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ARCHAEOLOGICAL AND GEOLOGICAL CONCEPTS ON THE TOPIC OF ANCIENT MINING

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ABSTRACT

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Geological and archaeological research on ancient mining and metallurgy are actually targeting the same goals: understanding the nature and value of a mining operation. Geologists are intent on locating and qualifying ores and minerals for future use, whereas archaeologists strive to link ores to relevant historic and prehistoric metal artifacts and activities. This article discusses research into ancient Anatolian metallurgy by underscoring the overlap between geological and archeological practices. The work of archaeologists and geologists can be mutually beneficial through a close collaboration on the collection and analysis of field data. Their accumulated and combined knowledge would accelerate the progress towards placing ancient mining activities in a chronological and meaningful context.

1. Introduction

This article attempts to outline the strategic approach that archaeologists take in studying ancient mining and metallurgy. It will be immediately discernable to geologists, for whom this article is being written, that there are striking similarities in the way an ore or resource deposit is studied. The goal of archaeologists who study the history of mining is primarily to determine how and where mining took place and to fit it into the cultural history of the past. In addition, they seek to determine the technologies applied in processing ores and how the end product, metal, is eventually used. Research does not end there. History becomes meaningful when all of societies' components –its industries, its crafts, and its social institutions– are fully understood and how they relate to each other. The production of metal played a vital role in how societies developed: their wealth, their crafts, their weapons, and their economy. None the least, metals contributed to how those societies reorganized internally into social classes and hierarchy. The rise of material wealth

created an elite class separate from political and clerical leaders and established another locus of power. Metal, especially silver, became a medium of exchange and thereby ensured the future of mining. Just as the ancient miners used a handful of rudimentary methods to locate deposits present-day geologists employ modern tools and techniques to locate profitable mining possibilities. The ancient miner and the modern geologist followed paths that cross today. It is not uncommon to see current mining companies digging through ancient mining operations. What may have been an exhausted mineral deposit long ago may very well be worthwhile today because of our advanced mining technology. Economic imperatives drive the need for mining, but unfortunately today's mining operations have on occasion erased many of the ancient mining remains before they could be documented and recorded in the historical record.

Compiling a history of mining and metallurgy requires a broad view of the literature and work of many different scholars who contribute to the science

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and history of metals. Not only do scholars look at the metalwork and its affinities with neighboring areas or sites, but scientists are instrumental in providing valuable information on the compositions of artifacts, isotopic analysis, and geology of metallic ores. Some of the analytical techniques covered in this paper give an indication of the breadth of the different disciplines involved.

General Directorate of Mineral Research and Exploration (hereafter; MTA) established in 1935 has not been on the sidelines of ancient mining research. Through its routine fieldwork it has noted many early mining operations, which has served as a guide to an historical assessment of mining in Anatolia. MTA has also sponsored fieldwork that explored ancient mining operations within the borders of Turkey (Kaptan, 1977, 1978, 1982, 1984, 2008, 2012; Başaran et al., 2012, 2010; Kartalkanat et al., 2011; Kaya et al., 2012; Pehlivan et al., 1986; de Jesus, 1977; Ryan 1960; Giles and Kuijpers, 1974). This involvement has yielded enlightening results. Valuable analyses and technical information on mining remains and ores have been produced in MTA's laboratories. MTA has been a loyal partner with other entities who share the same intense interest in the history of mining and metallurgy. Many mining artifacts are now displayed in MTA's museum for the public's enjoyment as a result of these efforts.

We have drawn the limits of this article to sketch out general concepts relating to the initial developments and characteristics of ancient mining and metallurgy in Anatolia. We will touch only lightly on mining and metallurgical developments in other areas. Relevant social and organizational impacts that mining exercised on technology and highland populations has been recently discussed by Lehner and Yener (2014). The primary goal of this paper is to demonstrate the relevance of present-day geological studies to the history of mining and metallurgy in Turkey, which we will refer to here as Anatolia.

2. Early Resource Mining

Mining has been a human activity since Palaeolithic times when early man collected stones that would best fulfill his needs, whether it was for pounding, cutting, grinding or self-defense. Flint and obsidian were eventually incorporated into the repertoire of early human groups because they could be chipped and shaped into refined tools and extremely sharp weapons. With the advent of

agriculture there came a demand for specialized blades, such as microliths, used in cutting wheat stalks. Because of its superior cutting qualities Anatolian obsidian was mined and traded across a vast area of the Near East and has been found as early as 14,000 BC (Before Christ) in northern Iraq and in the Levant (Cauvin et al., 1998). Originating from such Central Anatolian deposits as Göllüdağ, obsidian cores and blades were traded as far away as the Arabian Peninsula dating to Ubaidian times (ca. 4800 BC). They are found even earlier in Mesopotamia (corresponding to present-day Iraq) and Syria at Halafian sites dating to 6000-5500 BC (Balkan-Atlı et al., 2008; Özdoğan, 2008; Healey, 2007; Wright, 1969; Châtaignier et al., 1998). Obsidian was obviously recognized as a superior material with which to make tools. The qualities of the volcanic glass offered the opportunity to fashion tools of extreme precision and beauty, as illustrated by the obsidian bifacial points found at Neolithic Çatal Höyük (Hodder 2011), some of which are now displayed in the Museum of Anatolian Civilizations in Ankara.

2.1. Copper

Man's continued curiosity with materials led him to become acquainted with metal ores such as brightly colored copper oxides and to use them for decorative beads and pigments. Use of these materials has been documented in archaeological excavations and provides a starting point for the history of metallurgy. Thanks to their familiarity with these copper oxides, prehistoric people eventually came upon native copper metal and recognized its unique characteristics. Unlike stone, it could be hammered into simple shapes, and it was more durable.

