb}/^{206}\text{Pb}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ ratios, and the lowest $^{206}\text{Pb}/^{204}\text{Pb}$ ratio, and is well isolated from the other two clusters (figure 5.2). It is defined by $^{206}\text{Pb}/^{204}\text{Pb}$ ratios lower than 18.626, $^{207}\text{Pb}/^{206}\text{Pb}$ ratios above 0.839 and $^{208}\text{Pb}/^{206}\text{Pb}$ ratios above 2.074. Compared to the other two clusters, Cluster C contains significantly fewer members, as only eight samples lie in it. In this cluster, the Middle Bronze Age and Late Bronze Age I periods are represented by three and one items respectively, while there are four samples from the Late Bronze Age II period.

Of the three Middle Bronze Age samples, two are unalloyed copper objects from Kinet, while the remaining item is a tin-bronze object from Tell Atchana. On the contrary, all five samples from the Late Bronze Age belong to Tarsus, four of which are tin-bronzes. These observations indicate that Cluster C represents certain source areas with a limited usage in our region. These sources supplied Kinet and Tell Atchana in the early second millennium BC, while Tarsus became their primary user with the advent of the Late Bronze Age.

5.4.3. Samples out of Major Clusters

There are a number of samples that can neither be classified as outliers nor relate to any of the three major clusters. These items are grouped according to common characteristics that are marked by color-coded arrows in figure 5.8. One of these minor groups contains three elements marked by blue arrows. The group exclusively originates at Kinet and consists of one Middle Bronze Age and two Late Bronze Age I samples. Interestingly, the group contains the only two tin-bronze artifacts from this site that date earlier than the Late Bronze Age II period. This might imply that before the Late Bronze Age II period, the limited number of tin-bronzes at Kinet likely originated from a unique source, which is distinct from the other sources that supplied the region.

There is another small group constituted by two items which are isotopically very similar. These are two pins from the Late Bronze Age I period of Kinet (samples KNH 1040 and KNH 1071) that are marked by black arrows in figure 5.8. Although the $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ ratios of these two items are close to those of Cluster C, their $^{208}\text{Pb}/^{206}\text{Pb}$ ratio is clearly distinct from this cluster. In sum, these two pins were possibly produced from a single ore source, which does not isotopically match any of the major clusters identified.

There are eight samples, which show a common distinct character with regards to their $^{208}\text{Pb}/^{206}\text{Pb}$ for a given $^{207}\text{Pb}/^{206}\text{Pb}$ ratio, as these are lower than observed in the main group of objects (marked by red arrows in figure 5.8.a). These samples lie scattered in the graph and therefore do not constitute a single cluster. All samples are from the Late Bronze Age II period, aside from one single item (sample JH 223 from Tell Atchana) that belongs to the Middle Bronze Age.

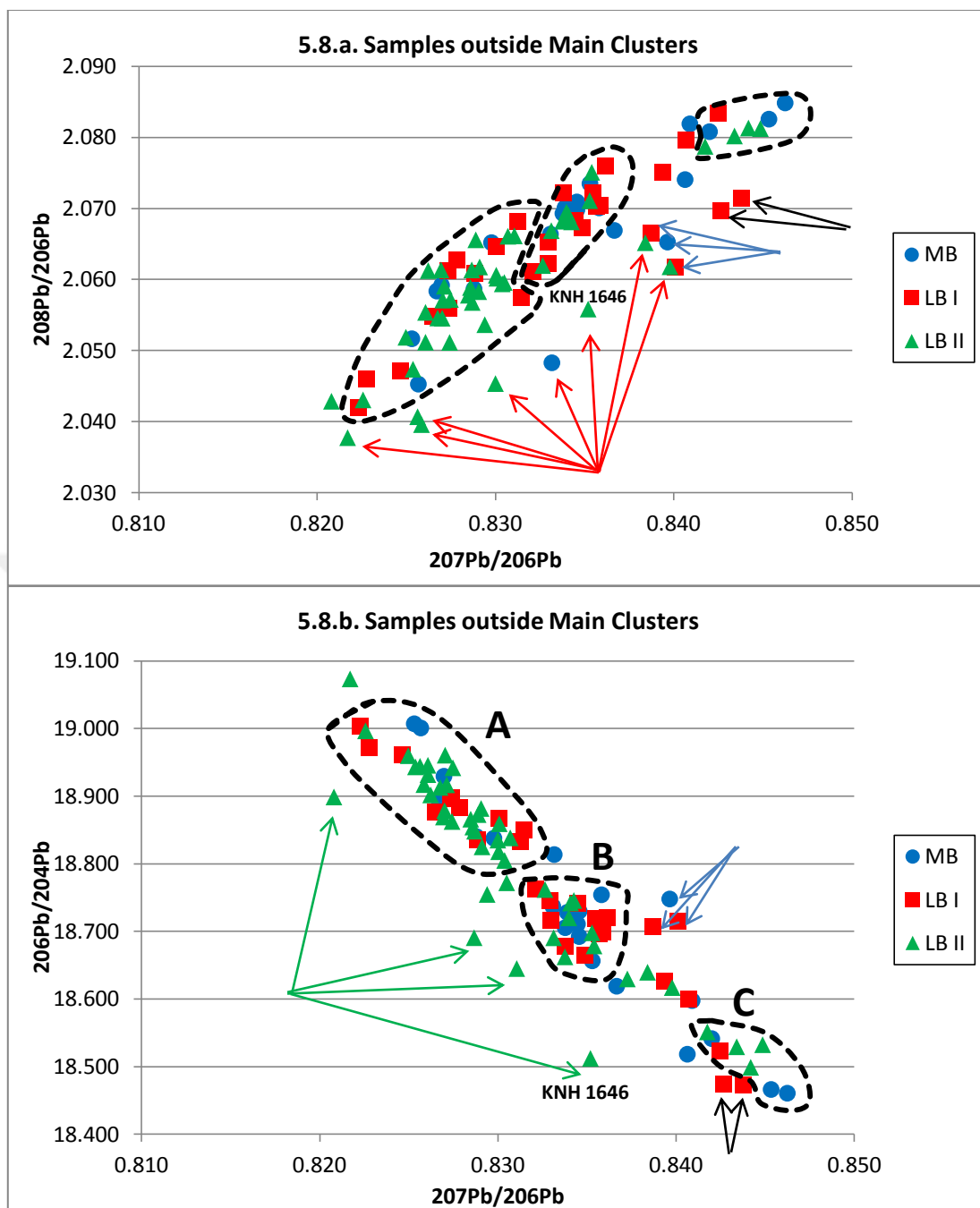


Figure 5.8. Samples outside main clusters.

In this group, unalloyed copper objects and tin-bronzes are equally well represented, while there is only one arsenical copper item. No sample of this class belongs to the Tarsus assemblage, whereas Tell Atchana and Kinet are represented by three and five samples respectively.

Finally, there are four samples, which stand out with their relatively low $^{206}\text{Pb}/^{204}\text{Pb}$ ratio with respect to $^{207}\text{Pb}/^{206}\text{Pb}$ ratio (marked by green arrows in figure 5.8.b)⁸⁶. All four samples are from Kinet and date to the Late Bronze Age II period. Thus, this group exhibits a significant coherence in terms of period and location. As far as the alloys are concerned, all three alloy types are represented in this small group. It is, however, to note that even though the members of this group lie on the same linear trendline, they are too far separated from each other to constitute a cluster.

5.4.4. Ingots

As far as the ingots and ingot-like objects are concerned, they are not found to be similar to each other in terms of isotope characteristics (figure 5.9). The bun ingot from Late Bronze Age I Kinet (sample KT 11421) is found to have a relatively low $^{206}\text{Pb}/^{204}\text{Pb}$ ratio for a given $^{207}\text{Pb}/^{206}\text{Pb}$ ratio. Consequently, it lies on the same linear trend as the last group discussed above (those marked with green arrows in figure 5.8.b), which also consists of samples from the same site. The ingot, however, is from the Late Bronze Age I period and thus, predates this group of artifacts as they exclusively date to the Late Bronze Age II. The first possible ingot from Late Bronze

⁸⁶ It is also to note that sample KNH 1646 displays a low ratio of $^{206}\text{Pb}/^{204}\text{Pb}$, as well as $^{208}\text{Pb}/^{206}\text{Pb}$ for a given $^{207}\text{Pb}/^{206}\text{Pb}$ ratio. Hence, this item also belongs to the group marked by red arrows.

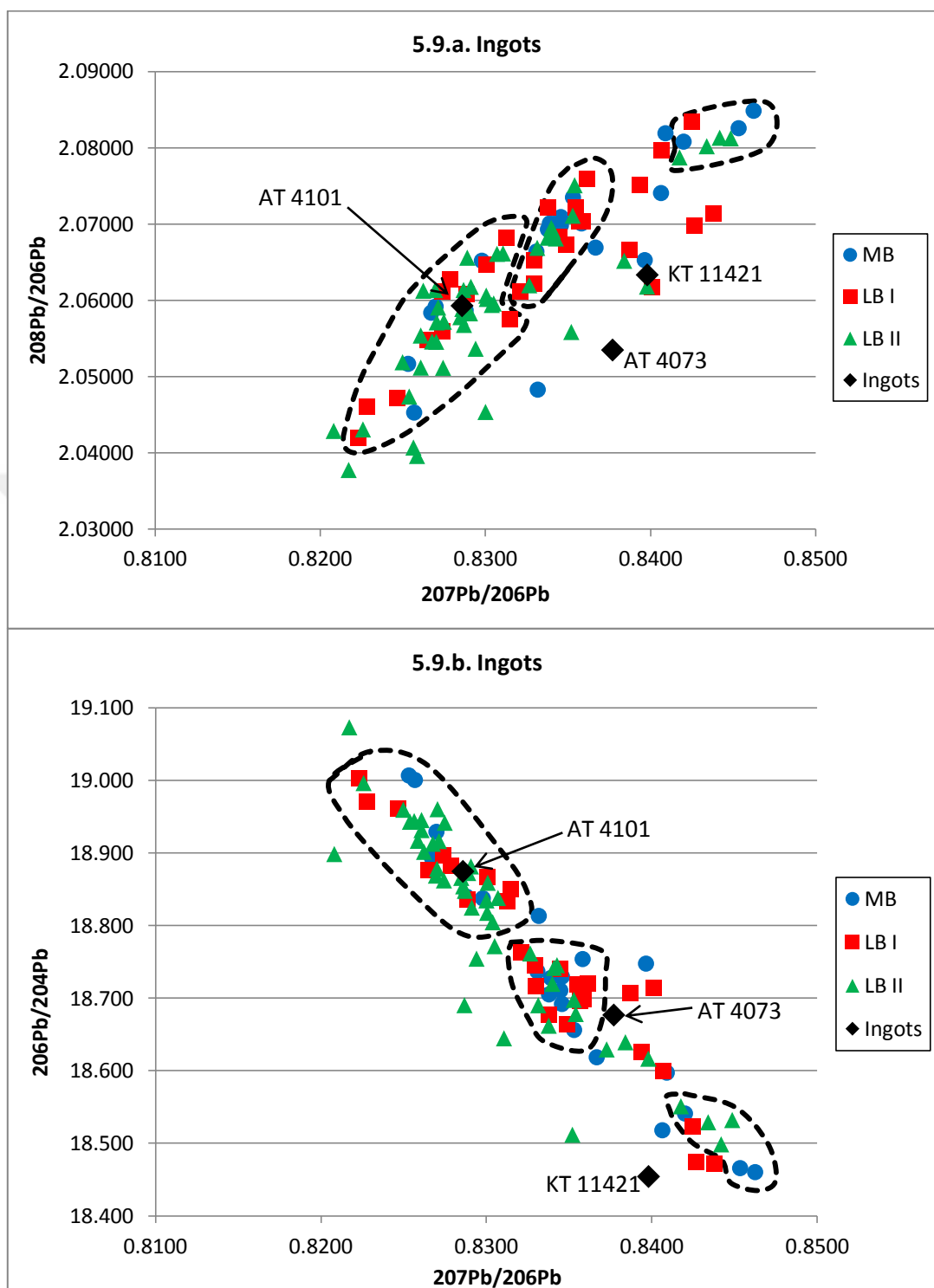


Figure 5.9. Ingots and ingot-like objects.

Age II Tell Atchana (sample AT 4101) displays similar isotopic ratios to those of Cluster A. This result is not surprising given that the vast majority of Tell Atchana samples, particularly those from the Late Bronze Age II period, lies in this cluster. The other possible ingot from Late Bronze Age II Tell Atchana (sample AT 4073) has a comparable $^{206}\text{Pb}/^{204}\text{Pb}$ ratio to that of Group B for the given $^{207}\text{Pb}/^{206}\text{Pb}$ ratio. However, its low $^{208}\text{Pb}/^{206}\text{Pb}$ ratio situates this item in proximity to the group marked by red arrows on figure 5.8.a.

5.4.5. Comparison with Objects Previously Analyzed

The comparison between the data of this study and those of earlier research from the region is presented in figure 5.10⁸⁷. An immediate observation is the strong resemblance between the earlier and current assemblages. Many of the samples analyzed previously are confidently situated within the clusters defined in this study. However, the low $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{206}\text{Pb}$ ratios for a given $^{207}\text{Pb}/^{206}\text{Pb}$ ratios, which are displayed by several samples of the current study, are not observed in the earlier data.

Cilicia

Of the Cilician objects previously investigated, two lead items from Tarsus and two copper objects from Mersin belong to the Chalcolithic period. The two samples from Tarsus have now been determined to be associated with Cluster A.

⁸⁷ The data consists of twenty-five copper-based samples from Mersin (Gale, Stos-Gale, and Gilmore 1985, 167-71), two lead items from Tarsus, and six copper-based samples from the Amuq (Yener et al. 1991, 555-56).

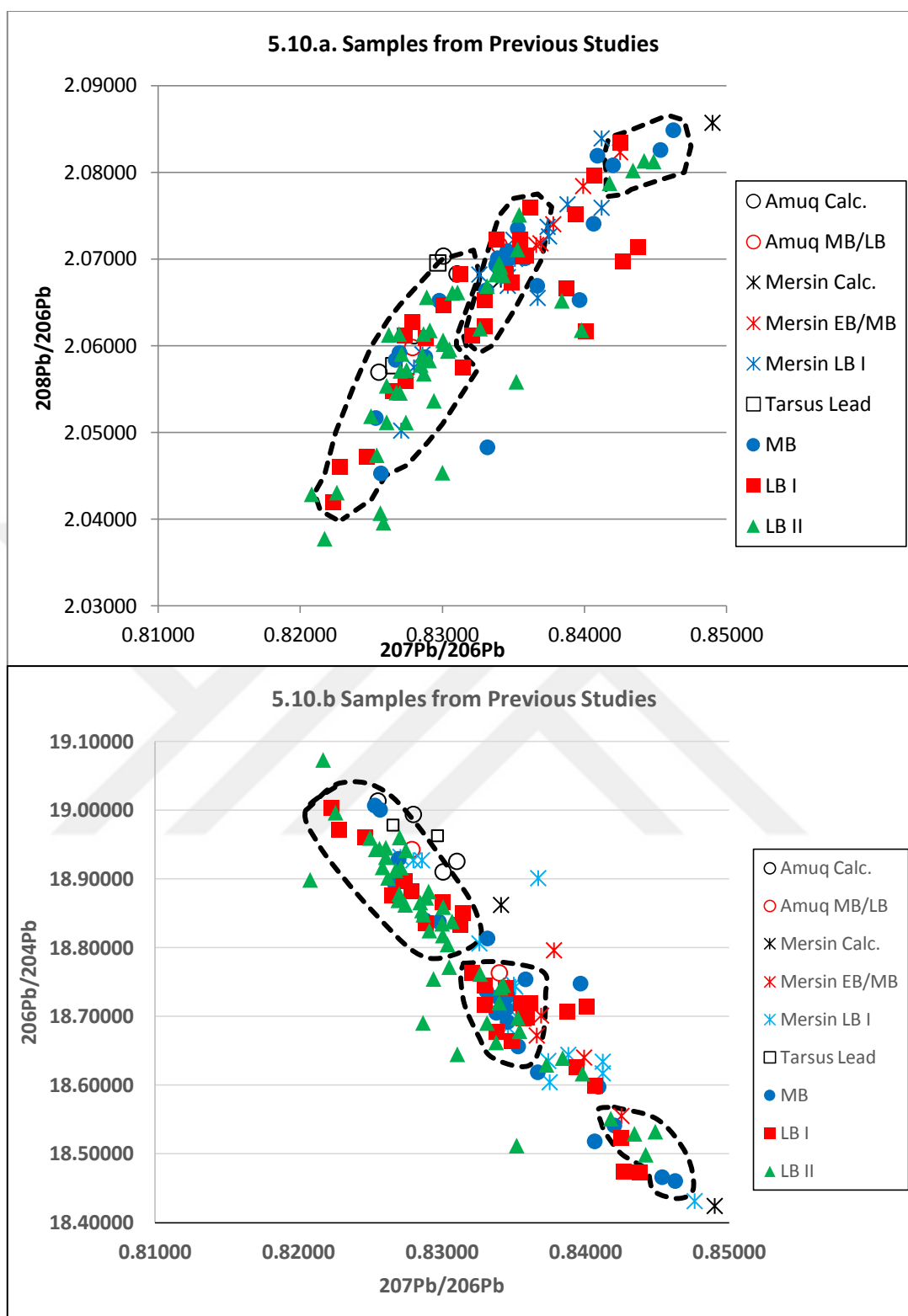


Figure 5.10. Comparison with samples from previous studies.

