

STRATEGIC INDUSTRIES AND TIN IN THE ANCIENT NEAR EAST: ANATOLIA UPDATED

YAKIN DOĞU’NUN İLK ÇAĞ’LARINDA STRATEJİK ÜRETİM KOLLARI VE KALAY: ANADOLU VERİLERİNİN GÜNCELLENMESİ

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ÖZET

Bu makale, Türkiye’de bulunan kalay kaynaklarının bir özeti ile Toroslar’daki Bolkardağı ve Kestel maden bölgeleri ile Kayseri yakınlarındaki Hisarcık’ta yeni keşfedilen bir maden yatağı ile ilgili bulguları sunmaktadır. Yakın Doğu’daki İlk Çağ yerleşmelerine komşu bölgelerde bulunan ulaşılabilir kalay kaynaklarına ilişkin bilgiler de burada tartışılmaktadır. Başta Tel Cüdeyde (Judaidah) olmak üzere Kuzeydoğu Akdeniz’e yakın yerleşimlerde kalay ve tunç kullanımına ilişkin en erken tarihli kanıtlar, Anadolu kalayını ithal eden muhtemel merkezleri saptamaya olanak vermektedir.

INTRODUCTION

While browsing through Jack Sasson’s on-line Agade announcements, a listing for a new book to be published by William W. Hallo, *The World’s Oldest Literature Studies in Sumerian Belles-Lettres*, called attention to the impact of strategic metals in the ancient Near East. According to the statement for the book “Literature begins at Sumer, we may say. Given that this ancient crossroads of tin and copper produced not only bronze and the entire Bronze Age, but also by necessity, the first system of record-keeping and the technique of writing.”

Food production, no doubt, maintains its primacy in terms of Mesopotamian record keeping and social

priorities, but the role of metal technology, nevertheless, has been relatively overlooked. This article aims to present an overview of the accessibility of tin metal, critical in the production of the-then high technology of the ancient Near East, bronze. The focus of the article will concentrate on Syro-Anatolian sites which reflect distinct strategies from the above cited Mesopotamian or Aegean systems of procurement.

During the 1970’s and 1980’s the consensus of archaeological scholarship was that the alloying material, tin, used in the production of Bronze Age tin bronze was not found locally in the Near East.

However nebulous textual evidence in the second millennium BC is about the “eastern” location of tin brought into Kanesh in central Anatolia by the Old Assyrian merchants, the prevailing thought was that Afghanistan or central Asia were the only sources available to the ancient Near East even during the earlier formative third millennium BC (see summaries in Moorey 1999). With the initiation of archaeometallurgy surveys in a number of countries, the understanding of the complexities of these procurement systems has changed markedly. Not only has Turkey become identified as an important ancient source area for tin, but Egypt, the Balkans and Iran have also been documented as having substantial deposits of this strategic metal. Consequently the early notion that tin was supplied from one eastern source has been significantly altered to the compelling question now arising, which is why one source was preferred over another during these critical years of state expansion and empire building. Some procurement networks were established in the Early Bronze Age but the production, trade, and consumption patterns of tin have much in common with shifts in the economic, political and social transformations during the end of the Early Bronze Age.

It has now been over 20 years since the discovery of cassiterite (tin oxide) deposits in the Taurus Mountain range in south central Turkey, ancient Anatolia (Yener *et al.* 1989; see summaries in Yener 2000 and 2008). This paper reiterates the findings at two Taurus sources, Bolkardağ and Kestel and a newly identified source at Hisarcık near Kayseri in central Anatolia. Two articles in this journal by Lehner *et al.* and Özbal present new analyses of the Göltepe bowl furnaces and crucibles that were used in the production of tin and other metals. The work accomplished to date at Early Bronze Age Kestel tin mine and the tin smelting village complexes at Early Bronze Age Göltepe, a special function processing site situated 2 kilometers from the mine, constitutes only one of many other archaeologically unresearched, but reported sources in Turkey. Recent information about neighboring regions accessible to the ancient Near East is also briefly mentioned.¹

These ancient metal production centers dated to 3000-1500 BC constitute the basis of wide ranging production, extraction, and exchange patterns of bronze and tin, its important alloying material.