Native copper outcrops are somewhat common in Turkey, so it is not surprising that copper artifacts have been found in early Neolithic settlements, such as Çayönü Tepesi in southeastern Turkey dated from the middle of the 9th millennium BC and Aşıklı in central Turkey (Maddin et al., 1999, Shoop, 1995, Yalçın, 2000, Esin and Harmankaya, 1999). Because of its relatively high melting temperature (1085°C) native copper pieces in the early phases of the Neolithic period could not be fused, as furnaces at that time could not reach this temperature. Hence, the objects that were fashioned out of native copper were limited to the size of the copper piece found. Consequently, the earliest copper artifacts from excavations are relatively small — points, borers, beads and pendants. Only after metal craftsmen had

designed furnaces or found means of melting native copper pieces do we find larger objects, such as knives, chisels and axes. The native copper mace head from Chalcolithic Can Hasan is an exceptional piece of work dating to about 4750 BC, and its size suggests that the technology of fusing bits of native copper into one large piece had been achieved. It had been thought for a long time that the mace head was cast by the lost wax process, but this has been recently disproven by analytical study. Yalçın (2000; 1998) has shown that it was forged into a shape that accommodated a central shaft hole for the haft. Shaft hole casting would come much later. The early copper craftsman's ability to melt copper opened the door to many possibilities, not only to make tools but to fashion refined shapes that were before made of bone or wood. Over time copper became the material of preference for many objects –needles, knives, borers, fish hooks, and arrow heads, just to name a few.

2.2. Early Copper Metallurgy

Archaeologists have often maintained that the source of copper metal for many early copper artifacts found in Turkey, Syria and northern Mesopotamia came from Ergani (Tylecote, 1976; Moorey, 1999; Bamba, 1972; Hauptmann, 2000; 2007). The Neolithic site of Çayönü, mentioned above, is located only 20 km away. Although Ergani is a massive copper deposit, it is unwise to assume that all the early occurrences of native copper artifacts found in eastern Turkey came from there. As it turns out, recent studies suggest that the copper and malachite pieces found at Çayönü may have come from another source (Esin, 1995). It has also been revealed by Esin that the copper found at the Aşıklı, located 25 km southeast of Aksaray, came from a source different from the copper found at Çayönü. It is, hence, clear that there are, or were, many copper deposits scattered throughout Anatolia that contained appreciable quantities of native copper metal available at remote times in Anatolian history (Wagner and Öztunalı, 2000; de Jesus, 1980; Ryan, 1960).

Yalçın and İpek (2012) have recently explored the site of Derekütüğü in Çorum Province where native copper was mined in antiquity. Based on archaeological finds, the excavators suggest that the mine may have supplied copper to Early Bronze Age sites in the region, such as Resuloğlu, Alaca Höyük, and Eskişehir. We must point out, however, that metal analyses have shown that not all of the

metalwork from these sites was made from native copper, confirming the fact that there were also other copper sources.

Once the native copper at an outcrop was exhausted, early copper miners would have easily made the connection between the copper metal and any associated oxides. We surmise that native copper is commonly found in context with a massive copper ore bodies, such as at Ergani. Ancient miners would have understood that the copper oxides, clearly visible by their bright blue, green and iridescent colors, were different forms of copper. The early metalworkers experimented with the ores, using different heating techniques known at the time. The discovery of smelting was the result of such efforts. Native copper is not always associated with copper ore. Substantial amounts of oxidized copper ore do not exist at Derekütüğü, so when the native copper was exhausted the mining operation there simply ceased, and the miners searched for sources elsewhere.

For the ancient smelter, extracting metal from ores was a process that involved tapping into the cosmic realm. It is generally accepted by scholars that throughout antiquity smelting was very much a ritual process that beseeched the gods to release metal from its ore. The activity of smelting was conducted by those individuals who possessed special skills and the required recipes. To arrive at a successful smelt, ritual procedures were carefully planned. The operation entailed mixing precise ore and fuel ratios, constructing efficient furnaces that could produce the temperatures required, and timing the operation accurately to extract the maximum amount of metal from the ore. The ancient smelters believed that no successful smelt would take place if the gods refused their cooperation. The smelting process was a carefully guarded ritual that constituted a portal to the secrets of the natural and occult world. Ancient smelters operated in a realm parallel to science, but it functioned on the same principles of cause and effect. For us today smelting is a technological process. For the ancient smelter it was a religious experience. Ancient metallurgy, then, was an industry that existed only by sacred authorization (Eliade 1987; 1977).

Metallurgical processes probably involved invoking the god of fire which, in the case of Mesopotamia, it was the god Gibil. Ninmug was the Mesopotamian smithing goddess and would have been invoked as metal smiths produced weapons and everyday objects whether for practical use, ritual, or

adornment. According to one Neo Assyrian text the day and month that a smelt could take place had to be selected for its favorability, and before the smelt was initiated incense was placed in front of the furnace and beer was ceremoniously poured onto the ground. Eliade (1977) informs us that even a special wood, from the styrax tree, was used to fire the smelt. This tree is indigenous to Cyprus and Turkey. The formula calls for the wood to be cut in the month of “Ab”, corresponding to July-August which may correspond to the time when the sap rises in the wood and hence infusing it with a fragrant odor as well as increased combustibility. To ensure sacred propriety, the ancient text goes on to say that all the laborers involved in the smelting process had to be “purified” beforehand. The prepared smelt was referred to as an “embryo,” a concept typifying the belief that the earth was female and metal was male. In the smelting process the earthen ore gave birth to metal, a male child. As a result, most forms of metal –such as weapons, tools, and vessels– were consistently considered male attributes (Eliade, 1977).

Ancient Egypt, too, had its versions of metal-related spirits. Gold was regarded as the flesh of Ra, the sun god, and Hathor, the goddess of mining and metallurgy, was often referred to as “the golden one.” A temple dedicated to Hathor was found at Serabit el-Khadim in the Sinai near where turquoise mining took place. As one might expect she also carried the epithet “Lady of Turquoise.” At Timna in the Negev north of Elat a shrine dedicated to Hathor was discovered and excavated in the vicinity of the copper mining operations. Again, this illustrates the close association between the goddess Hathor and metallurgical operations (Rothenberg, 1972).