Those from Mersin lie close to the main linear trend of the current samples; but fall outside the main clusters. Of the five objects from Early and Middle Bronze Age Mersin, two and one items are found in Cluster B and C respectively. A single sample is located in the zone between Clusters B and C. The last representative of this group lies close to Cluster B but deviates from it due to its high $^{206}\text{Pb}/^{204}\text{Pb}$ ratio with respect to the $^{207}\text{Pb}/^{206}\text{Pb}$ value.

A more significant number of analyses are available from the Late Bronze Age period of Mersin. It is, however, to note that all fourteen samples from this period belong to the Late Bronze Age I phase and thus no data are available from the Late Bronze Age II period. The majority of samples in this group are found either in Cluster B or in the zone between Clusters B and C, while three samples fall into Cluster A. In general terms, the assemblage from Mersin displays strikingly similar characteristics to Tarsus objects analyzed in this study. Cluster B appears to represent the most significant source areas for Mersin as we observed concerning our Tarsus assemblage. Moreover, a significant number of Mersin samples are situated either in Cluster C or in the gap between Clusters B and C, similar to several Tarsus samples of the present study. A final resemblance between Tarsus and Mersin is that the source areas associated with Cluster A seems to have become important for both sites only in the Late Bronze Age and only to a moderate extent.

Amuq

From the Amuq region, four analyses are available from the Chalcolithic and Early Bronze Age I (Amuq Phases F and G) levels of Tell Judeidah, and two from the Middle and Late Bronze Age levels of Tell Ta'yinat. All four samples of the earlier

group (two copper and two silver objects) fall into Cluster A. The two later samples from the second millennium BC are lead items. One of these matches Cluster A, while the other is located in Cluster B. Accordingly, this small dataset from the Amuq indicates a predominance of Cluster A, and thus, displays a significant resemblance to the Tell Atchana assemblage of the current study.

5.5. POSSIBLE SOURCES OF COPPER

5.5.1. Source Areas in Close Proximity (South Anatolia And Cyprus)

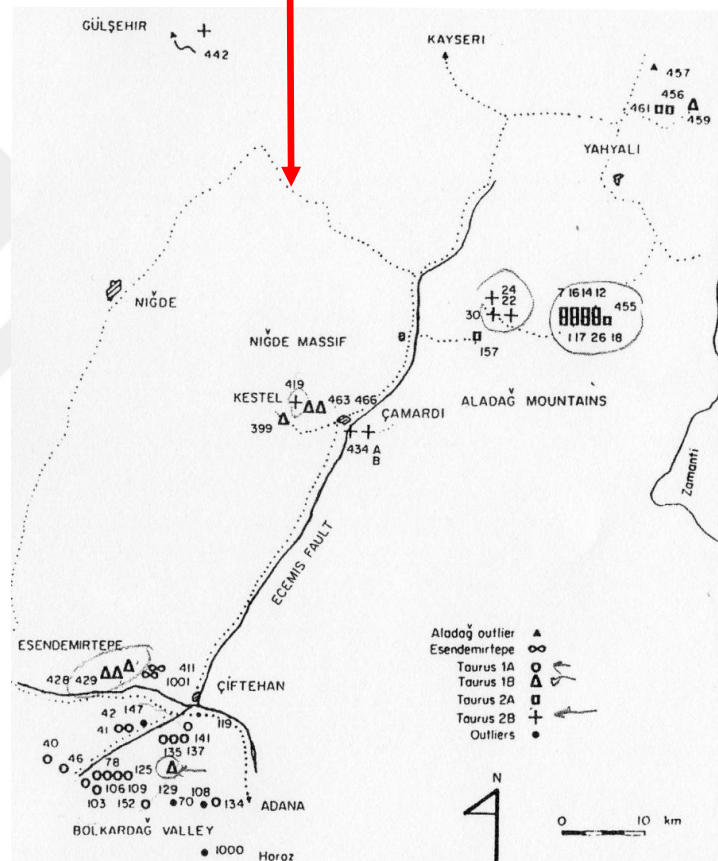
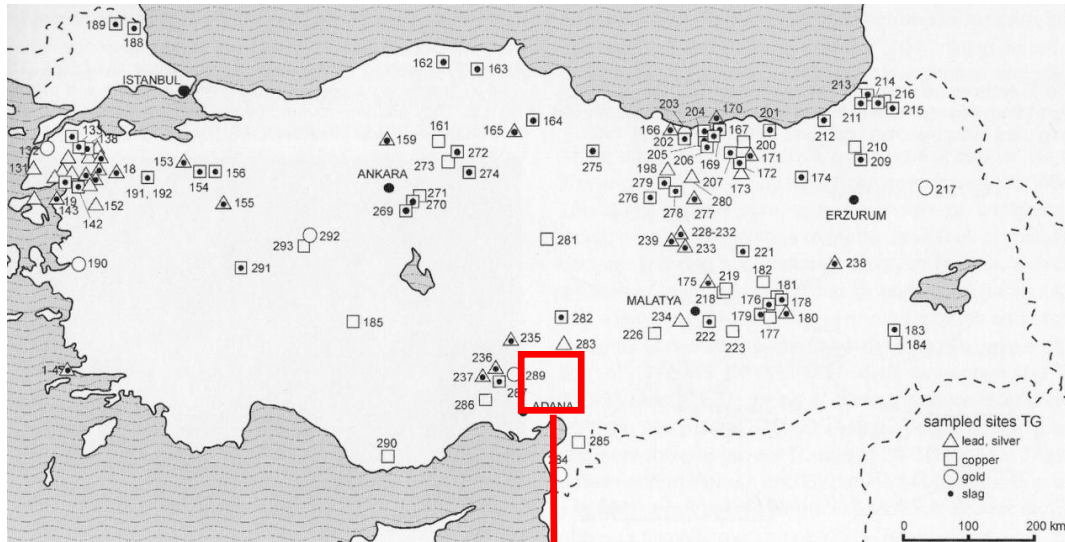
The central Taurus and the Amanus Mountains, which respectively border the Cilician and the Amuq plains, and Cyprus, which is known to have been an important copper supplier during the period of interest, host the most likely copper sources for the studied region. Of the two local mountain ranges, lead isotope data of ore samples are available from the central Taurus. The first research to characterize the isotopic composition of the ore deposits in this mountain range was carried out by Wagner and colleagues (Wagner et al. 1989). This study incorporated a relatively small number of samples and did not yield a detailed classification of the source areas.

More detailed studies are later conducted by Yener and colleagues, whose research particularly covered the Bolcardağ and Aladağ massifs in the Taurus Range and identified four distinct isotope groups designated as Taurus 1A, 1B, 2A, and 2B (Yener et al. 1991, 546-49). The Taurus 1A and the Taurus 2A groups exclusively consist of samples from the Bolcardağ and Aladağ ranges respectively. On the other hand, although the Taurus 1B and 2B groups form two isotopically homogenous

groups, both include ore samples from multiple localities in the central Taurus (map 5.1).

More recently, two intensive studies have been conducted in the area by a Japanese (Hirao, Enomoto, and Tachikawa, 1995) and a German (Begemann, Schmitt-Strecker, and Pernicka 2003) team. A close inspection of the results from these two studies and those of the earliest one by Wagner and colleagues reveals that all samples from the Bolkardağ Mountains overwhelmingly match the Taurus 1A group defined by Yener and colleagues. Considering this direct correspondence between the Taurus 1A isotopic group and the Bolkardağ area, all samples from the Bolkardağ are assembled under the “Bolkar” group in this study for convenience. Likewise, the samples from the German and Japanese studies originating in the Aladağ area display very close isotopic similarity to the Taurus 2A group of Yener and colleagues. Therefore, all samples from the Aladağ area are assembled under the “Aladağ” group in this study.

It is also observed that a minor number of samples examined by Hirao and colleagues originating from locations further to the north in the central Taurus are associated with the Taurus 1B group defined by Yener and colleagues. Finally, a few samples obtained by the Japanese team from the Niğde massif, also in the central Taurus, west of Aladağ, display similarity to the Taurus 2B group. Since both Taurus 1B and 2B groups do not directly associate with a distinct area of the central Taurus, the original designations by Yener and colleagues are used in this study. However, these groups are now expanded to incorporate the matching samples of the Japanese team.



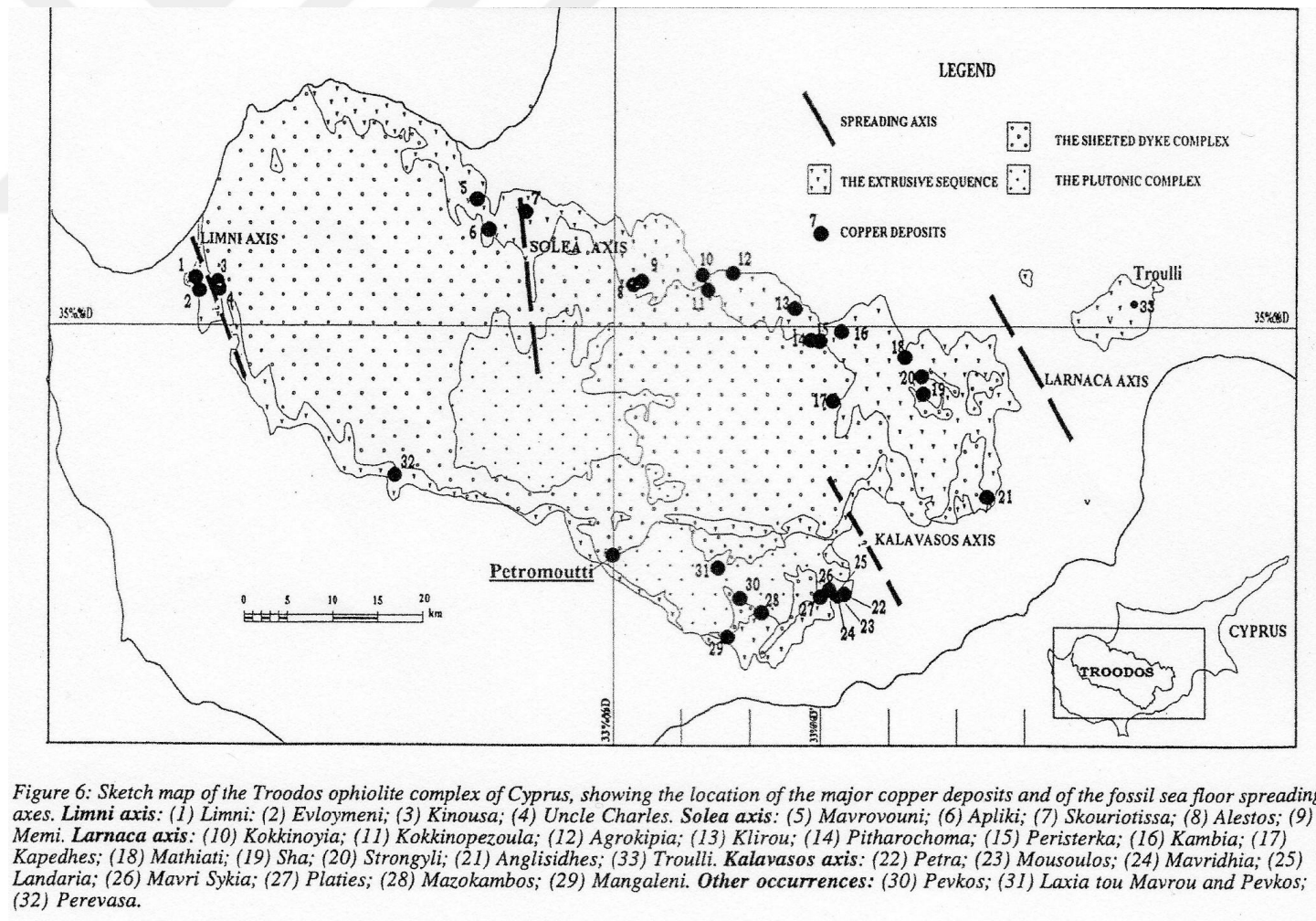
Map 5.1. Ore deposits in the central Taurus mountains. Adapted from Wagner and Öztunalı 2000, figure 1, and Yener et al. 1991, figure 2. Note that the Taurus 1A and Taurus 2A samples originate exclusively in the Bolcardağ and Aladağ Mountains respectively. Taurus 1B and Taurus 2B samples are widely dispersed in a broader part of the mountain range.

The source areas on Cyprus are extensively studied by the Oxford team, whose data are to a large extent publicized by Gale and his colleagues (Gale et al. 1997)⁸⁸. Their surveys distinguished four major isotope zones in the Troodos Mountains, which they designate as the Kalavassos, Larnaca, Limni, and Solea Axes. Besides these major zones, deposits are also located in the Limassol area in the southern fringes of the Troodos Range (map 5.2). The large number of analysis from each of these zones led to relatively broad isotopic fields that define their fingerprints. Thus, for a more effective comparison with the samples of this study, these axes are divided into isotopically homogenous sub-groups (table 5.1).

Table 5.1. Grouping of Cypriot ore zones in this study.

Subgroup	Localities
Kalavassos Axis	
Kalavassos 1	Anglisides, Landania, Mangaleni
Kalavassos 2	Platies, Petra, Mousolos Mine, Mavridhia, Mavri Sykia
Larnaca Axis	
Larnaca 1	Sha, Astri, Lythrodhonas, Milepost 17
Larnaca 2	Mathiati
Larnaca 3	Agrokipia, Kambia, Kirou, Kokkinopezoula, Kokkinoya, Mitsero, Peristerka, Pitharochoma, Troulli
Solea Axis	
Solea	Konizis, Alestos, Mavrovouni, Memi, Skouritsa
Solea/Apliki	Apliki
Solea/Ambelikou	Ambelikou
Limassol Area	
Limassol 1	Petramouti
Limassol 2	Laxia tou Mavrou
Limassol 3	Pevkos

⁸⁸ Minor additions to the database are made in Stos-Gale, Maliotis, and Gale 1998 and Gale and Stos-Gale 1999b. Some unpublished data are available at <http://oxalid.arch.ox.ac.uk/>.



Map 5.2. Source areas in the Troodos Mountains in Cyprus. Source: Stos-Gale et al. 1997.

The comparison between the south Anatolian and Cypriot ore fields (figure 5.11) reveals a striking distinction, which is more visible in the $^{207}\text{Pb}/^{206}\text{Pb}$ vs. $^{206}\text{Pb}/^{204}\text{Pb}$ plot (figure 5.11.b). The samples from southern Anatolia tend to align on a linear trend, which is located clearly above that of the Cypriot sources. Of the source areas on Cyprus, this characteristic is displayed only by a few samples from the Limassol 1 group (Petramouti deposit).

The overall sample assemblage of this study largely overlaps with the trends demonstrated by the local and Cypriot source areas (figure 5.12). Only those eleven samples, which have either low $^{208}\text{Pb}/^{206}\text{Pb}$ or low $^{206}\text{Pb}/^{204}\text{Pb}$ ratios with respect to $^{207}\text{Pb}/^{206}\text{Pb}$ values (those marked by red arrows in figure 5.8.a and by green arrows in figure 5.8.b), deviate from these ore fields, as they also deviate from the major linear trend. These outsiders may point to the possibilities that they either originate from non-local sources, or from certain local sources, whose isotopic signatures are yet to be determined. Because both groups exclusively consist of samples from Tell Atchana and Kinet, deposits in the Amanus Mountains, which are not yet isotopically characterized, may be considered as possible sources.

Separations between distinct groups are particularly visible in figure 5.12.b. As far as our Cluster A is concerned, it can now be observed that this cluster is associated with the deposits of Kalavassos 2, Bolkar, Kalavassos 1 and Larnaca 1 groups, listed in increasing order of $^{207}\text{Pb}/^{206}\text{Pb}$ values. Larnaca 1 group in the rightmost sector of the cluster displays a direct association to two samples only. Kalavassos 2 group at the left end does not have a significant relation to our samples due to its relatively high $^{208}\text{Pb}/^{206}\text{Pb}$ and low $^{206}\text{Pb}/^{204}\text{Pb}$ values.