STRATEGIC PRODUCTION

Much archaeological evidence has been published of early production attempts, whether intentional or not, of a variety of copper-based alloys throughout Anatolia dating to the fifth through fourth millennia BC (see summaries in Yalçın 2000; 2002; 2005). These copper based products contained varying amounts of lead, antimony, arsenic, tin, and iron depending on the host ore used. Mechanical and visual properties varied in these very early utensils and jewelry and eventually arsenic contents from two to four percent gained precedence in the fourth millennium BC. The advantages of using arsenic as an alloying material with copper were soon recognized, especially given the improvements in mechanical properties (Northover 1989). Optimum hardness for a copper alloy with arsenic is 5-8% giving superior ductility (for casting) and can be worked hot or cold without breaking (Lechtman 1996). Tin above two percent, on the other hand, gives greater hardness and slightly superior strength to copper (Craddock 1995) than arsenic and optimum hardness is achieved at 8-12% (Charles 1967; Lechtman 1996). Preferences for tin or arsenic may also have been culturally mediated as tin based bronzes are golden in coloring and arsenic segregation in copper yields an attractive silvery color. Varying regional preferences for these colors and the intentional selection of alloying materials for particular groups of artifacts regardless of mechanical properties or accessibility of alloying materials has often been pointed out.

The earliest archaeological evidence of tin bronzes cluster around the bend of the northeastern Mediterranean Sea in the Amuq valley of Turkey, Gaziantep, and northern Syria (Figs. 1 and 3). These sites date to the Late Chalcolithic-Early Bronze I, c. 3000 BC and slightly thereafter. This pivotal area linking the coastal Mediterranean with the cultures of Syro-Anatolia has immediate relevance to the early production of tin metal from Taurid sources such as Kestel, Bolkardağ, and Hisarcık. The site of Tell Judaidah in the northeastern passes of the Amuq valley in southern Turkey yielded numerous tin bronze artifacts, which were determined to contain from 5-37 % tin content from Phase G levels in both the TT20 sounding and JK3 operation². The highest quantity of tin measured was from a crucible fragment encrusted with bronze slag from Phase G (JK3 operation). Earlier analysis of this crucible during

the 1950's had detected 5 % tin content, whereas new and more sensitive instrumentation has given a much more nuanced understanding of the alloying technique (Fig. 2a and 2b). Eight globules (prills) of bronze entrapped in the crucible slag were tested using SIMS (secondary ion mass spectrometer) and tin ranged from 2.1-12.6 % (also 1.49 % Ni and 1.8 % As) and one bronze prill was found to contain 36.81 % tin content (Adriaens *et al.* 2002).

Clearly a sizable amount of tin was available to make bronze at c. 3000 BC. From the same context at Judaidah come ten tin bronze pins, chisels, and awl fragments, which had been previously tested and again contained appreciable tin content. From the TT20 sounding in a clearly documented and marked context just above floor XIV-3 dated to Phase G (R. Braidwood personal communication, February 23, 1994) and not from a pit as has erroneously been claimed³, came six polymetallic tin bronze figurines. Regardless of numerous stylistic and iconographic arguments based primarily on parallels to other unexcavated figurines, which can notoriously be erroneous in their chronological implications, these figurines were carefully excavated and still remain part of a whole assemblage of early tin bronzes from various operations at Judaidah dated to Phase G.