We know very little about Anatolian-based mythologies, as few texts have survived that inform us about the sacred Anatolian pantheon. Yet, it is fair to speculate that gods played a vital role in the daily lives of Anatolians from the earliest of times. We are reminded by the shrines at Göbekli that, even before the Neolithic, symbols represented the mythical spirits that inhabited the world and represented an important concept to which hunter-gatherers could devote their religious tendencies (Schmidt, 2007). Although the names and mythical adventures that surrounded the Göbekli spirits are still unknown to us, for the people of that time mythical and spiritual beings encapsulated natural forces that invited their devotion. The uses of animal symbolism at Göbekli, and later at Çatal Höyük, were metaphors, or cultural codes, that conceived of the world and, in another

way, revealed it. Prehistoric people had found an access to the cosmological order and supernatural forces through symbolism and ritual. Thanks to their beliefs and symbolic expression they found their spiritual place in the universe, and from that vantage point they ultimately sought to harness nature’s forces. Manipulating these supernatural forces mirrored the profane technology we use today.

It is not until writing was introduced thousands of years later that we have a glimpse into the world of Anatolian mythology. The rare Yozgat tablet of the Hittite Period contains the myth of Telipinu, the god of agriculture, and mentions the existence of a “thousand gods” (Gurney, 1969). The mythological past of ancient Anatolia must have been exceedingly rich in events and concepts that touched every aspect of Anatolian life, including mining and metallurgy. We can only hope that the progress of archaeology will reveal more of this cultural heritage and fill in the blank chapters associated with this land.

While copper started as a humble native metal it had a different destiny from the precious metals such as native gold or smelted silver. From the time that craftsmen succeeded in melting copper, smelting copper ore and fashioning useful tools and weapons, it did not take long before civilization became metal-dependent. After the development of agriculture and the domestication of animals copper production constituted one of humanity’s most important and durable industries.

2.3. Smelting complex ores

After the easily smelted oxides had been exhausted, miners were confronted with sulphides and complex ore bodies. The early smelters had to figure out what was required to obtain permission from the gods to release the metal from these more complex ores. Most likely through trial and error they came upon the technique of pre-roasting the ore concentrate before passing on to the smelting stage. A number of exploratory rituals and manipulations of the ore mix were no doubt attempted before a successful process was discovered. Based on archaeological evidence it appears that sometime in the Chalcolithic period in Anatolia, perhaps as early as the 5th millennium BC, that sulphide and polymetallic ores were being smelted on a routine basis. It could have been at this time that different metallurgical traditions converged and exploited their respective metals at the same site. It could be, too, that this convergence resulted in the development of

alloys. As we shall discuss below, smelters had figured out a way to produce arsenic-copper alloys for specific uses. From what we know about arsenic ores (e.g. orpiment and realgar), it is unlikely that smelters isolated arsenic as a metal. This leaves us with the notion that copper and arsenic ores were co-smelted resulting in a copper-arsenic alloy. We do not know how the copper smelter came upon arsenic nor whether co-smelting was in fact the technique used. The technology of creating copper-arsenic alloys, possibly known as early as the 5th millennium BC, remains one of the enigmas of ancient metallurgical history. Silver-copper alloys are also known, as are copper-antimony alloys, though rare. We can see from analysis of metalwork that by the end of the 4th millennium BC smelters were intentionally alloying copper with tin and producing good quality bronze (Lehner and Yener 2014: 539). It can be safely claimed that smelters in the Late Chalcolithic developed alloying and practiced it regularly to arrive at specific and anticipated results. The mining and processing of polymetallic ores should retain our interest, as it may very well represent a point at which ancient metallurgists collaborated and technologies merged, resulting in the fundamental practices that led to the sophisticated techniques evident in later periods.

2.4. Late Chalcolithic Beginnings

There is an increasing notion amongst archaeologists that the Late Chalcolithic was an important period of incubation in the development of metallurgical techniques as well as socio-political changes that deeply affected the material life of people across a broad stretch of the ancient Near East (Sagona and Zimansky, 2009). While the developments in political organization and the exploitation of material resources was by no means uniform, it is clear that the economic fortunes of settlements was growing steadily in the Late Chalcolithic Period, which we can place at ca. 3800-3100 BC. One cannot describe the situation properly without considering Southern Mesopotamia and socio-political developments during this time. Southern Mesopotamia's urban development was fueled by a growing elite class and their desire for essential natural resources, including metals. To satisfy the demand of urban centers Mesopotamian traders reached out in different directions to obtain the metal resources they needed, principally copper, silver and gold. Later, tin would be added to this list. Some of these metals may have come from Iran, and even beyond (Nezafati et al., 2008). More relevant to

our discussion here, evidence of Mesopotamian trade and contacts is visible at sites in the upper reaches of the Euphrates in Syria and farther north into eastern Anatolia where metal resources could be obtained.

The cultural impact of trading enclaves originating from Mesopotamia in the Late Uruk period will not be dealt in these pages, as the purpose of our comments here is to provide a sketch of how, where and when resources were exploited and how they are relevant to present-day geological research. It is nevertheless important to mention that Mesopotamia's trade in metals, as well as other products, traveled on a reliable path of cultural acceptance. Religious and political ideologies flowed in tandem with the trade that took place over many hundreds of years, and elements of Mesopotamian culture gradually made their way into the heart of Anatolia.

Trade was no doubt a factor in the development of the urban site of Arslantepe near Malatya and where elements of Mesopotamian culture are evident, as well as Hacinebi Tepe, Hassek Höyük and other sites situated along the Euphrates (Stein et al., 1996; Stein 2001). It has not been determined to what extent the large site of Arslantepe was involved in the metals trade, but it is likely that it was a part of the regional network that traded metals down the Euphrates to eager sites in southwest Anatolia, Syria and Mesopotamia. Archaeological surveys have revealed a number of ore deposits and polymetallic ore bodies — mainly copper but also containing silver and gold ores — that could correspond to this period of mining activity or slightly afterward (Yener and Özbal, 1987; Özbal et al., 1999; Palmieri et al., 1996). Geologists have also studied these areas (Kalender, 2011). These are good starting points for future field research aimed at establishing the origins of metal used in ancient metalwork.