Most of the samples in Cluster A, including the possible ingot (sample AT 4101), are found between the $^{207}\text{Pb}/^{206}\text{Pb}$ values of 0.824-0.829, and lie close to the

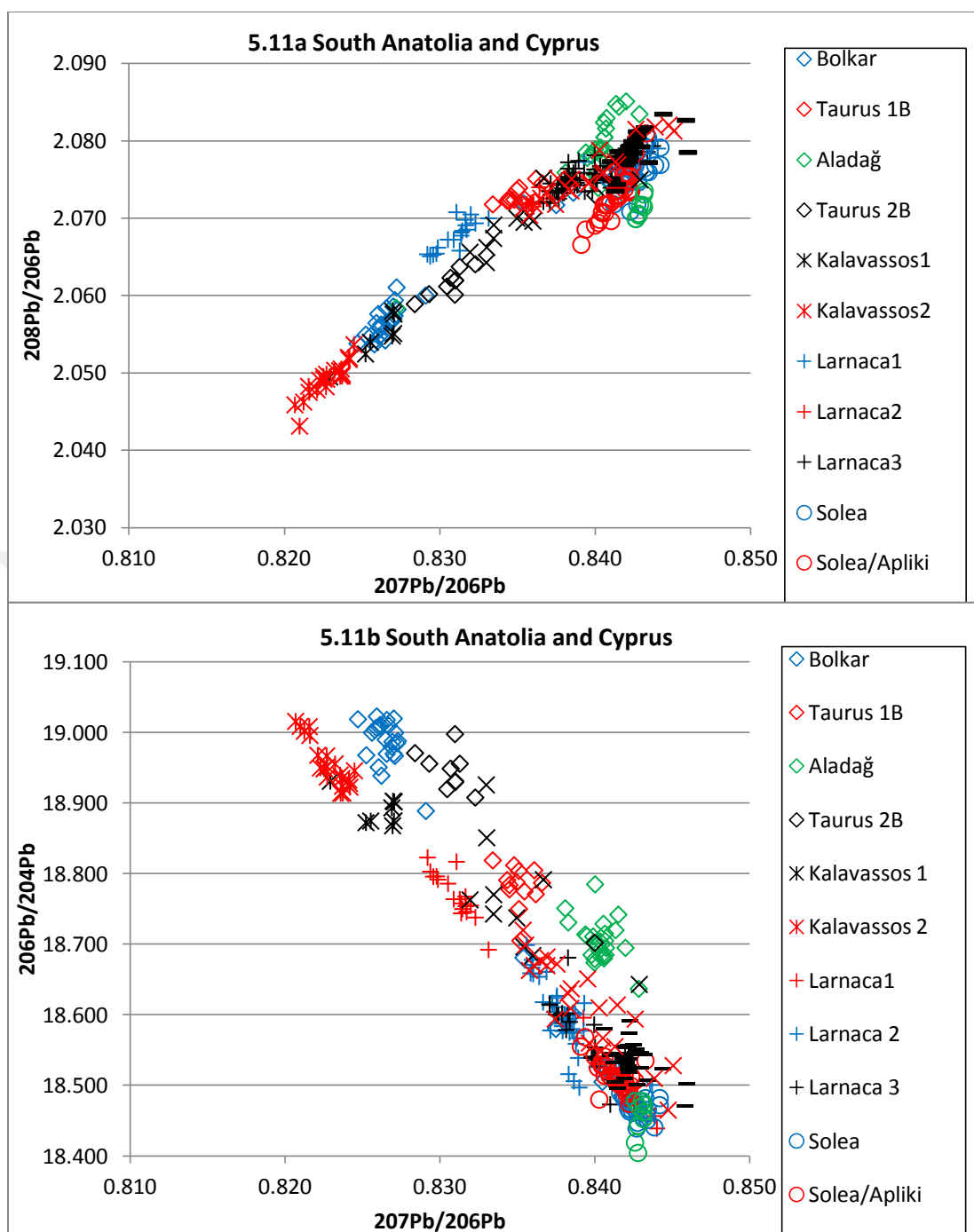


Figure 5.11. Ore deposits in close neighborhood (South Anatolia and Cyprus).

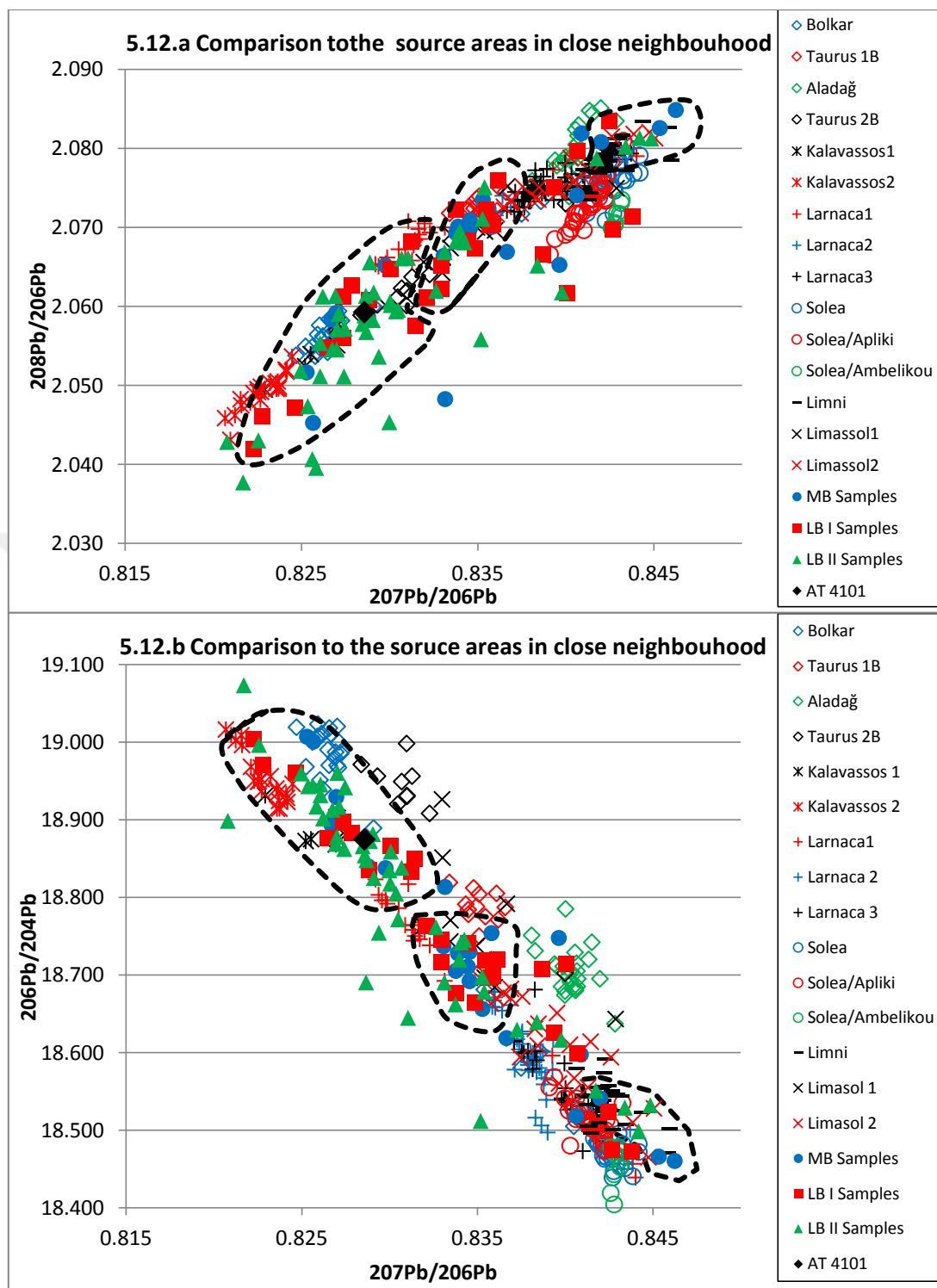


Figure 5.12. Comparison to south Anatolia and Cyprus.

few members of the Kalavassos 1 group. However, since the Kalavassos 1 group is represented by only few samples, it does not constitute a broad field, and as a result does not directly overlap with most of the samples in this part of the plot.

Two samples from Middle Bronze Age Tell Atchana, one sample from Late Bronze Age II Tell Atchana and one sample from Late Bronze Age II Tarsus directly overlap the Bolkar Group. Hence, these items should now be considered to constitute a unique group within Cluster A. Of the objects analyzed in earlier studies, two copper artifacts from Amuq, and one lead item from Tarsus were also found to match this source area. The remaining samples from earlier research, the associations of which with Cluster A are noted above (two silver and one lead item from the Amuq and one lead item from Tarsus), were noted to match other areas in the central Taurus Range (Yener et al. 1991, 555-59).

Cluster B shows associations to Larnaca 2 and the two Limassol groups of Cyprus. Larnaca 1 and Taurus 1B groups overlap this cluster only on one of the two plots and thus, cannot be considered to demonstrate a significant relationship. Larnaca 2 and Limassol 2 groups are relatively tightly concentrated at the right fringe of the cluster and display association only to a few samples. In contrast, Limassol 1 group has a wide-spread distribution pattern within the cluster, and as a result, shows a better overlap with the samples. However, on the $^{206}\text{Pb}/^{204}\text{Pb}$ vs. $^{207}\text{Pb}/^{206}\text{Pb}$ plot (figure 5.12.b) the majority of our samples are not located close to the dispersed representatives of this group. In sum, the observed correlation between the Cluster B samples and any source area is not particularly strong; but Limassol 1 deposits display the closest association to this cluster.

The samples of Cluster C have their strongest relationship with the Limassol 2 and Limni groups of Cyprus. Most of the samples dispersed within the zone between

Clusters B and C correlate with the source areas in only one of the two plots. Of the samples in this zone, only three are considered to have somewhat significant isotopic resemblance to known source areas: Two Late Bronze Age I items are associated with the Limassol 2 group, while one Middle Bronze Age object from Kinet lies closer to the Solea Axis, perhaps to the Apliki mine. Finally, the small group of two Late Bronze Age I items from Kinet (marked by black arrows in figure 5.8) has a strong correlation with the Ambelikou area of the Solea Axis.

In sum, the assemblage of samples displays a greater degree of overlap with the Cypriot deposits than those of south Anatolia that have higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios for the given $^{207}\text{Pb}/^{206}\text{Pb}$ values. In this respect, Kalavassos 1 and Limassol 1 groups appear as the best matching sources respectively for Cluster A and B. However, in both cases the majority of our samples are found in gaps between the fields representing the source areas, which renders a straightforward assignment of samples to these sources difficult. For our samples with higher $^{207}\text{Pb}/^{206}\text{Pb}$ ratios, Limassol 2 and Limni groups are better candidates as the origin of copper.

The Solea Axis, which was argued by the Oxford team to be the predominant source of oxhide ingots (Gale and Stos-Gale 1999, 274-275; Stos-Gale and Gale 2003, 97; Gale and Stos-Gale 2005; Gale 2006; Gale 2011, Stos-Gale 2011), matches only three samples in our assemblage. Strikingly, all three items are from Kinet. Of the source areas in the Taurus, only the deposits in the Bolkardağ area seem to correlate with a few samples of this study.

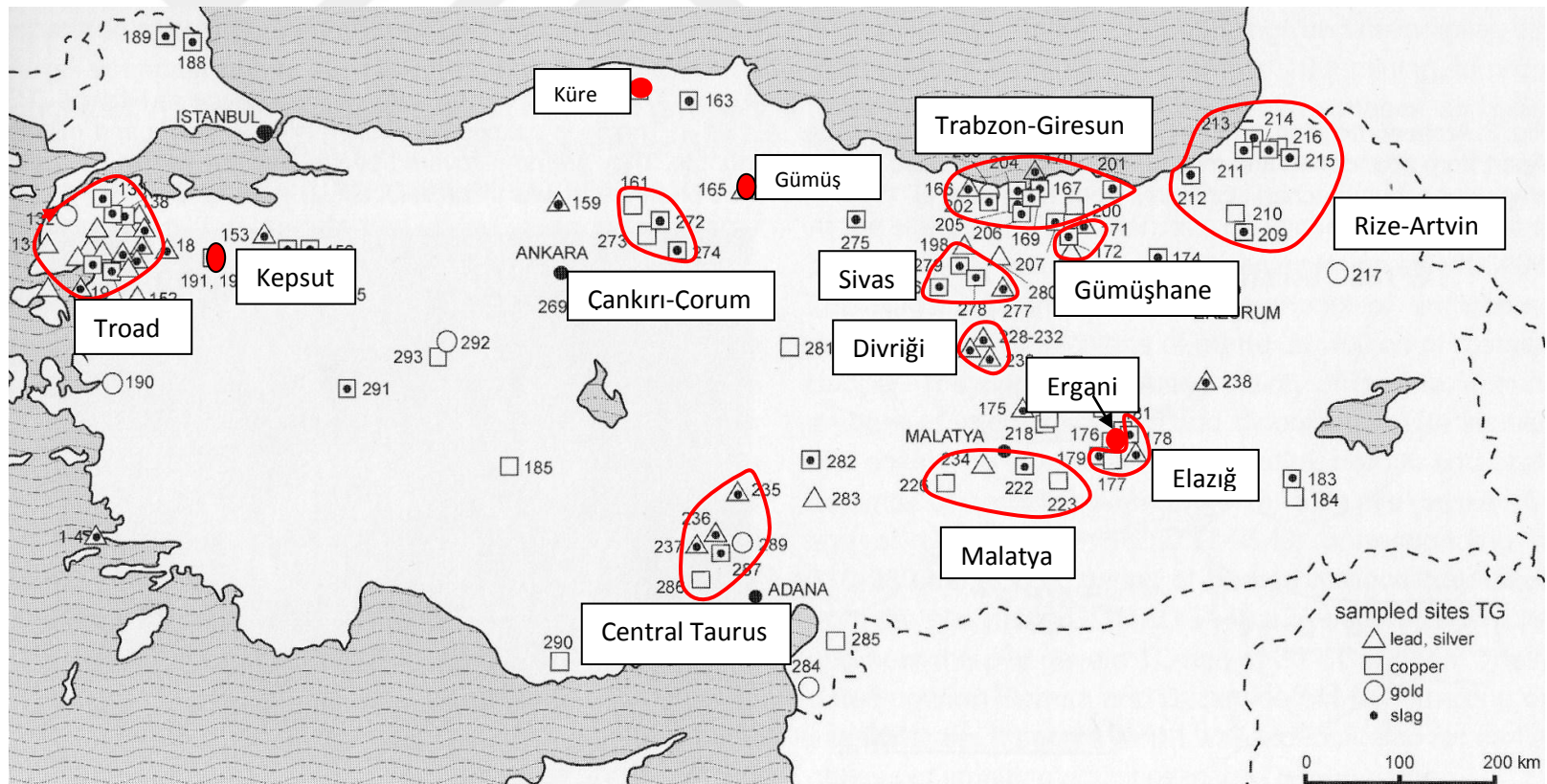
5.5.2. Comparison to the Aegean and Western Anatolian Source Areas

The extensive surveys of the ore deposits on the Greek mainland and the Aegean islands between 1979 and 1996 by the Oxford team resulted in the accumulation of a rich body of data⁸⁹. The deposits in Aegean Turkey have been surveyed by the German teams, whose data are made available in various publications⁹⁰ (map 5.3). The isotopic composition of the Aegean and western Anatolian deposits (figure 5.13) resemble those of the Taurus Mountains of southern Anatolia with respect to their $^{206}\text{Pb}/^{204}\text{Pb}$ vs. $^{207}\text{Pb}/^{206}\text{Pb}$ characteristics. Hence, they also display a linear trend which lies above the main group of our samples and does not have a strong correlation to them (figure 5.13.b).

Of the Aegean source areas, only those from Crete have somewhat lower $^{206}\text{Pb}/^{204}\text{Pb}$ ratios for the given $^{207}\text{Pb}/^{206}\text{Pb}$ values, and thus, lie closer to our samples. These Cretan deposits exhibit some overlap with samples in Cluster C. However, the Limassol and Limni areas of Cyprus, which we already associated with this Cluster, appear as better candidates given their closer proximity to the study region. Furthermore, copper deposits on Crete are well known to yield only low grade ores and the island most likely used imported copper during the Bronze Age (Muhly 2008, 72; Stos and Gale 2006, 304). As a result, Crete was not a likely exporter of copper during this period.

⁸⁹ The data from mainland Greece and the Aegean islands are available in Stos-Gale, Gale, and Alletts 1996. The data from the Cretan deposits are added in Stos and Gale 2006.

⁹⁰ The data from the German researches are available in Wagner et al. 1985, Wagner et al. 1986, and Begemann, Schmitt-Strecker, and Pernicka, 2003, with minor additions by the Japanese team (Hirao, Enomoto, and Tachikawa 1995). A number of samples from western Anatolia have been analyzed by the Oxford team. These analyses, which remain to a large extent unpublished, are available at <http://oxalid.arch.ox.ac.uk/>.



Map. 5.3. Major copper source areas in Anatolia.