Recent Advanced Photo Source synchrotron X-Ray analyses initiated at Argonne National Laboratory on one of the male figurines yielded 10 % tin content (Friedman *et al.* 1999). Lead isotope analysis conducted at the National Institute of Standards and Technology (NIST) on the silver helmet of the figurine as well as other bronze artifacts from the Amuq sites linked all of them to the Taurus ore sources (Sayre *et al.* 1992; Yener *et al.* 1991). That the raw materials for these artifacts are being supplied locally from argentiferous lead and copper rich mines in Aladağ, Bolkardağ, and Çamardı in the central Taurus mountains in the neighborhood of a fully operational Kestel tin mine and are made of tin bronze gives relevance to the suggested directionality of the tin production at Göltepe.

Further evidence of an early technological breakthrough in bronze alloys in this region comes from Gaziantep in southeastern Turkey during the EB II period (Duru 2006: 206. Level III radiocarbon dates calibrated range 3090-2500 BC, 1 s.d.). The analyses of 96 copper-based objects (mostly pins) from

burials at the site of Gedikli were determined by AAS. 25 samples were tin-bronzes with an average tin content of 6.33 % (Bengliyan 1985). Tell Qara Quzaq situated in the north Syrian Euphrates region yielded tin bronzes dating to c. 2900-2750 BC, contemporary to Phase G in the Amuq. Two chisels and fourteen pins had tin contents from 1.47-19.07%, one of which is an exceptionally high level of tin (Montero Fenollós 1996). Throughout the third millennium BC during the fluorescence of Kestel mine operations, Tells Tayinat (Snow 2005) and Judaidah in the Amuq valley, Tarsus in Cilicia southern Turkey (Kuruçayırılı and Özbal 2005), north Syrian sites as well as central Anatolian settlements (see summaries in Kuruçayırılı 2007) continued to use tin in the production of bronzes.

The 1980's discovery of the seemingly anomalous occurrence of production sites such as Kestel and Göltepe had the disadvantage of being exotic and unique examples in Turkey and thus initially difficult to comprehend by the scholarly community⁴. These sites, however, have been the harbingers of other special function Bronze Age industrial mining-settlement complexes now being documented in Turkey and neighboring regions. The occurrences of crucible fragments, ingot molds, and vast quantities of ore and ore dressing stones surveyed in mining districts, significantly altered ideas about early urban industrial activity. The appearance of tin bronzes around 3000 BC and their distributions all over Anatolia, Syria, and Mesopotamia in the third millennium BC has long been documented, but their production and transmission, which follows a distinct qualitative and quantitative pattern during the period of early urban formation and increasing demands, demonstrate the potential importance in tracing commercial patterns in this area. The last destination of this initial stage of metal production would be the workshops in the lowland reciprocal town site assuredly situated in agriculturally fertile areas. These lowland workshops are where specialized crafts of refining the rough first-smelt metal, alloying and then casting the molten metal into idiosyncratic shapes.

KESTEL TIN MINE AND GÖLTEPE MINING VILLAGE

A first foreshadowing of tin occurrences in Turkey came from the discovery of stannite in the complex polymetallic ores of Bolkardağ in the Taurus range

(Yener and Özbal 1987; Sayre 2001; Yener *et al.* 1991). However, no ancient workings were identifiable since later Ottoman mines extant until the early twentieth century had obliterated all traces of early operations. Thus the viability of stannite (a complex ore of tin, copper and other minerals) as an early source of tin was hotly debated. Augmenting the evidence of tin in the central Taurus Mountains was the discovery of cassiterite at an Early Bronze Age dated mine, called Kestel, located near Çamardı, Niğde approximately 40 km north of the initial Bolkardağ discovery. The excavations at an Early Bronze Age tin mine at Kestel and its miner's village, Göltepe, shed light on a major enigma puzzling scholars for decades—a third millennium BC source of the elusive tin of antiquity accessible to Bronze Age sites. The discovery attracted wide attention after its publication in *Science* (Yener *et al.* 1989) and much heated discussion was unleashed by this discovery in the 1980s.