The Arslantepe excavation has yielded exceptional metalwork that deserves mention, as it relates to increased production of metals and the development of metallurgical skills in the Late Chalcolithic Period. The hoard of swords and spear heads recovered in the Palace complex at Arslantepe Period VIA (dated by the excavators to ca. 3000 BC) has been celebrated as a spectacular example of smithing skills at the end of the Late Chalcolithic Period, or by other accounts, at the onset of the Early Bronze Age. In the literature the swords have been carefully described, stressing the delicate work on the handles and pummels that include silver inlay and a

superb finish of the blades. Close examination of the swords indicates that they were not intended for practical use, rather they were flat cast and are symbolic models of real swords. They were perhaps used in an emblematic fashion but were never intended for use in battle. This does not diminish their importance, as their shape and form reveal that there existed a contemporary craftsmanship that produced real swords with proper tangs, elaborate handles, silver inlay and robust hilts. These are not backwater characteristics; on the contrary, the features on the flat, symbolic swords reflect a sophisticated metallurgical tradition that must have developed earlier in the Chalcolithic period. Hence, if we accept the excavators' chronological dating of the hoard, the symbolic Arslantepe swords clearly express well-honed technologies of real, practical swords that have not yet been found anywhere in this timeframe. Given a period of time for metallurgical technology and smithing skills to develop, it is logical to assume that the metallurgical technology represented in the Arslantepe hoard began much earlier than the archaeological literature has heretofore expressed. Moreover, the coexistence of silver and arsenic-copper alloy of the swords at this time indicates an intimate relationship in the production of these metals. It appears that silver, arsenic and copper smithing techniques have converged to produce a single artifact. Gnawing questions still haunt us. The source of the silver is unknown and attempts to identify the sources of copper are still inconclusive (Di Nocera, 2010: 271). The so-called ancient workings at the metal deposits mentioned earlier have no confirmed dates. Their importance lies solely in the fact that they had been exploited in antiquity and that they are within proximity of archaeological sites.

What this means in the context of our discussion here is that much work remains before we can have a clear picture of the mines-to-metalwork process. It is not likely that excavations in settlement areas will provide the answers we are seeking. Even though some smelting may have taken place within settlements, as at Arslantepe, Hacinebi, Norşuntepe and other sites in eastern Anatolia (Hauptmann and Palmieri, 2000: 75-6; Di Nocera, 2010: 268-270; Özbal et al., 1999: 59; Zwicker, 1977: 13, ff.), their output must have been frustratingly small. At Hacinebi, for example, four smelting furnaces were discovered, but blowpipes (as opposed to bellows) were used for the forced air. This system does not suggest a large-scale operation. Experiments in crucible smelting using blowpipes have always shown to yield only small amounts of copper. To

produce sizeable amounts of copper metal large and more efficient installations are called for, such as tapping furnaces, pot bellows, plenty of charcoal, and manpower for the ore preparation and smelting operation. Hence, although smelting inside settlements is known, they are conceivably designed for small outputs. The answers to our big technological questions lie in the remote areas of Anatolia where the bulk of smelting took place and where the ore deposits were mined (and here is where present-day geology can play an important role). Nearby wooded areas would have provided ample fuel, and the miners would have delivered the required manpower for ore preparation and smelting. True, full-fledged mining-processing sites are still an archaeological rarity. At present, we have the Early Bronze Age site of Göltepe-Kestel that provides us with a body of evidence pointing to the mining and processing of tin ore within a defined cultural context (Yener, 2000; Yener and Özbal, 1987, Yener and Vandiver, 1993). New research on the Hisarcık province of Kayseri also provided promising evidence for the Early Bronze Age tin resources of Anatolia (Yener et al., 2015). The corollary that links settlements with the relatively isolated mining sites is crucial to the understanding of the metallurgical industry in the ancient past. Was it proximity, cultural affinities, convenient trade routes, or economic necessity?

This brings us back to the heading of this section. The Late Chalcolithic Period still holds the secrets to the dynamic developments of mining, complex ore smelting, unprecedented alloying techniques, and sophisticated smithing practices as well as the trade mechanisms that allowed the industry to thrive. The challenge lies in further fieldwork that can locate these activities in the remote areas of Anatolia. It is well worth our effort to seek out those places that subsequently gave rise to the Early Bronze Age.

2.5. Early Bronze Age Metallurgy

We have embraced the concept that the Late Chalcolithic was that period in the past when great strides were made in metallurgical techniques. The emergence in the Early Bronze Age of different types of alloys, sophisticated smithing skills, abundant metal resources, and the elegant use of gold and silver presupposes that these developments owed their existence to prior initiatives in the Late Chalcolithic Period. The Early Bronze Age can be characterized as a spectacular flowering of metallurgical practices that was long in coming. Although we find exquisite

examples of metalwork and artifacts of unique design in the Early Bronze Age, we are in no better position to indicate from where the metalworkers obtained their raw copper, silver, or gold. We have candidates, but until archaeology can provide us with reliable dates and analytical data of mine workings, the picture we sketch out for ourselves will remain lamentably hypothetical. Apart from Derekütüğün mentioned above, the only other Early Bronze Age copper mine currently known is Kozlu, discovered in the course of geological work in central Anatolia, and subsequently explored by Ergun Kaptan of MTA (Giles and Kuijpers, 1974; Kaptan, 1986). The area near the mine includes a settlement where late period artifacts were found, but a thorough exploration of the site still awaits the archaeologist's spade. While our lack of dated mining sites is frustrating, we can delight in the fact that we have abundant analyses of metalwork and many studies that enlighten us on smithing technologies in the Early Bronze Age.

Metallurgists of this period had mastered the sophisticated techniques of lost wax casting, annealing, gilding with gold and silver, multiple mold casting, shaft-hole casting, and soldering. These techniques are typical of the metalwork from Alaca, Horoztepe, Eskiyapar, Resuloğlu and other sites on the central Anatolian plateau and from İkiztepe on the Anatolian north coast (Sagona and Zimansky, 2009; Öztürk, 1992; Yıldırım, 2006, 2010; Bilgi, 1990, 2001). In the west of Anatolia, the metalwork from Troy best represents a western metallurgical tradition that excelled in goldworking and had links with the Aegean (Tolstikov and Treister, 1996; Sazcı, 2007; Mellink, 1986). Regional metallurgical traditions appear to have existed throughout the Early Bronze Age and may reflect from where they obtained their copper and other metals, as well as their technological preferences that were traditionally attached to regional cultures. Arsenical copper seems to be common in eastern Anatolia and along the north coast. Arsenic ore outcrops are known in this region, and it has been reported that ancient galleries are associated with the arsenic deposit (orpiment and realgar) at Durağan east of Kastamonu (Özbal et al., 2000). Tin bronze tends to appear on the central Anatolian plateau, in southern Anatolia and along the Mediterranean coast. The Early Bronze Age tin mine at Kestel and/or Hisarcık could have provided tin metal for a good portion of this region (Yener and Vandiver, 1993; Yener et al., 2015). Of course arsenical copper and tin bronze artifacts crossed these regional boundaries as a result of trade and human migration.