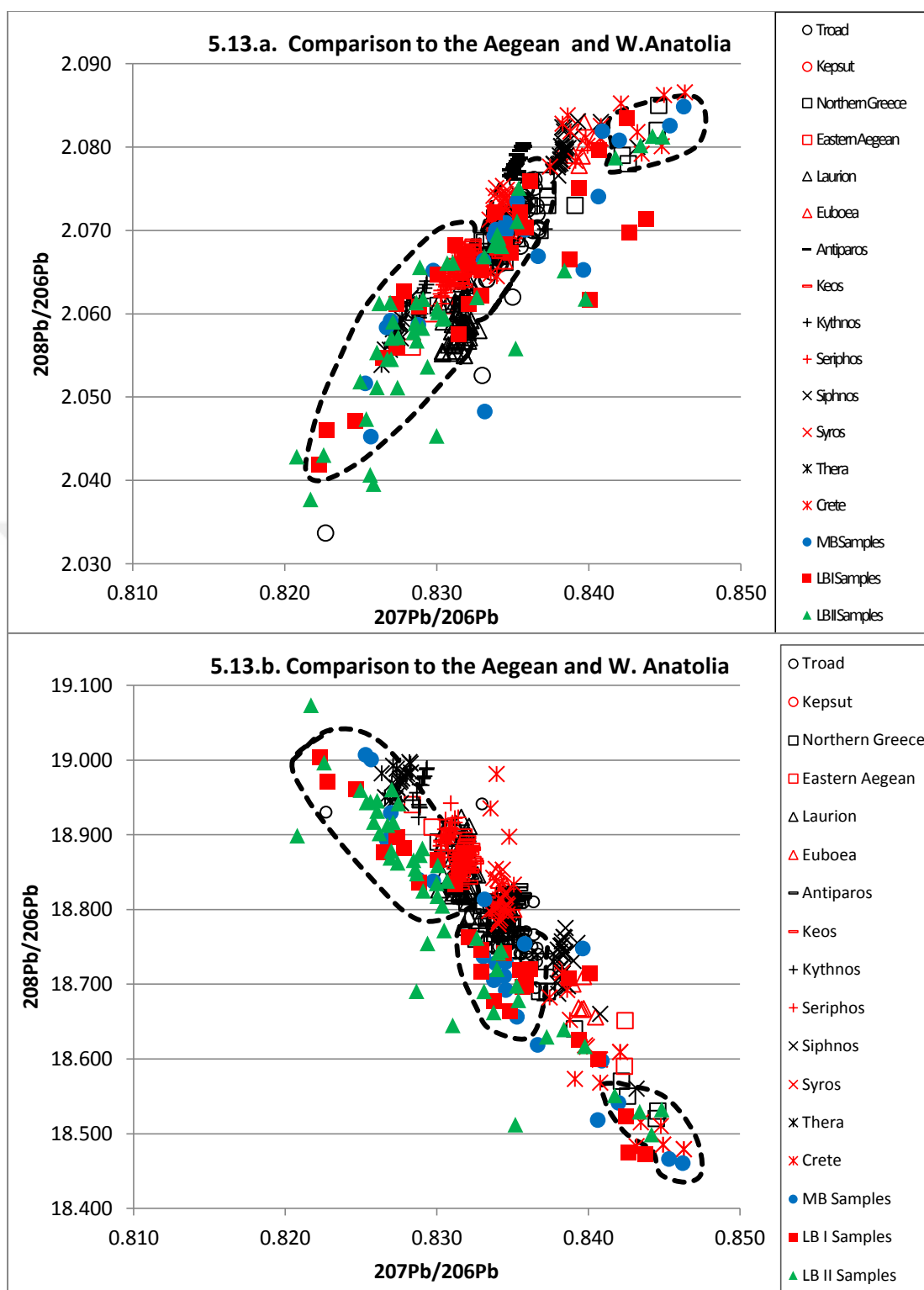


Figure 5.13. Comparison to the source areas in the Aegean and western Anatolia.

There are few items in Cluster A that seem to overlap with the ore deposits of Thera. However, the same items were seen to correspond at the same time to the Bolkar Group. In this situation, an association with the nearer source, namely the Bolkardağ area, would be more rational. Cluster B, which already had been weakly associated with the Larnaca and Limassol areas of Cyprus, does not display any convincing relation to any of the Aegean sources. Similarly, for our samples, which deviate from the main trend-line due to either low $^{208}\text{Pb}/^{206}\text{Pb}$ or low $^{206}\text{Pb}/^{204}\text{Pb}$ ratios, no matching source area in the Aegean can be determined.

5.5.3. Comparison to Northern And Eastern Anatolia

The situation of deposits in northern and eastern Anatolia with respect to our samples is shown in figure 5.14. The assemblage includes source areas in Ergani, Elazığ and Malatya in eastern; Giresun, Trabzon, Rize, Artvin and Gümüşhane in northeastern, Sivas and Divriği in east central, and Küre, Gümüş, Çankırı and Çorum in north central Anatolia (map 5.3). The data from these parts of Anatolia are the results of German surveys carried out in the 1980s⁹¹.

Ore deposits from these parts of Anatolia display isotopic characteristics, which are in general not easily distinguishable from many counterparts in southern Anatolia and Cyprus. This resemblance is best observed between Ergani in the east and the Bolkar Group in the south. Similarly, the isotopic fingerprint from all deposits of the northeast (Giresun-Trabzon, Rize-Artvin, and Gümüşhane groups) and some from central Anatolia (Çankırı-Çorum and Sivas groups) overlap Cluster C and the

⁹¹ The major part of the data is published in Seeliger et al. 1985, and Wagner et al. 1989. Later contributions are made in Sayre et al. 1992, and Hirao, Enomoto, and Tachikawa 1995. Finally, the unpublished analyses from north central Anatolia by Prof. Ü. Yalçın of German Mining Museum are included.

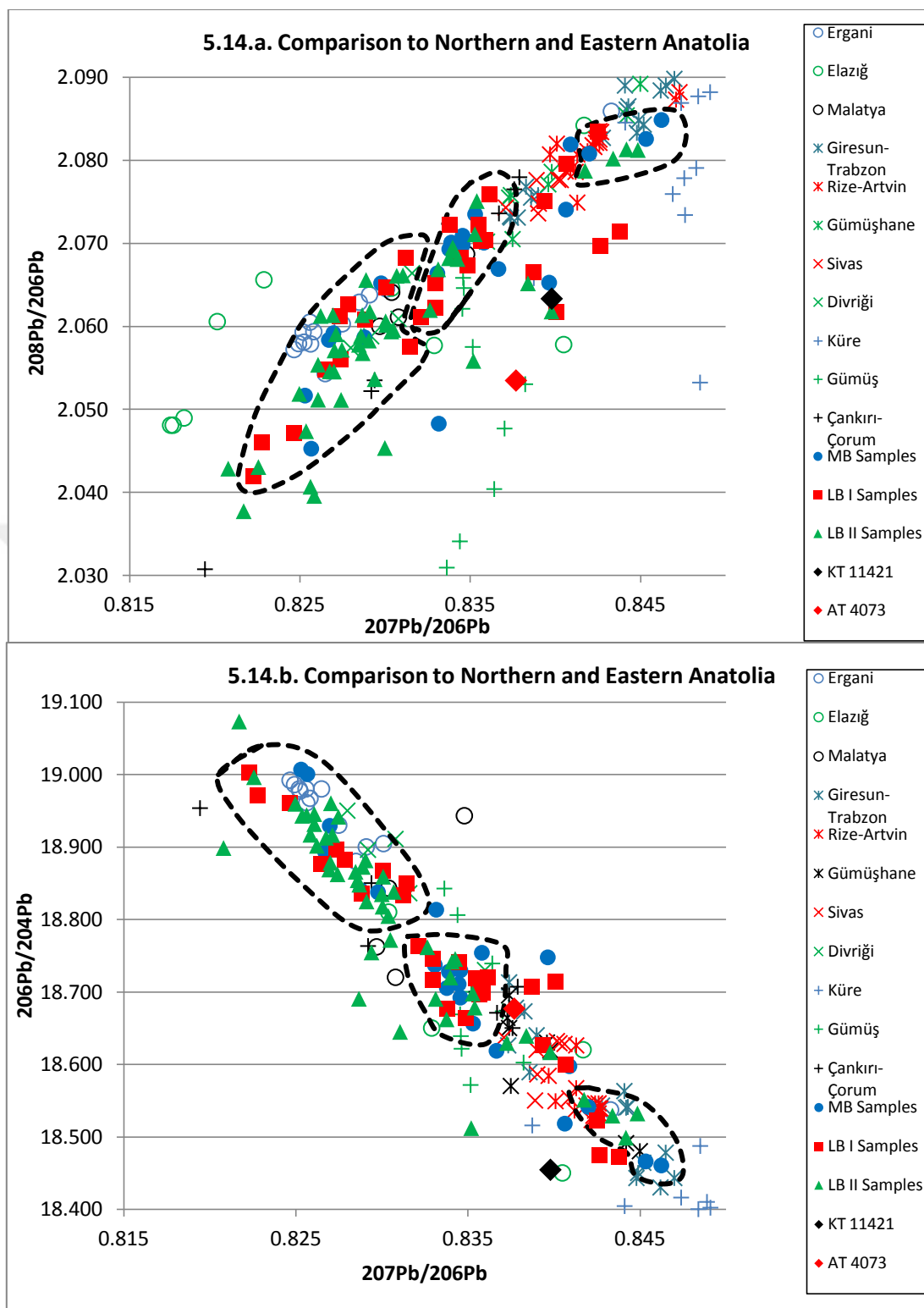


Figure 5.14. Comparison to deposits in northern and eastern Anatolia.

gap zone between Clusters B and C. Hence, these source areas are also isotopically similar to the Limni and Limassol areas of Cyprus, which occupy the same zone in the plot. In view of the distance and accessibility, the Bolkardağ area and the Cypriot source areas are tentatively considered the most likely sources for samples in these sectors of the plot.

Isolated representatives of the Gümüş and Çankırı-Çorum groups of north central Anatolia have relatively low $^{206}\text{Pb}/^{204}\text{Pb}$ ratios for the given $^{207}\text{Pb}/^{206}\text{Pb}$ value; and are thus situated on the same linear trend as the four Late Bronze Age II artifacts and the Late Bronze Age I bun ingot (sample KT 11421) from Kinet that display the same characteristics. However, neither the studied objects nor the ore samples in question lie close to one another, which renders a direct association difficult.

We also encounter for the first time a source area that displays a drastic downward shift of $^{208}\text{Pb}/^{206}\text{Pb}$ ratios from the main linear trend of our assemblage (figure 5.14.a). This feature is demonstrated by samples from Gümüş in north central Anatolia. However, our samples (including the possible ingot AT 4073), which are situated below the main trend and the main clusters, do not have any significant affiliation with these representatives of the Gümüş area. This is because the Gümüş group has such low $^{208}\text{Pb}/^{206}\text{Pb}$ values with respect to the $^{207}\text{Pb}/^{206}\text{Pb}$ ratio that their linear trend lies even below that of our samples.

5.5.4. Comparison to Other Near Eastern Sources

As demonstrated in figure 5.15, major copper supplying areas of the ancient Near East, such as Timna, Feinan and those in Oman significantly deviate from the

source areas of Anatolia and Cyprus in their isotope ratios⁹². The ores of these regions are particularly characterized by their relatively high $^{207}\text{Pb}/^{206}\text{Pb}$ ratios that are generally above 0.85. As a result, the main body of the sample assemblage does not show any significant overlap with these sources. As noted earlier in this chapter, only four of our samples have such high $^{207}\text{Pb}/^{206}\text{Pb}$ ratio, and are considered outliers.

Apart from these source areas, there are few ore samples from northern Syria that show a closer resemblance to the ores of southern Anatolia, Cyprus and the objects studied in this research. As far as the $^{208}\text{Pb}/^{206}\text{Pb}$ to $^{207}\text{Pb}/^{206}\text{Pb}$ plot is concerned, the Syrian samples are well aligned with the major linear trend of our samples (figure 5.15.a). However, three members of this group, which lie close to Clusters A and B, display somewhat lower $^{206}\text{Pb}/^{204}\text{Pb}$ ratio for a given $^{207}\text{Pb}/^{206}\text{Pb}$ value (figure 5.15.b). Hence, these Syrian samples resemble the four Late Bronze Age II artifacts and the Late Bronze Age I bun ingot from Kinet that have the same characteristics. It is, however, to be stressed that the samples from Syrian deposits are few in number and show a widely scattered distribution pattern. Hence, they do not constitute a coherent field.

⁹² The data from the ore deposits of southeastern Arabia are assembled from Begemann et al. 2010, Gale, Spooner, and Potts 1981, and Stos-Gale et al. 1997. For the data of Syrian deposits and those in Wadi Arabah, Gale, Spooner, and Potts 1981 and Hauptmann 2007, table A.2, A.3) are respectively consulted.

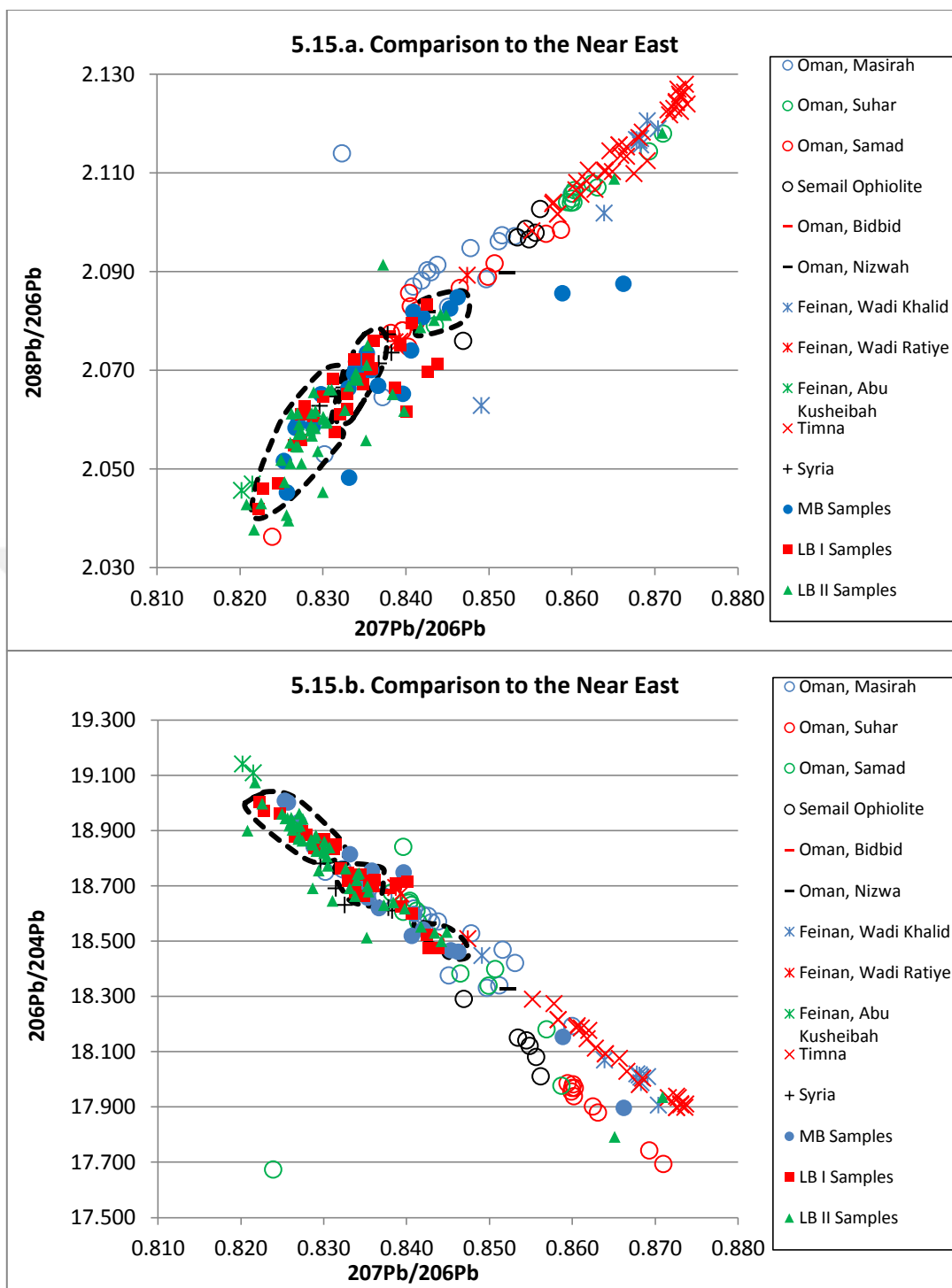


Figure 5.15. Comparison to Near Eastern deposits.