2.6. Gold

Although gold also occurs in native metal form it was apparently not recognized for any of its qualities until the Early Bronze Age. Gold has some outstanding characteristics that other metals do not. First of all, it is very durable, and it does not oxidize or corrode like copper or iron. It can be hammered easily into very thin sheets and bent into graceful and interesting shapes. It lends itself to decorative forms, such as filigree and granulation, hence its use in jewelry. Gold was not only valued for its beauty but for its special powers. Chinese alchemists were known to have eaten small quantities of gold, which was thought to have given them long life.

The discovery of gold was probably not a complicated matter. At a very early time in human history hunter-gatherers would surely have observed shiny particles of gold collected in the bends of rivers where the natural action of the water deposited granules of heavy materials. Gold particles may have been known at a very remote time in prehistory, but they were likely viewed as no more than curiosities. The initial use of gold was dependent upon a craftsman's ability to reach gold's melting temperature of 1,064°C, and it was not until then that gold could be amalgamated into sizable pieces and shaped into decorative items. Although the higher melting temperature of copper was well known and routinely reached in the 5th millennium BC by craftsmen, present evidence suggests that they were either simply not interested in gold at that time or they did not have abundant access to it (Roberts et al., 2009: 1013-1016). Despite the existence of skilled craftsmen in Neolithic Anatolia, gold metal lingered in the shadows before it attracted any interest.

The first gold artifacts that occur in the region are outside Anatolia. A gold earring from Dhimini, Greece was recovered from Late Neolithic contexts dating to the beginning of the 5th millennium BC. Slightly later in time, a gold bead was recovered at Sitagroi III (4600-4200 BC), also in Greece. In addition to these early examples are ceramic pots gilded with gold from Varna, Bulgaria dating to ca. 4000 BC, all of which exhibit techniques that are unknown anywhere in Anatolia at this time. Stöllner et al., claim that they have excavated the oldest gold mine so far known, north of the Caucasus in Georgia. The mine shafts there indicate a mining activity lasting many centuries, and the excavators suggest a date, of "perhaps in the 2nd half of the 4th millennium B.C." (Stöllner et al., 2008). It would appear, then,

that Trans-Caucasia and southeast Europe were precursors of Anatolia in terms of gold production and technology. Archaeologists generally agree that the role of gold became associated with individuals of high status and was a symbol of their authority and power. The incentive for the production of a noble, yet impractical, metal such as gold may be related more to the social make up and hierarchy of cultures than to craftsmen's metallurgical skills. At the present time there is simply not enough known about the Chalcolithic period in Anatolia to relegate its metallurgical technologies to simple and unwarranted backwater status (Düring, 2011). While we should not claim that there is a gold producing activity in Anatolia contemporary in date to its neighbors, we can make a case for early gold production in Anatolia at some point in the Late Chalcolithic-Early Bronze Age timeframe. An early example of Anatolian gold comes from Arslantepe Level VIA in the form of a gold disc (ca. 3000 BC) (Di Nocera, 2010). This item and a spiral ring from the later "Royal" burials signal the development of a gold metallurgical industry that had likely developed previously and operated in the hinterlands of Anatolia. It is also possible that these were traded items from afar.

With the advent of the Early Bronze Age more gold artifacts in Anatolia are found, as at Troy Level II dating to ca. 2500 BC and used, as one might expect, for decoration. The keen interest in gold as late as this in Anatolia was possibly a result of the dynamic changes that took place when metallurgical traditions interacted, polymetallic ore bodies were being exploited on a large scale, population increased, and a socially-based demand for luxury goods developed in earnest (Lehner and Yener 2014: 548). Cultural developments and unequal social stratification were undoubtedly linked to the appearance of gold in currently-known Anatolian settlements. It has been convincingly pointed out that non-egalitarian communities existed in Anatolia since the Neolithic Period, but with the advent of new and precious materials that distinguished privileged classes of society from commoners there emerged a greater incentive to produce luxury items for them. In short, gold became a symbol of distinction for the growing number of elite.

The finer details relating to the initial uses of gold, its discovery, its processing, its trade and comparison with other gold-production centers will have to be addressed at another time. For the moment it is worthwhile stressing that gold production from Anatolian deposits was closely tied to the indigenous

craftsmen of gold artifacts. This does not in any way suggest that Anatolia was a leader in all forms of gold craftsmanship. On the contrary, Mesopotamia seems to have led the world in splendid granulation and filigree work. The lack of resources in Mesopotamia did not prevent its craftsmen from developing a level of sophistication that exceeded all its neighbors. This is a common situation. One need only cite in passing the expertise of Egyptian shipbuilders, even though they had to import the basic material – wood. Technologies are born out of defined cultural contexts that meet the strict needs of the population. The size, quality and sophistication of an artifact are inextricably linked to its cultural foundations, hence the way an object or material is produced and how it is used. The great surge in the use of gold came around the middle of the 3rd millennium BC. Gold production must have increased considerably when one considers that amount of gold artifacts that occur at this time at Troy II, in the tombs of Alaca Höyük and elsewhere in the Near East, particularly at the Ur Royal burials (Sazcı, 2007; Arık, 1937; Zettler and Horne, 1998).

The high demand for gold resulted in dwindling primary sources. We assume that after alluvial and placer deposits could no longer provide sufficient amounts of gold metal, the early miners were obliged to seek other sources. They were quick to understand that the gold particles they had been recuperating in the rivers initially came from a higher elevation. It did not take long for them to trace the source of gold back to its primary deposit. The gold in this case would be locked up in the higher elevated host rock, commonly in amalgamated quartz. Unlike copper mining and smelting, recuperating gold was primarily a grinding and sifting process. To free gold from its gangue it is thought that miners first ground the gold-bearing quartz (hence the presence of grinding stones at mining sites) and then used a mix of water and gold ore slurry which they poured over a sifting table that imitated the actions of a flowing river. Just like nature had done before, the heavier gold particles collected in hollows and pockets of the sifting table. Such an apparatus, called a buddle, was known in Egypt dating to ca. 2000 BC (de Jesus 1980: 84). This process could be repeated as many times as possible to arrive at a concentrate of nearly pure gold particles without its gangue. Craftsmen ultimately developed refining processes using a cementation technique to refine this concentrate even more and produce gold metal of an acceptable quality (Moorey, 1999; Craddock et al., 2005). However, gold craftsmen continued to struggle with the refining process, as it

has been shown that the gold from the Royal Cemetery at Ur varied in purity between 7 and 22 carats (Fossey, 1935).

The primary and secondary sources of gold in Turkey are still in the process of being researched, but some published work has appeared in books and journals that can serve as a convenient overview (Başaran et al., 2012, 2010; Kartalkanat et al., 2011; Kaya et al., 2012; Bayburtoğlu and Yıldırım 2008, de Jesus 1980, MTA 1970).

2.7. Silver

The history of silver is generally separate from that of gold and perhaps from copper as well. Silver's development may have come about from a less noble metal: lead. As lead does not exist in native metal form, the presence of lead at an ancient site presupposes that the lead was smelted from one of its base ores, the most common being galena. The existence of lead metal is important, as it is generally thought that early silver was discovered as a result of smelting silver-bearing lead ore (Hess et al., 1998). This notion is reinforced by the fact that most lead artifacts contain silver in percentages that are higher than what one would expect from a simple lead ore. If silver came about as a result of lead smelting, in the course of time the situation conceivably became reversed; that is, lead became a by-product of silver smelting. It is consequently valid to assume that the search for evidence of ancient silver exploitation in Anatolia is linked to lead workings of some sort, either mining or smelting operations. To a lesser extent silver is associated with the occurrences of gold (Bayburtoğlu and Yıldırım, 2008). The only silver deposit systematically investigated in Anatolia is at Bolkardağ which represents not one site but several hundred stretched over 15 kms (Yener, 1986; 2000). Other sites in Anatolia have been explored and show promise of providing valuable information on lead-silver operations in the past, such as in the areas of Gümüşköy, Kütahya (Kaptan, 1984) and Niğde (Kartalkanat et al., 2011).

In the Aegean the silver-lead mines at Agios Sostis on the island of Siphnos may have been exploited as early as Early Cycladic I (3400 – 2900 BC), but details on any smelting operations are still not available. Elsewhere in the Aegean six lead-silver deposits have been located on Cycladic islands (Gale et al., 1981), but, here again, details are still needed.

The early finds of lead artifacts may help us to determine when silver might have been first

produced. A confirmed example of lead comes from Yarım Tepe I in northern Mesopotamia in the form of a bracelet made from lead wire of exceptionally pure metal. Combined with other metal finds and C-14 dates the Yarım Tepe excavators state with confidence that a copper and lead metallurgy was thriving in northern Mesopotamia at the beginning of the 6th millennium BC (Merpert et al., in Yoffee et al., 1993). The afore-mentioned bracelet presupposes that somewhere lead ore was being smelted within the sphere of Anatolian lead deposits, possibly in eastern Anatolia (de Jesus 1980). Gale et al., (1981) cite other lead artifacts dating from the 5th and 4th millennium BC from Syria and Iran and suggest that lead smelting may have begun as early as the 7th millennium BC. The key question here is: how long would it have taken lead smelters to come upon silver extraction from silver-bearing lead ores?

To address that question let us review how silver is extracted. Silver is obtained in a two-step process, first by typically smelting a silver-bearing lead ore resulting in an alloy of lead and silver metal. The silver is then extracted from the alloy using a process called cupellation that oxidizes the lead (into litharge) leaving precipitated refined silver behind (Pernicka et al., 1998; Moorey, 1999; Gale et al., 1981; de Jesus (1980). Gale et al. (1981) analyzed a silver artifact from Pre-Dynastic Egypt and claim that it is an example of cupelled silver based on its lead content (0.4 %). The artifact dates from ca. 3600 BC. This would seem to be a fairly convenient date from which to consider the routine use of cupellation. It is important to note that there are no silver or lead ore deposits in Egypt, which means that the silver found there had to come from somewhere else (Nicholson and Shaw 2009: 170). Silver artifacts from the Levant fit conveniently into this timeframe, particularly those from Byblos in Lebanon (Prag 1978: 36-8), and it is tempting to see Anatolia as the principal supplier of silver at this time, perhaps coming from operations in the Bolkardağ.

Evidence for the cupellation of silver exists elsewhere. Litharge has been found at a Fatmalı-Kalecik in eastern Anatolia and also at Habuba Kabira in Syria dating to the Late Chalcolithic period (Hess et al., 1998, Lehner and Yener, 2014). The date of the "litharge cakes" from Habuba Kabira has been set at 3300 BC (Pernicka et al., 1998). These finds indicate that silver was being extracted from argentiferous lead ore sometime around the middle of the 4th millennium BC, a conclusion we come to despite the significant lack of silver artifacts from

archaeological excavations. Recent publications reveal that Iran has significant deposits of lead-zinc-silver ore complexes that were worked in antiquity. Moreover, litharge has been recovered at a number of Iranian sites as well, indicating the practice of cupellation as early as the first half of the 4th millennium BC (Nezafati et al., 2008). Hence, when viewing the general picture for silver production, Anatolia, the Aegean, and Iran all have the capability of producing silver metal for the antique world.