5.5.5. Comparison to the Central Mediterranean

Just as we observed concerning the ores of Timna, Feinan, and Oman, the source areas of the central Mediterranean region are primarily characterized by their high $^{207}\text{Pb}/^{206}\text{Pb}$ ratios (figure 5.16)⁹³. This ratio is predominantly above 0.85, and as we noted previously, only four of our samples bear such a high $^{207}\text{Pb}/^{206}\text{Pb}$ ratio. Those few samples from Sardinia with $^{207}\text{Pb}/^{206}\text{Pb}$ values lower than 0.85, display some overlap with samples in Cluster C. However, the relation of this cluster with Sardinian ores does not seem as strong as that with Cypriot deposits. This fact and the much closer proximity of Cyprus to the study region renders Sardinian ores as unlikely sources for the copper used in second millennium BC south Anatolia.

5.5.6. Possible Sources of Isotopic Outliers

Three items from Late Bronze Age II Tarsus and two from Middle Bronze Age Kinet have been identified as isotopic outliers at the beginning of the discussion due to their significant distinction from the rest of the samples. The sample with the highest $^{207}\text{Pb}/^{206}\text{Pb}$ and $^{208}\text{Pb}/^{206}\text{Pb}$ ratios is a chisel from Late Bronze Age II Tarsus (sample TKG 38.1624). Some close association is apparent between this item and the Sardinian deposits on both plots (figure 5.17). On the other hand, an isolated ore sample from the Çankırı-Çorum region of north central Anatolia also lies close to this item on both plots. Thus, more ore analyses from this region in the Hittite heartlands may render the area another likely source for this object, given the Hittite involvement in Cilicia during the Late Bronze Age II period.

⁹³ The data from central Mediterranean ores are published in Stos-Gale et al. 1995.

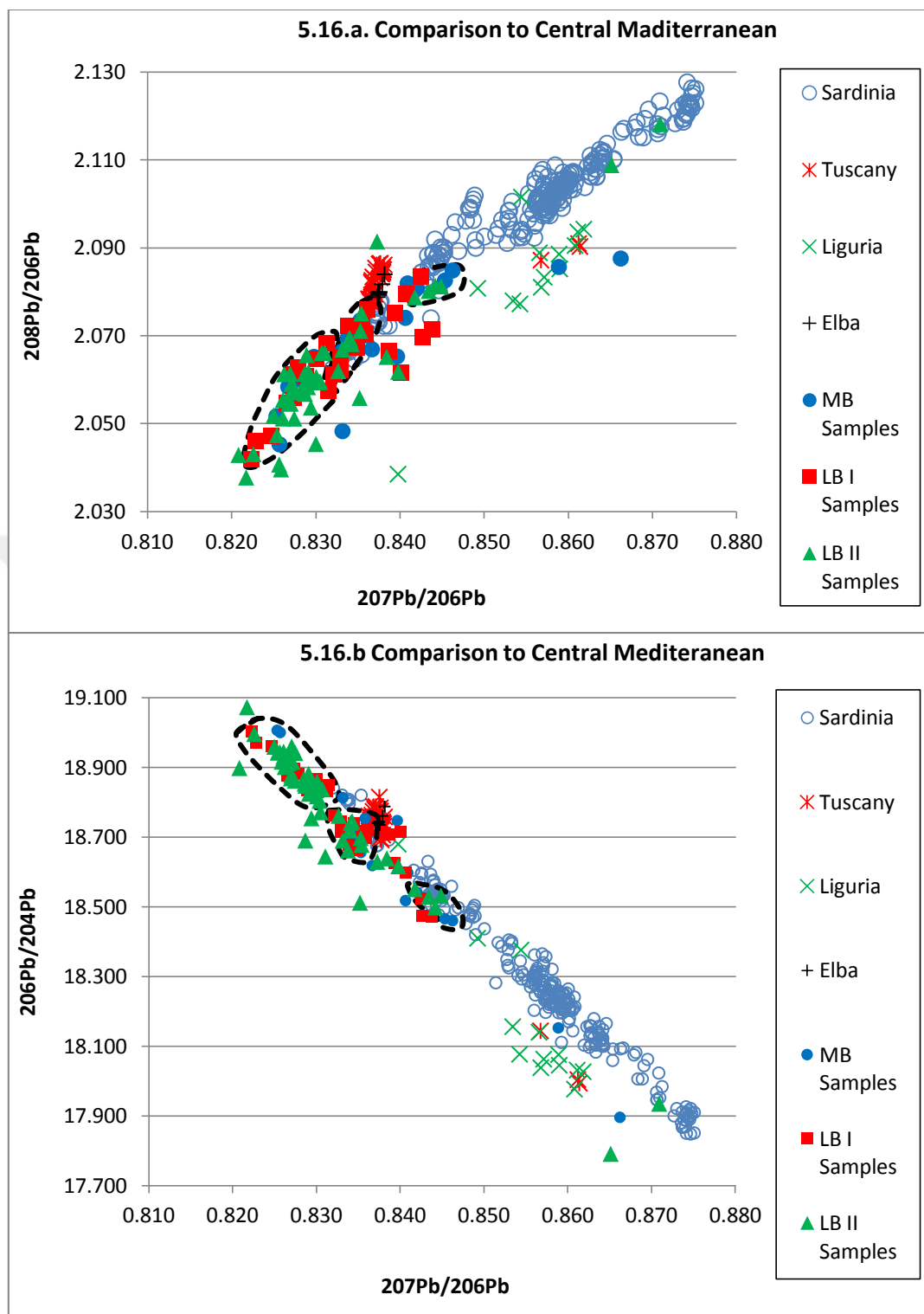


Figure 5.16. Comparison to deposits in the central Mediterranean.

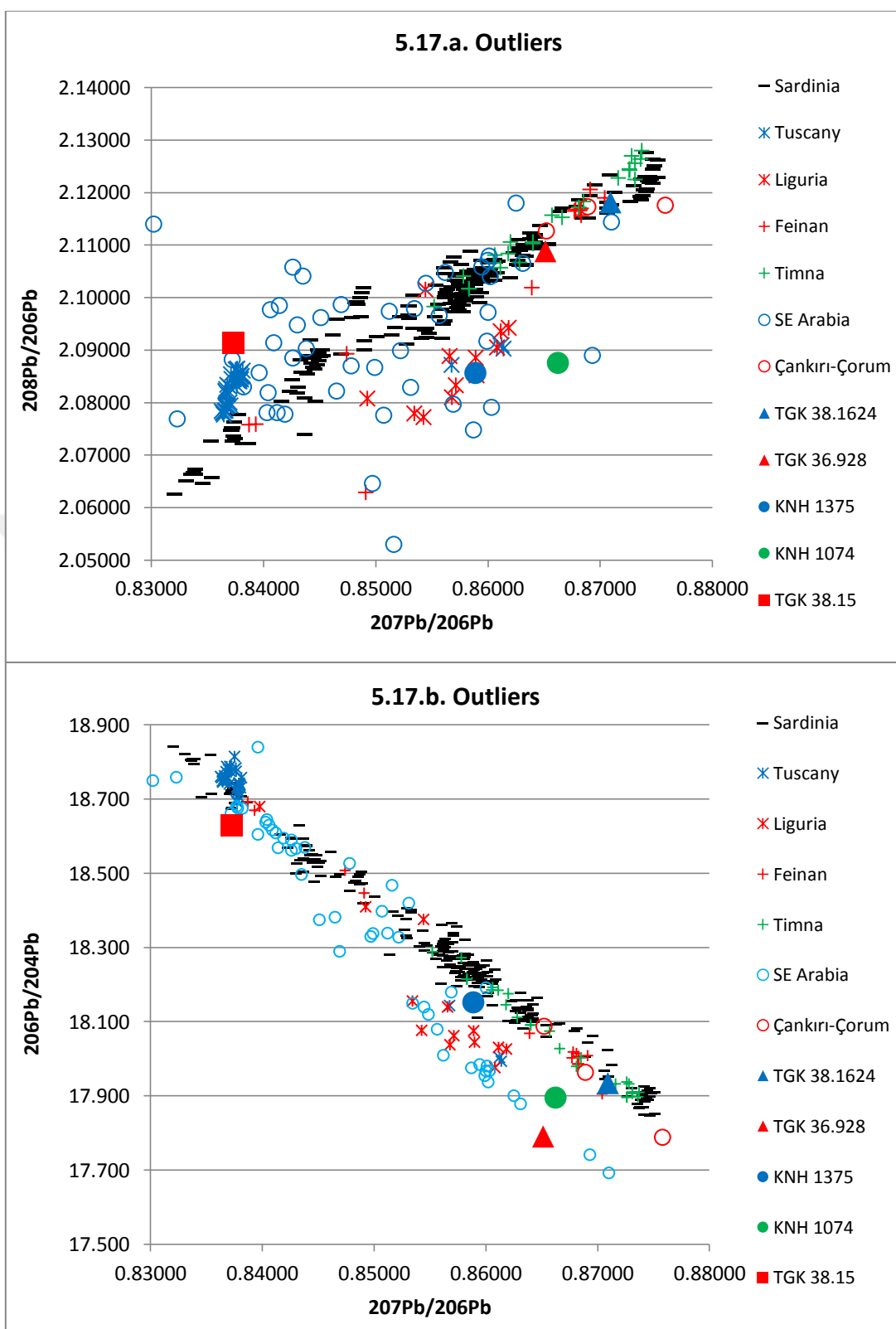


Figure 5.17. Possible sources of outlying samples.

The second object from Late Bronze Age II Tarsus is the pin TGK 36.928, which has noticeably lower $^{206}\text{Pb}/^{204}\text{Pb}$ ratios than the deposits in the central Mediterranean and Wadi Arabah. This item is clearly situated on the same linear trend as some ore samples from southeastern Arabia (Oman) on the $^{206}\text{Pb}/^{204}\text{Pb}$ vs. $^{207}\text{Pb}/^{206}\text{Pb}$ plot, without, however lying close to them. The Middle Bronze Age pin from Kinet (sample KNH 1375) lies only somewhat close to the samples from Liguria. The Late Bronze Age II ring from Tarsus (sample TGK 38.15) and the Middle Bronze Age needle from Kinet (sample KNH 1074) cannot be associated with any of the known source areas.

5.6. SUMMARY AND CONCLUSIONS

In general terms, the results of the lead isotope analysis indicate that the copper industries at all three sites were to a major extent supplied by the same source areas throughout the second millennium BC. On the other hand, the relative significances of these sources appear to have fluctuated with time and locality. Consequently, certain geochemical distinctions between different time periods, which were detected by the geochemical analysis, seem to be the result of these fluctuations rather than complete changes in copper sources utilized. Likewise, the geochemical differences observed between the sites can be attributed to the different importance of these source areas for individual sites, rather than completely distinct deposits that supplied each site.

Of the three clusters tentatively defined, Cluster A corresponds to certain source areas that were used gradually more extensively through the second millennium BC, to become ultimately the most important supplier of Cilicia and the

Amuq. The deposits represented by this cluster always constituted the most significant copper source for Tell Atchana starting with the Middle Bronze Age, while the other two sites did not start to use these sources significantly until the Late Bronze Age. In contrast, the source area associated with Cluster B gradually lost its importance through the second millennium BC. This area, however, remained the primary supplier of Tarsus, and as the data from previous studies indicate, of Mersin until the end of the Bronze Age. Finally, the copper sources associated with Cluster C supplied Tell Atchana and Kinet in the Middle Bronze Age, while Tarsus became their only client in the Late Bronze Age.

Certain deposits in the Kalavassos, Limassol, and Limni areas of Cyprus seem to be the best candidates to be associated with these clusters. However, we need to stress that a direct isotopic overlap between our samples and the ore data are observed only in rare cases and thus, the relationship to Cypriot sources is tentative and should not lead to absolute conclusions about the provenance of copper. As far as the Taurus deposits are concerned, four of our samples exhibit association to the Bolkardağ area. No sample of the current study could be identified to match other zones of the central Taurus, even though this had been observed for five objects in previous research from the region.

There are five items defined as isotopic outliers due to their distinct separation from other samples. Four of these display no relation to any of the source areas examined, while one item from Late Bronze Age II Tarsus displays association to Sardinian ore fields. Unless the copper of this item originated from an Anatolian or eastern Mediterranean deposit, the isotope characteristics of which has not yet been determined, Sardinia does not seem as an unlikely source. The contacts of this central Mediterranean island with the eastern Mediterranean basin during the 13th-11th

centuries BC are well evident (Sherratt and Sherratt 1991, 371-72; Lo Schiavo 2005, 404-7). Moreover, some Late Bronze Age copper objects from the Aegean (Stos-Gale and Gale 2003, 94-97) and Cyprus (Stos-Gale 2001, 203) were also determined to have matching isotope ratios with Sardinian deposits, implying that some moderate quantities of Sardinian copper might be reaching the eastern Mediterranean during this period.

There are also several samples that do not fall into the three defined clusters without, however, being significantly distinct from the main body of samples. Compared to the main group, these objects display either relatively low $^{208}\text{Pb}/^{206}\text{Pb}$ or low $^{206}\text{Pb}/^{204}\text{Pb}$ ratios for the given $^{207}\text{Pb}/^{206}\text{Pb}$ values. The majority of these objects are from Kinet, while few items belong to the Tell Atchana assemblage. With respect to low $^{208}\text{Pb}/^{206}\text{Pb}$ ratios, only some isolated ore samples from north-central Anatolia exhibit somewhat similar isotopic compositions. The objects with such low $^{208}\text{Pb}/^{206}\text{Pb}$ ratios are almost exclusively from the Late Bronze Age II period, and hence, it might be tempting to assume that small quantities of copper from the Hittite heartlands was reaching Cilicia and the Amuq during the period of Hittite involvement. However, the ore samples bearing these characteristics are very few and they do not directly overlap the samples in question. Thus, it is not possible to draw absolute conclusions from the current evidence.

It is also a possibility that the copper with such isotope characteristics might originate from the deposits of the Amanus Mountains, which are yet to be characterized isotopically. This possibility seems strong once we consider that all objects in question are either from Tell Atchana or Kinet, both of which lie in proximity to this mountain range. In contrast, no item from Tarsus or Mersin further to the west displays such an isotopic composition.

Also, as the majority of samples that fall outside the main clusters are from Kinet, certain geochemical peculiarities of the Kinet assemblage noted in the preceding chapter (high bismuth and antimony contents, strong Pb-Ag and Pb-Bi correlations) can perhaps be explained by the uniqueness of some deposits that supplied this site, and only to a minor extent Tell Atchana.

As far as the comparison between the alloy types is concerned, we observe that the majority of tin-bronze objects fall into Cluster A. This fact is a normal outcome, as most of the samples from the Tell Atchana and Late Bronze Age II assemblages, respectively the heaviest tin-using site and period, belong to this cluster. In contrast, there is a tight concentration of arsenical copper objects in Cluster B. This tight clustering is to a major extent caused by the Tarsus assemblage, as nine of the total eleven arsenical copper objects in Cluster B are from this site. The logical cause of this phenomenon appears to be that Cluster B was a prominent source particularly before the Late Bronze Age II period. Consequently, the majority of samples from the site and period that display the most extensive arsenic usage are hosted in this cluster. Thus, the tight clustering of arsenical copper samples, which was already demonstrated by the principal component analysis in the preceding chapter, can thus be explained.

Compositional analysis determined that tin-bronze objects have significantly higher arsenic concentrations than unalloyed copper items. Likewise, the arsenical copper assemblage displays a higher tin concentration than unalloyed copper objects. These differences possibly correlate with the distinct distribution patterns of alloy types within the defined clusters. However, the isotope data do not indicate that copper from completely distinct sources was used for the production of different alloys.

6. CONCLUSIONS

In this final chapter, the major results of the thesis will be summarized and evaluated. The first part of the discussion examines the implications on the position of the study region within the interaction networks of the second millennium BC. Subsequent to this, the important observations on the aspects of copper-based metallurgy will be investigated, which will be followed by the inferences on the absolute provenance of copper. Finally, the most important outcomes of the study will be reviewed, with reference also to the questions that remain unanswered and prospects for future research.

6.1. CILICIA, AMUQ AND INTERREGIONAL TIN TRADE

6.1.1. Summary of the Evidence

Middle Bronze Age (ca. 2000-1600 BC)

In the Middle Bronze Age, tin-bronze was in use in Cilicia and the Amuq, however to a somewhat modest extent compared to neighboring regions in Anatolia and the eastern Mediterranean. It is not easy to determine through which exchange routes and mechanisms this limited amount of tin was reaching the region of interest. There is no textual evidence to indicate that the two major networks of tin trade, namely the Assur-Kaneš and Elam-Mari routes, reached as far as Cilicia or the Amuq. Nevertheless, the latter route seems to be a more likely source of tin used in this

region at this time. Firstly, even though the Mari archives bear no direct reference to Alalakh or the Kingdom of Mukiš, several major centers in the vicinity, such as Aleppo, Carchemish and Ugarit are known to have received tin through Mari (Klengel 1992, 69-70, 75-78; Knapp and Cherry 1994, 145). Hence, it is fair to assume that, a slight westward extension of this exchange route could have brought tin to Alalakh/Tell Atchana, whose political connections to Aleppo is well documented.