Anatolia has so far produced the earliest silver artifact, or so it seems. Its first appearance comes from the Late Chalcolithic hoard (a silver ring) at Beycesultan Level XXXIV in the Lake District dated in the literature “before 4000 BC” (Mellaart, 1970 and Stronach in Lloyd and Mellart, 1962). However, this date has been challenged, based on a C-14 date from an earlier level, and it has been suggested that the date of the silver ring and its hoard should be ca. 3000-2900 BC (Prag, 1978; Kohler et al., 1961). It is the opinion of the present authors that the C-14 date is far too late for this level. Compromises are not scientific method, but if we accept a date of ca. 3500 BC for Level XXXIV because of the nature of the hoard and associated materials, it would be close in date to the cupelled silver artifact mentioned above from Pre-Dynastic Egypt and evidence of cupellation at Habuba Kabira cited above. Based on these assumptions, the practice of cupellation can be conveniently placed at the beginning or middle of the 4th millennium BC.

Decorative silver jewelry and pieces occur at the Korucutepe graves, Alişar Höyük Level 14 and somewhat later at Arslantepe Level VIA where flat swords, mentioned above, were decorated with silver inlay (Van Loon, 1973; von der Osten, 1937; Muhly, 1997; Joukowsky, 1996; Palmieri, 1981; Hauptman et al., 2002). To this we can add the silver-copper rings from the Arslantepe “Royal” tomb (Hauptmann et al., 2002). The quantity of silver and silver-copper alloys clearly represent a well-established and sophisticated silver-producing industry, operating probably somewhere in eastern Anatolia. Arslantepe’s affinities with Mesopotamia in the Late Chalcolithic - Early Bronze Age indicate not only cultural exchanges and borrowings but a possible route southward of Anatolian silver prior to the establishment of Assyrian colony trade routes to central Anatolia in the 2nd millennium BC. It is worthy to mention that excavators at Hacinebi, located on the Euphrates near Syria, state that silver was possibly produced there (Özbal et al., 1999: 60).

If this were the case, the silver-bearing ore could have come from farther north in the direction of Arslantepe. It is interesting that cupellation took place in a settlement and away from the argentiferous deposit, which would mean transporting the ore to a habitation site for processing.

Silver was an important commodity, not only for the crafting of decorative and precious objects but it eventually became a common currency in Mesopotamia. Its use in this way assured its continued exploitation.

3. Archaeological Field Procedures

Locating mineral deposits is not always an easy process, in the present as it was in the past. Turkey is not a small country and has a varied geology and rough topography. Setting out on foot today with the expectation of finding by chance an ore deposit or an ancient mine is not a practical or methodological strategy. Successful field prospection relies on a variety of inputs, often from local inhabitants who are familiar with the terrain and geography in their area. In many remote areas of Turkey members of the local population had been shepherds who walked over vast areas of the land with their flocks and in doing so acquired an intimate knowledge of the local geography as well as its content. Plants, rocks, and structures constitute visual landmarks when shepherds navigate across an area. They become so familiar with the landscape that they are able to notice where subtle features are somehow different from the norm, whether it is a small pile of stones, an isolated depression in the soil, or a scattering of rubble. They are aware of anomalies or changes in local geographic details just as an urban dweller might see comparative changes in the urban landscape. An archeologist’s or geologist’s prelude to field prospection logically starts with an interview with the local inhabitants and shares with them the purpose of the field research. When local inhabitants are aware of the types of materials we are seeking the chances of locating those materials are considerably increased.

Once a site has been identified, the first step is to acquire a general layout of the site, whether it is a somewhat localized mine or simply a scatter of slag. Major topographical features and outstanding characteristics are then noted on maps and in field notes. Mapping of the site and locations of archaeological materials, ore dumps, slag remains and relevant structures are typical of the significant features that need to be recorded. Estimated tonnage

of rubble and slag are useful in classifying the magnitude of mining and metallurgical operations. To further understand the ancient mining contexts the ore, the slag dumps and the host rock are then sampled, which is a routine procedure for the mining archaeologist, just as it is for geologists. What is non-routine for the geologist is the examination and reporting of cultural material that might be present, and we are appealing here for more information of this type. Below we outline how archaeologists might handle cultural material present at a site.

3.1. Archaeological Analytical Techniques

As we have seen, analytical and sampling procedures for archaeologists follow closely what geologists do today. Characterization of an ore body, which we might refer to as ore finger-printing, is crucial in efforts to link ancient metalwork with its source. There are many other methodologies that can be used to identify a metal artifact's origin. One is isotopic analysis — especially lead isotope analysis (LIA) — that occupies a particular importance for archeology. Isotopic composition of the ore body (a form of ore finger-printing) and artifacts provides possible linkages to provenance as well as helping us to suggest certain trading patterns of goods among ancient settlements. LIA is based on measuring ^{204}Pb , ^{206}Pb , ^{207}Pb and ^{208}Pb isotopes of lead with the aid of a mass spectrometer, especially a multi collector inductively coupled plasma mass spectrometer (hereafter; MC-ICPMS) which provides high accuracy (Stos-Gale and Gale, 2009 and references cited here, Yener et al., 1995). The basic methodology of lead isotope analysis on metals involves the application of multivariate statistics and interpretation of the scientific data. In order to explain archaeological phenomenon of metallurgy through the graphs of horizontal $^{207}\text{Pb}/^{206}\text{Pb}$ and vertical $^{208}\text{Pb}/^{206}\text{Pb}$ and $^{206}\text{Pb}/^{204}\text{Pb}$ it is important to understand the specific choices behind these three independent ratios of lead isotope measurements in isotope geology (Gulson 1986). Lead isotope analysis can be tricky even with professional evaluation of the isotopic ratios, since different mineralogical zones with the same age may end up with the same isotopic ratios and, likewise, the mixing of ores could provide similar values.

Ancient miners could exploit an ancient mining site for a long and continuous period as well as for a brief one. To establish a chronology of an ancient mine it is extremely important to contextualize the available archaeological data. Hence, any information

lacking chronological data will not be relevant to answer the questions that archaeologists eagerly seek, namely the the date of technologies relevant to ancient mining and metallurgy. C-14 dating is based on the radioactive decay rate of C-14 to estimate the age of organic based materials. This has become a routine process for archeologists to determine the antiquity of a mine when organic materials are available, such as wooden tools, mining implements, or firewood. Though rare, these materials have been found in mining galleries.