As for Cilicia, archaeological evidence demonstrates that during this period the region was culturally linked to the Amuq and wider north Syria, rather than central Anatolia. As a result, a further westward extension of the Elam-Mari-Aleppo route appears as a more likely source of tin than a possible southward extension of the Assur-Kaneš line. On the other hand, we should also bear in mind that these two major routes were probably not the only networks, through which tin could be obtained, as several other long or short distance exchange routes may not be visible in textual records.

Late Bronze Age I (ca. 1600-1400 BC)

The destruction of Mari and Kaneš in the mid-18th century BC brings the two major exchange networks of the Middle Bronze Age to their ends. Likewise, the collapse of the dynasties of Babylon and Iamhad under Hittite aggression early in the 16th century BC significantly changed the political situation of the Near East. Textual sources from the 16th and 15th centuries BC are relatively scarce and thus, it is difficult to delineate the routes and mechanisms of interregional exchange. However, the general increase in the use of tin in the eastern Mediterranean indicates that long distance trade routes were active during this period.

Just as with many other parts of the Near East, the region under study now yields very limited written records. The few cuneiform tablets from Alalakh/Tell Atchana imply that Mukiš possibly remained an independent political entity from the fall of Aleppo until the Mittanian hegemony of the late 15th century BC. Archaeological evidence indicates that the Amuq region was still incorporated in the cultural sphere of the wider Syro-Levantine area. Alalakh's contacts with Cyprus are evidenced by the imported pottery, which first appears during this period. Relations with northern Mesopotamia are manifested by imported Nuzi Ware, especially during the period of Mittanian hegemony.

As far as Cilicia is concerned, the region might have been under a certain degree of Hittite control for some period during the 16th century BC, as at least one king of the Hittite Old Kingdom had the capacity to grant land in the country of Kizzuwatna. However, through most of the 15th century BC, when the Hittite kingdom was in a weakened state, Kizzuwatna clearly appears as an autonomous entity that several times appears as an equal treaty partner of the Hittites. At Tarsus and Kinet, Hittite pottery types constitute a significant portion of the ceramic corpus of this period, whereas the scarcity of Cypriot imports indicates only limited contacts with this island.

Parallel to the situation throughout the eastern Mediterranean, the period witnesses a notable intensification of tin usage in both Cilicia and the Amuq, which indicates their involvement of in interregional exchange. However, tin is still detected only in a quarter of the total assemblage in contrast to the wider Mediterranean including Cyprus and the Levant, where tin-bronze had now become the predominant copper alloy (Gale and Stos-Gale 1989b, 252-54, Balthazar 1990, 161, 431,

Rosenfeld, Ilani, and Dvorachek 1997; Pare 2000, 25-27, figure 1.14; Philip, Clogg, and Dungworth 2003).

Because of the dearth of textual evidence, it is difficult to deduce how tin reached the eastern Mediterranean during this period. Cilicia and the Amuq might have obtained tin through different trade networks, as their primary external contacts were now with different regions. The coastal sites of Cilicia might have obtained tin from central Anatolia, with which they had significant contacts, or through maritime trade. On the other hand, the Amuq region could have received tin by its contacts with northern Mesopotamia, through a possible trade route, which replaced the Elam-Mari-Ugarit line of the Middle Bronze Age. Such a route was perhaps controlled by the Kassites, who took control of the Middle Euphrates and Babylonia by 1475 BC, and finally expanded into the Persian Gulf by the 14th century BC (Van de Mieroop 2007, 123, 175; Evans 2008, 201). Thus, if tin was indeed coming from such eastern sources as Afghanistan or central Asia as commonly assumed, the Kassites might have played a major role in its distribution to the wider Near East.

Late Bronze Age II (ca. 1400-1200 BC)

Intense interregional correspondence and exchange, which characterizes the last two centuries of the Bronze Age enabled the long distance circulation of commodities in more substantial quantities than before. As an expected outcome, the influx of tin into the Near East and the Mediterranean intensifies and tin-bronze was now used more extensively throughout this geography. The bulk, maritime shipment of tin during this period is well documented at the Uluburun Ship, the cargo of which incorporated ingots of metallic tin with a total weight of one ton. The significant

increase in the availability of tin is also evidenced by the documents from Ugarit, as they demonstrate that the metal now became about fifteen times cheaper than referred in the early second millennium texts from Mari and Kaneš (Heltzer 1977, 205).

Textual information indicates that the circulation of tin was carried out primarily by certain mechanisms, which do not seem to have been administered by political authorities. In the case of Anatolia, the amount of tin owned by the Hittite state appears to have been obtained exclusively as taxes from its vassals and provinces (Siegelova 2005, 37). Thus, it seems more likely that tin was reaching the Hittite territory through some exchange networks, in which the royal authority had no direct intervention (Archi 1984, 201-2). Likewise, tin is not mentioned in the Pylos tablets, even though one would expect it to have accompanied the copper entrusted to metal-smiths. Unless the allotments were made in the form of pre-alloyed bronze, the smiths seem to have obtained tin through some non-palatial exchange (Gillis 1997, 512). The large-scale circulation and availability of tin outside palatial contexts is best documented at Nuzi during the 15th century BC and in the Middle Assyrian Kingdom during the 14th and 13th centuries BC. In both cases tin functioned as the currency, in which the prices of commodities and land were expressed (Muhly 1982, 257; Muhly 1995, 1509; Snell 1995, 1493; Faist 2001, 64; Monroe 2009, 199-202). As the royal annals provide no reference to interregional circulation of tin, it is tempting to assume that the interregional exchange of this metal was carried out primarily by independent merchants.

In Cilicia and the Amuq, this period overlaps with the hegemony of the Hittite empire. At least in the case of Alalakh/Tell Atchana, the Hittite dominance did not seem to have an inhibiting effect on exchange relations, as indicated by the continuity of contacts with the Levant, and more significantly, the increase in Cypriot and

Mycenaean imported ceramics. As far as Cilicia is concerned, the region now had tighter contacts with the Hittite heartland. On the other hand, in contrast with Alalakh/Tell Atchana, Cypriot pottery is present in relatively small quantities, while the Mycenaean imports are represented only by a handful of examples.

In this period, the use of tin significantly intensified in both Cilicia and the Amuq, and tin-bronze objects finally constitute about half of the study assemblage, similar to other regions of the eastern Mediterranean. Unfortunately, once again textual evidence is not sufficient to delineate the possible routes and mechanisms that brought tin into Cilicia and the Amuq. We may, nevertheless, presume that maritime trade was a possible source of tin that reached the region in this period. The evidence from the Uluburun Ship and tin ingots salvaged off the coast of Israel demonstrate that maritime trade mobilized substantial quantities of tin during this period. Considering the dominant winds and currents in the eastern Mediterranean, long distance vessels, such as the Uluburun Ship, are thought to have followed a counterclockwise route that started in the Levant and Cyprus, followed the south Anatolian coast in a westward direction until Rhodes, then turned south to Crete and subsequently to the Libyan coast to eventually follow the African coast to reach the Levant again (Sherratt and Sherratt 1991, 358). Hence, the sites on the south Anatolian coast lay on this major exchange route and most likely benefited from maritime trade.

Moreover, ships and merchants from the Cilician harbor town of Ura are known to have visited Ugarit regularly to conduct commerce (Linder 1981, 35; Knapp and Cherry 1994, 136; Bryce 2002, 95-96). Hence, Cilicians were among the active players involved in the intense interregional maritime exchange of the period. Therefore, it seems likely that Cilician sites obtained at least part of their tin through

these overseas contacts. Regarding Alalakh/Tell Atchana, even though this site does not lie directly on the coast, its access to maritime networks is even better evidenced than the Cilician sites thanks to the significant quantities of Cypriot and Mycenaean pottery. Thus, the same networks that brought these ceramic imports into this site might also have transferred at least part of the tin that reached the Amuq region.

6.1.2. Interpretation of the Evidence

The gradual increase in the use of tin through the second millennium BC clearly testifies that the relative abundance of tin-bronze in Cilicia and the Amuq followed the general pattern observed in the wider Mediterranean and the Near East. Therefore, the evidence from the area under study indicates that it had access to the major interregional exchange networks that transferred tin into the eastern Mediterranean area. The period when tin-bronze became the predominant copper alloy is now more confidently determined to be the Late Bronze Age II period in both Cilicia and the Amuq. If we examine how this would compare with the rest of the eastern Mediterranean and Anatolia, it is observed that this is a date later than in the neighboring regions. Tin-bronze had been in consistent use already during the third millennium in central Anatolia on the opposite side of the Taurus, and the Islahiye Plain, to the northeast of the Amuq. With respect to the second millennium BC, in other areas of the eastern Mediterranean such as Cyprus and the Levant, tin-bronze objects started to constitute more than half of the metal assemblages already during the 17th and 16th centuries BC.

Certain possibilities can be put forward to explain this phenomenon. At first sight, one might envisage that even though Cilicia and the Amuq were capable of

receiving tin from the major trade networks of the period, they did not have as much access to the metal as their neighbors. In other words, the degree of integration of Cilicia and the Amuq into these interaction spheres was less than other areas of the eastern Mediterranean and Anatolia. At least in the case of Cilician sites, such an explanation would seem to be in correlation with the scarcity of Cypriot and Aegean imports throughout the Late Bronze Age. However, the Amuq region, represented by Alalakh/Tell Atchana, displays more intense contacts with the outside world as evidenced by the significant quantities of pottery imports, and to some extent by the international character of its elite art. Thus, it is more difficult to assume that this site, or the region of Amuq in general, had a relatively inhibited access to exchange networks.

The second and more likely explanation could be that the interregional exchange of tin was carried out by down-the-line trade, in which the metal was transferred along its route in gradually diminishing quantities. In the Middle Bronze Age, the travel of tin from Elam to Mari and further to the west might have occurred in this way. As discussed above, it is quite possible that our region of interest lied at the western end of this line, and thus, received a relatively modest amount of the metal. The overland trade networks of the 16th and 15th centuries BC, which possibly replaced the Elam-Mari-Ugarit line of the Middle Bronze Age, might have operated in the same manner. Such a possibility could explain the shortage of tin in the study region until around 1400 BC. After this date, however, this situation changed perhaps as an outcome of the increased significance of maritime trade, in which our region of interest became actively involved.

The final possible explanation is that this observed difference between the study region and other areas of the Mediterranean and Anatolia could be an outcome

of the different contexts of studied assemblages. Due to the scarcity of elite burials and luxury metal items from Bronze Age Cilicia and the Amuq, the studied metals from the region are almost exclusively of utilitarian character recovered from domestic contexts. In contrast, the examined material from third millennium central Anatolia and the Islahiye Plain is almost exclusively from elite burials. Likewise, ornamental or ceremonial objects, some of which are burial finds, constitute a major part of the studied assemblage from Syria, the Levant and Cyprus. The preference for tin-bronze particularly in such objects and in elite contexts is much discussed concerning different parts of the Near East by many scholars (Stech and Pigott 1986; Stech 1999, 64-66; Weeks 2003, 188-91). The future discovery of Bronze Age elite burials with luxury and prestige copper-based objects in Cilicia and the Amuq may yield metal assemblages incorporating more significant quantities of tin-bronze items and provide us with a better basis for comparison, on which to speak with more confidence about the cultural preferences for tin-bronze in the region of study.

6.2. THE PATTERNS OF ALLOY USE

There are obvious differences between the three sites in terms of the intensity of tin-bronze usage. The relative abundance of tin-bronze within the total assemblage differs from Tell Atchana (47 percent) to Tarsus (35 percent) and to Kinet (24 percent). This ranking apparently echoes the relative degree of integration of the three sites into the interregional exchange networks. To start with Kinet, despite occupying the largest prehistoric mound in the eastern sector of the Cilician plain, it has a more modest size than the other two sites concerned. Moreover, situated on a coastal plain bounded by mountain ranges, the site had a predominantly sea-locked location and

was relatively isolated from major overland routes. Thus, Kinet appears as the most isolated locale among the three sites studied, which seems to be reflected by the relatively modest occurrence of tin at this site. Compared to Kinet, Tarsus appears as a more imposing Bronze Age center with its considerably larger size, its strategic situation near the entrance of the Cilician Gates, and its significance referred to in Hittite documents. Finally, Alalakh/Tell Atchana appears as the site most tightly connected to interregional trade, as evidenced by the significant quantities of ceramic imports. Hence, the ranking of the three sites with respect to the intensity of tin use does not come as surprise.

Parallel to the intensification of tin-usage, arsenical copper becomes progressively less common in the study region throughout the second millennium BC. The more interesting feature displayed by arsenical copper is the notable difference between its relative abundances in Cilicia and the Amuq. The alloy was intensively used in Cilicia until roughly 1400 BC, as evidenced by the current study, as well as earlier research. In contrast, it occurs very scarcely in the second millennium BC contexts of the Amuq as demonstrated by the Tell Atchana assemblage. Previous studies showed that this was also the case in the third millennium BC. At the moment it is not easy to explain why this alloy was so uncommon in the Amuq even in the third millennium BC, when it was in regular use in the entire Near East and the eastern Mediterranean.

Lead isotope analysis did not reveal any isotopic differences between the unalloyed copper and tin-bronze assemblages. Consequently, it is fair to assume that tin-bronze items were manufactured locally by the addition of metallic tin to the copper, which was otherwise used in an unalloyed state. Thus, the importation of tin-bronze in pre-alloyed form, which would likely lead to isotopic distinction between

the two assemblages, does not seem to have been practiced. This argument is supported by the Level IV documents from Alalakh, as they testify that the metal-smiths involved in palatial metal industry received copper and tin commonly in their raw forms (Wiseman 1953, 105). Only in particular cases, more specifically for the manufacture of chariot fittings, bows and weapons, they were entrusted with tin-bronze in its pre-alloyed form (Wiseman 1953, 14). The delivery of pre-alloyed tin-bronze to metal-smiths could have been facilitated by means of ingots, which, at least in the Hittite kingdom, appear to have been produced in state-administered workshops (Siegelova 2005, 37-38). Or alternately, tin-bronze was perhaps allotted in the form of scrap metal, which was commonly found in metallurgical workshops throughout the eastern Mediterranean.

6.3. COPPER SOURCES

A direct isotopic overlap between the study assemblage and the ore data are observed only in rare cases. However, the isotopic characteristics of our samples most closely resemble the ore fields on Cyprus, particularly certain deposits in the Kalavassos, Limni and Limassol areas. Besides this isotopic association, relating the second millennium BC copper objects from the study region to Cypriot deposits would also make sense based on archaeological and textual evidence. Cypriot copper is known to have reached Mari in the early 18th century BC, and Babylonia from the late 18th century BC onwards. In the last two centuries of the Bronze Age, textual evidence testifies to the exportation of Cypriot copper to Egypt and Ugarit in substantial quantities. Besides, 14th and 13th century BC copper oxhide ingots found all over the Mediterranean are argued to be isotopically compatible with deposits in

the Solea Axis. Therefore, the importation of Cypriot copper into Cilicia and the Amuq, which are already in proximity, throughout the second millennium BC does not appear as an unexpected phenomenon. Only very few samples have their origins most likely in the local deposits of the central Taurus Mountains, particularly in the Bolkardağ Massif. This is also not an unexpected outcome, as the primary metal ores in the central Taurus consists of lead and silver mineralizations, whereas the copper deposits are only of minor importance.

The distinct source areas that supplied Cilicia and the Amuq were used to different extents at different sites and periods. Alalakh/Tell Atchana predominantly made use of deposits associated with Cluster A, perhaps in the Kalavassos Axis, in all periods. For Tarsus, the source areas associated with Cluster B, perhaps in the Limassol Area, constituted the primary source of copper. Kinet, on the other hand, used copper from more diverse sources including clusters A and B. But most notably, the vast majority of samples that have low $^{208}\text{Pb}/^{206}\text{Pb}$ and low $^{206}\text{Pb}/^{204}\text{Pb}$ ratios for the given $^{207}\text{Pb}/^{206}\text{Pb}$ values, and thus are separated from the defined clusters, belong to Kinet. In the current state of knowledge, the samples with these isotopic characteristics could not be confidently associated with any source area. We can at least state that this situation seems to correlate with certain unique geochemical features displayed by the Kinet assemblage, such as high bismuth and antimony concentrations, as well as the high degree of lead-silver and lead-bismuth correlations.

A major observation is that the deposits associated with Cluster A, which had always been the most important copper source for Alalakh/Tell Atchana, started to be used to a more notable extent by Kinet and Tarsus, respectively in the Late Bronze Age I and Late Bronze Age II periods. Thus this source area perhaps in the Kalavassos Axis, became the predominant source to supply the region towards the

end of the Bronze Age. This progressive gain in importance of one single source area to the disadvantage of other sources cannot be explained at the moment. Actually, it was another area of Cyprus that has been proposed to have become prominent in the interregional circulation of copper during the 14th and 13th centuries BC. This is the Solea Axis, which was argued to be the source of almost all oxhide ingots postdating the mid-14th century BC. However, the Solea Axis isotopically matches only three samples of the current study, and does not seem to be a major source for Cilicia and the Amuq. Interestingly, all three samples belong to the Kinet assemblage, and two of these date to the Late Bronze Age. If the deposits in the Solea Axis are indeed the sources of Late Bronze Age copper oxhide ingots, the two items from Kinet might have been made from such ingots that reached the site only occasionally.

If the copper used in Cilicia and the Amuq during the second millennium BC was indeed coming from Cyprus, one should consider the possible socio-political organization of the island to explain the noted discrepancies between the sites and periods. Based on archaeological evidence, several researchers argued that Late Bronze Age Cyprus consisted of several polities centered at major sites of the island (Stech 1982, 102-3; Muhly 1989, 301-3; Keswani 1996, 236-37) and presumably exploited different source areas in the Troodos. If this was really the situation, the evidence from the current study probably indicates that the primary trade alliances of different sites on the Anatolian coast were with different polities or agents on Cyprus. Moreover, the importance of these alliances appear to have fluctuated through time.

On the other hand, based on Egyptian and Ugaritic textual references to the King of Alashiya, some scholars envisage that Late Bronze Age Cyprus was ruled by a single political authority, who administered the production and exportation of copper (Webb 2002, 139-40; Knapp 2008, 339-41; Knapp 2013, 443-47). If this was

the case, the situation would be more difficult to rationalize. Hence, it is not easy to understand why different sites in Cilicia and the Amuq received copper from different Cypriot deposits to unequal extents, if all these sources were exploited by a single authority. In the current state of the information, the situation cannot be readily explained.

There is one single sample from Late Bronze Age II Tarsus that is isotopically compatible with the copper deposits of Sardinia. Archaeological evidence for Sardinian contacts with the eastern Mediterranean during the 13th-11th centuries BC (Sherratt and Sherratt 1991, 371-72; Lo Schiavo 2005, 404-7), and the identification of Cypriot (Stos-Gale 2001, 203; Stos-Gale and Gale 2003, 97) and Aegean (Stos-Gale and Gale 2003, 94-97) copper objects, which also isotopically match Sardinian deposits, renders Sardinia indeed a likely source of this isolated sample. Therefore, this single item may demonstrate that copper from more distant sources could reach the region within the frame of the intense and complex exchange networks of the Late Bronze Age II period.

6.4. CONCLUSIVE REMARKS AND PROSPECTS FOR FUTURE RESEARCH

The primary aim of this study was to delineate the position of Cilicia and the Amuq within the interaction networks of the eastern Mediterranean and the Near East during the second millennium BC. As tin was a likely import from distant sources, as the current state of our information indicates, its acquisition required participation in interregional trade. Hence, the relative frequency of tin is considered in this study as a significant indicator of the degree of involvement in long distance exchange networks. The progressive intensification in the use of tin in Cilicia and the Amuq through the

second millennium BC echoes the general pattern from the wider eastern Mediterranean and would not have been possible if the region remained isolated from the interregional exchange routes. However, the relatively infrequent occurrence of tin compared to certain other parts of the Mediterranean and Anatolia, and the somewhat delayed emergence of tin-bronze as the predominant copper alloy imply that Cilicia and the Amuq did not have the same degree of access to tin as some of their neighbors. Consequently, it appears that the region was perhaps situated only on the fringes of the major routes of tin shipment, at least until the 14th century BC. This situation, however, appears to have changed in the last two centuries of the Bronze Age, perhaps as a result of the intensified sea-based circulation of the metal, from which the region of interest presumably benefited.

However, as underlined previously, the studied objects from Cilicia and the Amuq are almost exclusively utilitarian artifacts, whereas luxury or prestige items constitute substantial parts of the study assemblages from the neighboring regions. This situation may be responsible for the difference between the study region and other parts of the eastern Mediterranean and Anatolia with respect to the extent of tin usage. This possibility can be effectively tested if the recent fieldwork in the region will uncover prestige items of copper from such elaborate contexts as elite burials.

In more general terms, for a more effective delineation of the patterns of alloy use, more analysis is needed from multiple second millennium BC sites in the region. In this respect, investigation of objects from the recent fieldwork at Mersin and Kilisetepe in the western sector of the Cilician Plain, and from Tell Tayinat in the Amuq would broadly contribute to our current understanding of the second millennium BC metallurgy of the region.

In the current state of knowledge, it is not possible to determine through which routes and mechanisms tin was reaching Cilicia and the Amuq. We cannot confidently deduce whether overland or maritime trade contacts prevailed in the acquisition of this metal. Likewise, we cannot tell whether tin was imported into the region predominantly as private or public merchandise. Even a bigger question is the absolute provenance of tin, which continues to constitute a major problem for the Bronze Age archaeology of the Near East and the Mediterranean. These questions can only be answered in the light of yet to be discovered textual material, new isotope analyses of tin objects, and the expansion of the available isotope data to incorporate ore fields in Asia.

There is also the Kestel mine and the associated smelting facility in the central Taurus Mountains, which carries the potential to be a major source of Bronze Age tin. Even though several researchers in the field consider this as a serious possibility, conclusive evidence is yet to be provided. More extensive fieldwork in the Taurus range and the recently discovered prehistoric mine near Kayseri in central Anatolia will hopefully shed light on the issue.

If we turn to the situation of copper sources, this study demonstrated that Cilicia and the Amuq were supplied by multiple source areas in the second millennium BC. The majority of samples, however, can be grouped into a few clusters, which most closely resemble certain deposits on Cyprus isotopically. However, Cypriot pottery is found in relatively insignificant quantities in Cilicia compared to the Levant, which is paralleled by only a handful of possible Cilician imports on Cyprus. Therefore, if Cyprus was indeed a primary source of copper used in Cilicia, which seems the strongest possibility at the moment, the isotope analysis indicates that commercial contacts between the south Anatolian coast and Cyprus in

the second millennium BC were more intense than inferable from archaeological evidence.

Finally, more isotope analysis from the region, especially from the Early Bronze Age (third millennium BC), and the Iron Age would constitute another important research program. The study of the third millennium BC assemblages will examine whether the same copper sources supplied the region prior to the second millennium BC. Likewise, the study of objects from the Iron Age would provide a useful tool to investigate whether the same interregional contacts were maintained after the collapse of commercial networks around 1200 BC.

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APPENDIX I: DATA OF COMPOSITIONAL ANALYSIS

MIDDLE BRONZE AGE																	
	Number	Type	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	Cu
Tell Archana	AT 10559	Rod	0.039	0.716	0.019	0.007	0.043	0.003	0.088	0.058	1.013	0.001	0.000	0.001	0.0000	0.204	95.04
	JH 234	Toggle Pin	0.010	0.861	0.014	0.009	0.043	0.007	0.167	0.011	0.748	0.001	0.004	0.014	0.0001	0.066	99.02
	JH 226	Bracelet?	0.062	0.190	0.006	0.008	0.010	0.004	0.016	0.009	0.371	0.000	0.001	0.021	0.0001	0.087	98.30
	JH 223	Fishhook?	0.099	1.127	7.711	0.163	0.020	0.002	0.004	0.015	0.747	0.000	0.004	0.000	0.0001	0.043	87.61
	JH 232	Open band	0.005	0.312	0.008	0.011	0.016	0.003	0.045	0.004	0.650	0.001	0.004	0.011	0.0001	0.073	96.33
	AT 11716	Pin frag.	0.391	0.076	0.001	0.000	0.001	0.005	0.183	0.010	0.006	0.001	0.000	0.001	0.0001	0.049	67.14
	AT 6144	Toggle Pin	2.310	0.490	0.024	0.006	0.012	0.145	0.094	0.098	0.202	0.001	0.001	0.000	0.0000	0.110	95.48
	JH 215	Toggle Pin	7.679	0.459	0.048	0.025	0.051	0.005	0.108	0.028	0.180	0.001	0.003	0.005	0.0002	0.075	90.36
	AT 3561	Fishhook	0.578	0.093	0.018	0.001	0.049	0.309	0.075	0.138	0.194	0.002	0.001	0.019	0.0004	0.289	94.01
Tarsus	TGK 38.97	Needle	0.005	0.761	0.026	0.008	0.019	0.005	0.108	0.095	0.201	0.000	0.000	0.001	0.0000	0.195	94.32
	TGK 38.55	Needle	0.006	3.816	0.005	0.000	0.035	0.002	0.077	0.087	1.040	0.000	0.000	0.017	0.0000	0.077	98.62
	TGK 37.813	Needle	0.035	3.678	0.015	0.001	0.319	0.003	0.136	0.069	1.118	0.002	0.000	0.000	0.0000	0.058	90.42
	TGK 37.761	Pin	1.001	1.461	0.050	0.009	0.010	0.084	0.490	0.105	0.418	0.001	0.001	0.001	0.0001	0.100	96.32
	TGK 38.94	Roll Headed Pin	0.014	0.895	0.035	0.004	0.048	0.003	0.032	0.087	0.576	0.001	0.002	0.001	0.0003	0.047	96.03
	TGK 37.806	Awl	0.214	1.659	0.031	0.001	0.295	0.002	0.096	0.071	0.404	0.002	0.000	0.001	0.0001	0.048	95.05
	TGK 37.478	Volute Headed Pin	0.018	1.075	0.014	0.002	0.023	0.002	0.131	0.109	0.064	0.000	0.000	0.018	0.0000	0.061	96.27
	TGK 37.763	Roll Headed Pin	0.043	2.367	0.061	0.014	0.074	0.002	0.091	0.083	1.380	0.004	0.001	0.000	0.0004	0.027	95.57
Kinet	KT 16547	Pin	0.002	0.353	0.050	0.032	0.043	0.005	0.046	0.046	0.406	0.002	0.005	0.000	0.0015	0.069	84.28
	KNH 1375	Caps + pins (silver)	0.003	0.606	0.143	0.004	0.095	0.002	0.004	0.011	0.652	0.000	0.004	0.016	0.0003	0.757	88.13
	KNH 1076	Sheet	0.000	0.100	0.043	0.001	0.065	0.018	0.573	0.064	0.048	0.006	0.000	0.000	0.0002	0.009	87.25
	KNH 1074	Needle	0.798	0.706	0.031	0.001	0.021	0.004	0.796	0.057	0.540	0.008	0.010	0.000	0.0018	0.038	93.50
	KNH 1043	Needle	0.690	1.296	0.186	0.015	0.091	0.003	0.126	0.053	0.615	0.004	0.001	0.000	0.0025	0.044	97.35
	KNH 1042	Pin	6.232	0.416	0.081	0.023	0.424	2.122	16.756	0.167	0.219	0.017	0.001	0.000	0.0014	0.199	61.16
	KNH 1020	Wire	0.020	0.198	0.033	0.028	0.053	9.025	0.165	0.047	0.129	0.004	0.000	0.003	0.0001	0.126	74.55

LATE BRONZE AGE I																	
	Number	Type	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	Cu
Tell Archana	AT 878	Bodkin	0.007	0.267	0.008	0.001	0.023	0.002	0.013	0.012	0.095	0.001	0.010	0.013	0.0001	0.103	86.80
	AT 798	Sheet frag.	5.496	0.084	0.008	0.005	0.014	0.002	0.021	0.009	0.161	0.001	0.001	0.000	0.0001	0.077	78.96
	AT 873	Wire	0.022	0.314	0.025	0.003	0.018	0.003	0.119	0.009	0.260	0.001	0.004	0.008	0.0001	0.110	88.88
	AT 7672	Ring	3.679	0.015	0.003	0.001	0.002	0.001	1.865	0.006	0.049	0.001	0.001	0.000	0.0000	0.170	39.49
	AT 10045	Chisel	6.661	0.767	0.060	0.005	0.050	0.002	0.129	0.107	0.209	0.006	0.001	0.001	0.0002	0.059	85.16
	AT 4366	Blade	1.491	0.278	0.047	0.005	0.015	0.003	0.077	0.081	0.066	0.002	0.000	0.000	0.0002	0.138	73.63
	AT 7110	Chisel	1.379	0.923	0.092	0.013	0.044	0.003	0.040	0.098	0.444	0.001	0.002	0.005	0.0002	0.055	94.55
	AT 4384	Arrowhead	0.037	0.309	0.010	0.016	0.020	0.005	0.025	0.005	0.437	0.001	0.008	0.014	0.0000	0.119	99.74
	AT 1351	Needle	0.045	0.620	0.062	0.010	0.062	0.003	0.061	0.057	0.302	0.004	0.002	0.000	0.0001	0.029	96.77
	AT 1228	Pin frag.	0.018	0.290	0.015	0.016	0.027	0.002	0.019	0.005	0.326	0.001	0.005	0.009	0.0003	0.169	98.98
	AT 984	Bodkin	0.024	0.077	0.007	0.006	0.004	0.001	0.010	0.001	0.083	0.000	0.001	0.000	0.0000	0.020	21.21
	AT 1355	Arrowhead	0.093	0.369	0.023	0.018	0.017	0.007	0.073	0.021	0.232	0.001	0.005	0.007	0.0005	0.114	97.29
Tarsus	TGK 36.668	Socketed Chisel	4.218	0.097	0.011	0.001	0.006	4.518	0.255	0.106	0.048	0.007	0.001	0.000	0.0001	0.083	71.82
	TGK 36.861	Needle	0.313	0.956	0.026	0.003	0.072	4.067	0.119	0.056	0.468	0.006	0.002	0.006	0.0003	0.195	76.13
	TGK 36.905	Needle	0.018	0.375	0.012	0.002	0.005	0.868	0.146	0.071	0.565	0.001	0.002	0.002	0.0000	0.369	91.53
	TGK 36.925	Toggle Pin	0.209	1.672	0.154	0.008	0.045	2.365	0.033	0.060	2.727	0.001	0.001	0.000	0.0006	0.160	82.73
	TGK 36.934	Chisel	2.279	0.824	0.070	0.009	0.028	1.403	0.054	0.080	0.258	0.002	0.000	0.005	0.0002	0.194	88.75
	TGK 36.886	Chisel	0.014	1.246	0.017	0.002	0.399	0.046	0.150	0.098	0.196	0.001	0.000	0.000	0.0000	0.105	98.52
	TGK 38.691	Awl	6.710	0.662	0.062	0.023	0.151	0.013	0.126	0.030	0.034	0.001	0.004	0.025	0.0002	0.100	89.97
	TGK 36.669	Tube	1.942	0.662	0.022	0.004	0.023	0.070	0.104	0.123	0.082	0.004	0.000	0.000	0.0003	0.068	92.00
Kinet	KNH 1073	Bracelet?	0.031	0.569	15.040	0.375	0.020	0.002	0.001	0.006	2.022	0.000	0.002	0.000	0.0008	0.178	75.40
	KNH 1072	Needle	0.017	0.374	0.017	0.008	0.024	0.007	0.024	0.022	0.351	0.002	0.002	0.012	0.0002	0.111	92.36
	KNH 1071	Pin	0.037	1.157	0.045	0.003	0.052	0.008	0.021	0.031	4.363	0.000	0.001	0.035	0.0012	0.065	66.95
	KNH 1070	Point	5.266	0.712	0.174	0.017	0.048	0.010	0.307	0.082	0.355	0.003	0.003	0.000	0.0041	0.078	92.58
	KNH 1040	Pin	0.003	0.492	0.018	0.002	0.018	0.005	0.020	0.035	0.212	0.000	0.000	0.021	0.0003	0.073	93.30
	KNH 1019	Needle	0.135	1.098	0.247	0.001	0.336	0.002	0.012	0.063	0.769	0.000	0.002	0.020	0.0005	0.192	89.10
	KNH 1018	Axe	0.036	1.951	0.282	0.001	0.403	0.001	0.178	0.066	0.556	0.001	0.001	0.011	0.0005	0.062	97.80
	KNH 1017	Needle	0.120	1.313	0.384	0.001	0.182	0.003	0.045	0.026	0.483	0.000	0.002	0.037	0.0004	0.392	91.52