In an ideal situation, regardless of choosing one method over the other, a cumulative group of analyses should be carried out to evaluate a site. In their excavations of ancient settlements archaeologists have at their disposal a range of prospection techniques. Among these are aerial photography, resistivity measuring, and magnetic surveying. Environmental studies play an important part in archaeological reporting, including climatology, plant life, wildlife, paleobotany, osteology, dendrochronology and geography. Ethnographical studies are proving to be increasingly important in compiling a valid history and folklore of an area. For the analysis of artifacts themselves archaeological laboratories may use a variety of techniques depending on the nature of the object: carbon dating, thermoluminescence, spectroscopic analysis, isotope studies or biochemical examinations of the organic materials. Each object has its own story to tell.

The follow-on activity of any fieldwork is heavily loaded with laboratory labor. There is a vast variety of techniques available for both archaeologists and geologists. Starting from the basic optical microscopy and scanning electron microscopy (SEM), different methodologies for different research questions on ancient technologies can be applied with the aid of a wide variety of high-tech instruments, including X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), ICP-MS, Laser Ablation (LA) technologies as well as isotope studies (Begemann et al., 1989, Henderson, 2000, Hauptmann, 2007). We will not deal with these applications here. However, the interested reader can find abundant published literature on laboratory techniques used in a post-excavation stage in the works cited here (Joukowsky 1980; Bintliff (ed.) 2006; and Renfrew and Bahn, 2012).

3.2. Analysis of Artifacts

An archaeologist is exceedingly lucky to find anything in the way of archeological materials in

mining sites. As mentioned above, occasionally wood tools and implements are found, such as shovels, ladders, and other fragments (Kaptan, 2006). Ancient mining operations were not elegant. Rudimentary materials were commonly used. Large stone hammers or rocks used for crushing ores have been identified at various sites in Anatolia in addition to multi-pitted stone mortars as well as flat saddle querns (Kaptan, 2012). Hand tools made out of various types of stones (generally locally-found stones) were used to further crush ore to various particle sizes and prepare it for smelting and/or melting.

Metallurgy can be counted as a branch of pyrotechnology and is not possible without the use of hot fires and smelting or melting equipment. Mines were exploited to obtain valuable ores which could be smelted in simple crucibles or in complex installations like metallurgical furnaces. Careful examination of a site can yield fragments of crucibles and other remains related to ore processing. In rare instances, or in case of an archaeological excavation, a furnace may be uncovered. If, in the course of their fieldwork, geologists happen to come across evidence of a furnace they should bear in mind that such remains are archaeological in nature and contain valuable information on the furnace's design and technology. Much scientific data can be gathered by sampling the furnace linings and analyzing material in and around the furnace, such as slag and ore rubble. Analyses have the potential to indicate firing temperatures and firing techniques — questions that are crucial to the understanding of ancient metallurgical processes. A geologist's awareness and reporting of cultural remains could be instrumental in helping archaeologists link mining areas with archaeological settlements or other historical landmarks.

Analytical techniques and formal procedures are not the only tools that an archaeologist uses. Archaeology is a study of the history of people, but it is also a study of the material life of people. What archaeologists recover from sites are implements made by hand, and the examination and evaluation of these artifacts is as much a tactile process as it is a straight forward scientific one. The touch and feel of pottery expresses information that is often difficult to capture in scientific terms. The quality of a tool, its weight in the hand, the care with which it was designed, and the wear in certain places in the course of its use convey cultural impressions that do not lend themselves to numbers. Archaeologists seek to provide a

meaningful interpretation of the artifacts and sites which goes beyond just pure scientific reporting.

It was not always possible to have a mining operation and a habitation quarter at the same site. Habitation sites, or settlements, could be associated with mining operations if the latter were not too remote. The Early Bronze Age tin mining site of Kestel at Niğde and its associated settlement Göltepe, which is 2 km away from the mining operations, illustrates a classic example of a mining site-settlement relationship. In this case, archaeologists had an opportunity to date the mining operations, determine the ore processing technologies, and acquire a glimpse of the life in a mining village (Yener, 2000; Yener and Vandiver, 1993; Yener and Özbal, 1987; Kaptan, 2012). Isolated mining operations in the remote, mountainous locations in Turkey are much harder to fit into a cultural context and associate them with known settlements, which makes an integrated view of ancient mining and metallurgy challenging.

3.3. Literature Review

Follow on research entails bibliographic documentation of the site and its immediate area. As a prelude or follow-up to fieldwork one can find mention of deposits and former workings in early surveys carried out or referenced by: De Launay, 1911; Karajian, 1920; Chaput, 1936; Kovenko, 1946; de Jesus & Kaptan, 1974; and Bachman, 2008. Complementary information may be obtained from early and more recent geological reports: Simmersbach, 1904; Sharpless, 1908; Birgi, 1951; Ryan, 1960; Gümüş, 1964; MTA, 1964, 1970, 1972; and Bernard, 1970. Early travelers' accounts can also provide locations and historical accounts of ancient mines (Marco Polo in Wright, 1892; Ainsworth, 1842; Smyth, 1845; Taylor, 1868; Sayce, 1880). Classical and later accounts can also assist in the location of past mining operations (Strabo and Pliny, in Bunbury, 1879; Hamilton and Falconer, 1854-1857). An increasing amount of practical information on the flow of ancient metalwork through trade can be determined from philological studies of ancient texts, a perfect example of which is the publication on Old Assyrian copper trade in Anatolia by Dercksen (1996).

4. Conclusions

We hope we have provided in this paper some useful insights and procedures for the examination of

ancient mining sites and why cultural observations are important. The history of mining and metallurgy in Anatolia is a fascinating topic and very much-discussed in archaeological and scientific journals. Anatolia is located geographically in the middle of polarized and prolific metallurgical developments on all sides. The Balkans to the northwest, the Aegean to the west, Cyprus to the southwest, the Levant to the south, Iran to the east, and Transcaucasia to the northeast. Each of these areas had developed vibrant and innovative metallurgical technologies in antiquity. Hopefully, with more knowledge about Anatolia's mining past and MTA's continued involvement in this area of fieldwork geologists and archaeologists will be able to clarify the role of Anatolia in the development of early mining and metallurgy in the region.

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