LATE BRONZE AGE II																	
	Number	Type	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	Cu
Tell Archara	AT 272	Point	2.693	0.411	0.014	0.002	0.041	0.001	0.008	0.005	0.679	0.001	0.002	0.003	0.0001	0.250	94.28
	AT 4052	Chisel	0.009	0.534	0.009	0.002	0.036	0.005	0.086	0.025	0.712	0.000	0.003	0.012	0.0001	0.082	87.68
	AT 8237	Arrowhead	0.086	0.254	0.016	0.062	0.008	0.023	0.009	0.014	3.337	0.001	0.010	0.004	0.0001	0.504	93.62
	AT 8626	Bracelet	3.657	1.144	0.092	0.006	0.077	0.002	0.016	0.053	0.057	0.001	0.001	0.000	0.0005	0.021	96.04
	AT 8630	Ring	3.025	0.078	0.016	0.004	0.010	0.003	0.043	0.015	0.105	0.000	0.001	0.000	0.0001	0.465	69.50
	AT 6683	Ring	7.606	0.194	0.456	0.015	0.017	0.006	0.207	0.046	0.059	0.001	0.001	0.004	0.0001	0.053	82.65
	AT 3460	Toggle Pin	8.123	0.729	0.109	0.013	0.196	0.010	0.148	0.031	0.508	0.001	0.003	0.002	0.0003	0.122	90.63
	AT 4142	Toggle Pin	9.602	0.546	0.046	0.012	0.050	0.003	0.073	0.029	0.246	0.001	0.002	0.004	0.0001	0.134	85.92
	AT 1396	Toggle Pin	7.661	0.369	0.040	0.038	0.034	0.002	0.119	0.009	0.197	0.001	0.003	0.009	0.0015	0.134	91.91
	AT 2457	R.H. Pin	0.828	0.040	0.004	0.002	0.034	0.002	0.019	0.022	0.158	0.000	0.000	0.000	0.0002	0.481	60.20
	AT 944	Needle	2.121	0.243	0.027	0.007	0.024	0.002	0.055	0.006	0.129	0.001	0.000	0.000	0.0012	0.167	75.44
	AT 6767	Needle	1.832	0.179	0.024	0.009	0.023	0.002	0.031	0.009	0.116	0.001	0.001	0.001	0.0003	0.166	88.04
	AT 7288	Bodkin	0.472	0.017	0.002	0.003	0.002	0.001	0.033	0.008	0.009	0.000	0.000	0.000	0.0003	0.163	73.36
	AT 1084	Blade	2.567	0.720	0.168	0.006	0.067	0.007	0.222	0.016	0.358	0.000	0.004	0.000	0.0003	0.083	95.51
	AT 7074	Bodkin	0.037	0.196	0.019	0.100	0.008	0.011	0.007	0.013	0.874	0.000	0.007	0.019	0.0004	0.297	98.22
	AT 4148	Blade	2.507	0.094	0.009	0.007	0.006	0.002	0.039	0.006	0.042	0.000	0.000	0.000	0.0001	0.131	69.48
	AT 4795	Chisel	9.039	0.975	0.056	0.056	0.359	0.024	0.404	0.026	0.663	0.001	0.007	0.004	0.0002	0.196	89.88
	AT 1712	Arrowhead	5.731	0.374	0.031	0.009	0.027	0.004	0.099	0.019	0.601	0.001	0.001	0.001	0.0023	0.144	66.64
	AT 1526	Arrowhead	5.071	0.456	0.023	0.004	0.025	0.003	0.038	0.015	0.234	0.001	0.004	0.001	0.0003	0.079	94.10
	AT 6086	Arrowhead	4.712	0.675	0.052	0.008	0.140	0.004	0.119	0.019	0.130	0.001	0.005	0.006	0.0001	0.102	95.86
Tarsus	TGK 38.15	Fingerring	0.584	0.066	0.028	0.016	0.009	8.881	0.405	0.066	4.007	0.005	0.000	0.016	0.0001	0.171	66.20
	TGK 37.826	Pin	0.035	2.702	0.014	0.005	0.050	0.048	0.164	0.095	1.085	0.000	0.000	0.010	0.0000	0.253	92.38
	TGK 36.928	Pin	1.639	0.004	0.040	0.003	0.002	0.005	0.020	0.077	0.002	0.000	0.000	0.000	0.0001	0.013	100.18
	TGK 36.730	Nail	4.436	0.185	0.015	0.005	0.013	0.234	0.020	0.061	0.166	0.000	0.001	0.003	0.0001	0.081	91.70
	TGK 38.1618	Spearhead	0.387	2.106	0.184	0.049	0.063	0.002	0.057	0.094	0.376	0.003	0.001	0.000	0.0007	0.049	93.49
	TGK 36.695	Arrowhead	1.218	0.103	0.009	0.005	0.006	3.397	0.057	0.002	0.026	0.000	0.001	0.005	0.0002	0.224	67.66
	TGK 36.734	Arrowhead	5.958	0.452	0.076	0.020	0.041	0.139	0.205	0.056	0.099	0.002	0.002	0.012	0.0005	0.111	83.25

LATE BRONZE AGE II (Continued)																	
Tarsus	Number	Type	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	Cu
	TGK 38.1601	Arrowhead	0.009	0.380	0.011	0.007	0.031	0.009	0.031	0.006	0.647	0.000	0.001	0.017	0.0000	0.098	97.07
	TGK 38.1627	Arrowhead	3.883	0.269	0.084	0.007	0.023	0.025	0.089	0.037	0.098	0.001	0.001	0.000	0.0001	0.141	66.39
	TGK 38.1619	Arrowhead	0.011	0.102	0.006	0.009	0.008	0.005	0.022	0.004	0.162	0.000	0.004	0.010	0.0000	0.080	98.06
	TGK 38.1226	Chisel	6.250	0.028	0.011	0.005	0.010	0.004	0.122	0.072	0.014	0.001	0.001	0.007	0.0006	0.152	90.76
	TGK 37.814	Chisel	5.663	0.493	0.154	0.046	0.035	0.008	0.072	0.021	0.080	0.001	0.006	0.012	0.0002	0.067	100.01
	TGK 38.1626	Chisel	4.568	0.839	0.089	0.034	0.041	0.003	0.104	0.033	0.466	0.000	0.007	0.002	0.0003	0.102	91.45
	TGK 38.1624	Chisel	7.186	0.532	0.240	0.039	0.033	0.013	0.858	0.032	0.242	0.001	0.003	0.001	0.0002	0.146	86.98
	TGK 38.1590	Awl	6.617	0.543	0.085	0.009	0.044	0.002	0.103	0.049	0.204	0.001	0.002	0.001	0.0001	0.108	85.18
	TGK 38.1628	Awl	0.016	0.171	0.032	0.009	0.018	0.006	0.130	0.036	0.015	0.000	0.003	0.000	0.0003	0.029	100.00
	TGK 37.817	Awl	4.460	0.374	0.091	0.018	0.022	0.004	0.035	0.013	0.100	0.000	0.005	0.006	0.0002	0.084	98.53
	TGK 36.935	Toggle Pin	0.322	1.880	0.122	0.010	0.057	0.467	0.156	0.072	0.796	0.003	0.001	0.000	0.0004	0.041	87.33
Kinet	KT 25447	Blade	10.154	0.196	0.017	0.017	0.045	0.003	0.046	0.011	0.161	0.001	0.002	0.001	0.0003	0.112	89.41
	KT 24269	Knife?	1.051	0.085	0.005	0.001	0.005	0.002	0.022	0.007	0.162	0.000	0.001	0.000	0.0001	0.115	60.27
	KT 24269	Knife?	1.064	0.085	0.005	0.001	0.005	0.002	0.020	0.007	0.161	0.000	0.001	0.000	0.0002	0.116	60.27
	KNH 1646	Spearhead	0.012	0.124	0.009	0.027	0.008	0.006	0.008	0.017	0.408	0.000	0.010	0.009	0.0003	0.297	96.13
	KNH 1041	Spearhead	11.549	0.229	0.068	0.001	0.043	0.001	0.017	0.014	0.152	0.001	0.004	0.005	0.0004	0.021	87.76
	KNH 1039	Toggle pin	0.387	1.193	0.060	0.003	0.094	0.005	0.136	0.098	0.178	0.014	0.003	0.001	0.0008	0.058	94.06
	KT 24589	Bracelet?	0.060	1.239	0.022	0.002	0.069	0.001	0.126	0.057	0.107	0.016	0.009	0.001	0.0006	0.171	92.97
	KT 23629	Pin	1.473	0.202	0.022	0.053	0.027	0.007	0.014	0.008	0.293	0.001	0.004	0.005	0.0003	0.204	94.61
	KT 23630	Pin	0.046	0.878	4.881	0.126	0.105	0.002	0.270	0.036	0.915	0.000	0.000	0.000	0.0019	0.123	80.64
	KT 23631	Pin	0.012	0.043	0.002	0.000	0.004	0.001	0.009	0.002	0.014	0.000	0.000	0.000	0.0000	0.005	9.01
	KT 22900	Bracelet	0.006	0.367	0.010	0.017	0.011	0.004	0.022	0.008	0.431	0.001	0.006	0.009	0.0001	0.154	94.95
	KNH 1580	Pin (roll-headed)	4.543	0.463	0.051	0.005	0.044	0.002	0.073	0.093	0.021	0.001	0.001	0.000	0.0008	0.072	81.30
	KNH 1564	Blade	6.718	0.487	0.041	0.033	0.111	0.004	0.031	0.025	0.614	0.001	0.004	0.000	0.0004	0.133	90.50
	KT 22885	Plaque	3.387	0.421	0.100	0.017	0.038	0.004	0.046	0.018	0.361	0.000	0.002	0.000	0.0003	0.082	82.37
	KT 22966	Pin	0.009	0.388	0.200	0.047	0.011	0.003	0.036	0.022	0.404	0.000	0.006	0.001	0.0006	0.223	95.77



INGOTS																
Number	Site-Period	Sn	As	Ni	Co	Sb	Zn	Pb	Ag	Fe	Bi	Te	Se	Au	S	Cu
KT 11421	Kinet-LB I	0.585	0.060	1.313	0.143	0.009	0.333	0.024	0.003	3.104	0.000	0.000	0.000	0.0001	0.106	26.613
AT 1675	Tell Atchana-LBI	0.001	0.030	0.008	0.003	0.003	0.006	0.002	0.005	0.022	0.000	0.003	0.000	0.0001	0.070	8.349
AT 4073	Tell Atchana-LBII	0.002	0.118	0.021	0.011	0.004	0.004	0.003	0.008	0.244	0.000	0.003	0.005	0.0001	0.362	85.190
AT 4101	Tell Atchana-LBII	2.746	0.611	0.051	0.005	0.049	0.002	0.058	0.041	0.013	0.001	0.004	0.006	0.0001	0.072	94.735

APPENDIX II: DATA OF LEAD ISOTOPE ANALYSIS

MIDDLE BRONZE AGE					
	Number	Type	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$
TELL ATCHANA	AT 10559	Rod	0.835	2.071	18.692
	JH 234	Toggle Pin	0.825	2.052	19.007
	JH 226	Bracelet?	0.826	2.045	19.000
	JH 223	Fishhook?	0.833	2.048	18.813
	JH 232	Open band	0.827	2.058	18.893
	AT 11716	Pin frag.	0.841	2.082	18.597
	AT 6144	Toggle Pin	0.842	2.081	18.541
	JH 215	Toggle Pin	0.827	2.059	18.929
	AT 3561	Fishhook	0.837	2.067	18.619
TARSUS	TGK 38.97	Needle	0.836	2.070	18.754
	TGK 38.55	Needle	0.834	2.069	18.705
	TGK 37.813	Needle	0.833	2.066	18.737
	TGK 37.761	Pin	0.835	2.070	18.730
	TGK 38.94	Roll Headed Pin	0.829	2.059	18.840
	TGK 37.806	Awl	0.834	2.070	18.728
	TGK 37.478	Volute Headed Pin	0.835	2.073	18.656
	TGK 37.763	Roll Headed Pin	0.830	2.065	18.837
KINET	KT 16547	Pin	0.841	2.074	18.518
	KNH 1375	Caps + pins	0.859	2.086	18.153
	KNH 1076	Sheet	0.845	2.083	18.466
	KNH 1074	Needle	0.866	2.088	17.896
	KNH 1043	Needle	0.834	2.068	18.711
	KNH 1042	Pin	0.840	2.065	18.748
	KNH 1020	Wire	0.846	2.085	18.460

LATE BRONZE AGE I					
	Number	Type	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$
TELL ATCHANA	AT 878	Bodkin	0.825	2.047	18.961
	AT 798	Sheet frag.	0.826	2.055	18.876
	AT 873	Wire	0.834	2.072	18.677
	AT 7672	Ring	0.827	2.061	18.896
	AT 10045	Chisel	0.836	2.070	18.697
	AT 4366	Blade	0.839	2.075	18.626
	AT 7110	Chisel	0.834	2.068	18.741
	AT 4384	Arrowhead	0.833	2.062	18.716
	AT 1351	Needle	0.830	2.065	18.867
	AT 1228	Pin frag.	0.823	2.046	18.971
	AT 984	Bodkin	0.822	2.042	19.003
	AT 1355	Arrowhead	0.827	2.056	18.897
	TGK 36.668	Socketed Chisel	0.842	2.083	18.523
TARSUS	TGK 36.905	Needle	0.835	2.067	18.664
	TGK 36.925	Toggle Pin	0.833	2.065	18.745
	TGK 36.934	Chisel	0.836	2.070	18.698
	TGK 36.886	Chisel	0.835	2.072	18.719
	TGK 38.691	Awl	0.831	2.068	18.833
	TGK 36.669	Tube	0.841	2.080	18.599
	KNH 1073	Bracelet?	0.840	2.062	18.715
KINET	KNH 1072	Needle	0.832	2.061	18.763
	KNH 1071	Pin	0.844	2.071	18.472
	KNH 1070	Point	0.839	2.067	18.707
	KNH 1040	Pin	0.843	2.070	18.474
	KNH 1019	Needle	0.831	2.058	18.850
	KNH 1018	Axe	0.829	2.061	18.836
	KNH 1017	Needle	0.828	2.063	18.882

LATE BRONZE AGE II					
TELL ATCHANA	Number	Type	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$
	AT 4052	Chisel	0.827	2.057	18.942
	AT 8237	Arrowhead	0.840	2.062	18.617
	AT 8626	Bracelet	0.829	2.059	18.854
	AT 8630	Ring	0.830	2.060	18.859
	AT 6683	Ring	0.834	2.069	18.742
	AT 3460	Toggle Pin	0.825	2.047	18.943
	AT 4142	Toggle Pin	0.829	2.058	18.881
	AT 1396	Toggle Pin	0.826	2.061	18.902
	AT 2457	R.H. Pin	0.827	2.051	18.862
	AT 944	Needle	0.827	2.059	18.916
	AT 6767	Needle	0.829	2.062	18.825
	AT 7288	Bodkin	0.827	2.055	18.878
	AT 1084	Blade	0.822	2.038	19.073
	AT 7074	Bodkin	0.838	2.065	18.639
	AT 4148	Blade	0.826	2.055	18.945
	AT 4795	Chisel	0.829	2.066	18.872
	AT 1712	Arrowhead	0.829	2.057	18.848
	AT 1526	Arrowhead	0.825	2.052	18.960
	AT 6086	Arrowhead	0.831	2.066	18.838
TARSUS	TGK 38.15	Fingerring	0.837	2.091	18.629
	TGK 37.826	Pin	0.834	2.068	18.662
	TGK 36.928	Pin	0.865	2.109	17.791
	TGK 36.730	Nail	0.830	2.059	18.805
	TGK 38.1618	Spearhead	0.835	2.075	18.678
	TGK 36.695	Arrowhead	0.843	2.080	18.529
	TGK 36.734	Arrowhead	0.845	2.081	18.532
	TGK 38.1601	Arrowhead	0.827	2.055	18.913
	TGK 38.1627	Arrowhead	0.834	2.068	18.745
	TGK 38.1613	Arrowhead	0.830	2.061	18.818
	TGK 38.1226	Chisel	0.827	2.057	18.960
	TGK 37.814	Chisel	0.828	2.058	18.866
	TGK 38.1626	Chisel	0.844	2.081	18.499
	TGK 38.1624	Chisel	0.871	2.118	17.935
	TGK 38.1590	Awl	0.834	2.069	18.720
	TGK 38.1628	Awl	0.835	2.071	18.698
	TGK 37.817	Awl	0.842	2.079	18.551
KINET	KT 25447	Blade	0.827	2.061	18.869
	KT 24269	Knife?	0.821	2.043	18.898
	KNH 1041	Spearhead	0.831	2.066	18.645
	KNH 1039	Toggle pin	0.829	2.061	18.690
	KT 24589	Bracelet?	0.833	2.067	18.690

LATE BRONZE AGE II (continued)					
	Number	Type	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$
KINET	KT 23629	Pin	0.829	2.054	18.754
	KT 23630	Pin	0.833	2.062	18.762
	KT 23631	Pin	0.826	2.040	18.917
	KT 22900	Bracelet	0.830	2.060	18.772
	KNH 1580	Pin (roll-headed)	0.830	2.045	18.835
	KNH 1564	Blade	0.826	2.041	18.944
	KT 22885	Plaque	0.826	2.051	18.931
	KT 22966	Pin	0.823	2.043	18.996

INGOTS				
Number	Period	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$
KT 11421	LB I	0.840	2.063	18.454
AT 4073	LB II	0.838	2.053	18.677
AT 4101	LB II	0.829	2.059	18.875