As a result of newly discovered tin deposits and mining-settlement complexes at Hisarcık and Kıranardı north of Kestel Mine, the Çamardı workings are no longer unique. It is extremely exciting that tin has been found to be more ubiquitous in Turkey than here-to-fore known, which is not surprising given the early traces detected in analyses of ores by the (Turkish Mineral Research Directorate, hereafter MTA) in Soğukpınar near Bursa in northwestern Turkey (Kaptan 1995). Recently several field projects from the MTA have been investigating the presence of tin in north central Turkey and reports of an important tin source within the Erciyes volcanic complex in Hisarcık and Kıranardı, Kayseri, have brought the location of tin deposits to within a few kilometers of the second millennium BC Kanesh trading system (see Dercksen 2005 on textual evidence for tin and copper trade). The Hisarcık and Kıranardı source is reportedly a mining gallery complex similar to Kestel mine (Özbal personal communication, see also Pehlivan *et al.* 2005). Not only have ore processing equipment and Early Bronze Age ceramics been found and identified, but the iron-rich tin ore resembles Kestel tin ores. Further demonstrating the complexity and variety of tin rich ores in Turkey, Sarp and Cerny (2005) announced the identification of a new mineral, Yazganite, containing tin associated with arsenic and iron. We eagerly await news of this mineral which contains 1.55% tin and the antiquity of the mining operations there.

Cassiterite at Kestel mine occurs in both granite hosted veins in the Niğde Massif and in the form of alluvial deposits in Kuruçay stream, below the mine. The Niğde Massif is a pre-Paleocene metamorphic unit of roughly 800 km². Tin is present in approximately 0.1-1% grade in Kestel mine today (undoubtedly higher in antiquity) found in quartz veins or along the contacts between the quartz and marble formations which are part of the young volcanics surrounding and overlaying the Massif. The mineral zonation (telethermal to catathedral) resulted from the Üçkapılı Granitoid intrusion and extended up as pegmatitic and pneumatolytic zonation carrying the cassiterite (Çopuroğlu and Yalçın 2000). According to geological and mineralogical reports there have been two primary mineralizing episodes, an earlier tin-bearing and a later hematite one with weak tin. The deposit was in small outcroppings and sizeable for antiquity (but not of economic importance today). There was more than one period of mineralization; the most likely mineral mined both on the surface and underground was tin, but with the possibility of subsidiary gold.

Evidence of ore extraction continues below the marble into the underlying quartzite schist and granitic pegmatites with a total of 1.5 km of extraction tunnels explored to date. The underground galleries are extensive, measuring a minimum of 4500 cubic meters. Extrapolating from the low-grade ore composition the space extracted would have yielded approximately 115 tons of tin; Kestel mine was only one of many collapsed gallery entrances. In addition to the Early Bronze Age I-III ceramics excavated in trenches placed in the galleries, five samples of charcoal from excavated contexts inside Kestel mine gave radiocarbon determinations calibrated 3240-3100 B.C to 2870-2200 B.C., dating the use of Kestel mine firmly in the Early Bronze Age.

Tin-bearing veins of Kestel are easily distinguished in appearance from other veins and from the host limestone, in both color and texture. Especially distinct in appearance is the tin-rich hematite ore which has a gray-sometimes burgundy tinted, glittering appearance, unlike the much more matte appearance of hematite ore without tin. Based on excavations inside Kestel mine, tin was mined in similar techniques of firesetting defined at Cwmystwyth copper mine in

Wales. Experiments there showed that 750 kilos dry logs fired against the rock face cracked the ore explosively. The ore was mined with stone hammers and antler picks. One person mined 1.5 tons of rock in a morning. This entailed breaking down the mineral lumps into a size small enough to allow easy smelting and enrichment with repeated washing. Indeed 77% gabbro-diabase hand held bucking stones surveyed on the Kestel slope had percussion traces. The exact opposite percentages were found at Göltepe where grinding was predominate.

A large number of tin impermeated hematite ore lumps were recovered during excavations at the miner's village Göltepe and these resemble the ore from Kestel. Analyses of these nodules by AAS yielded an average tin content of 2080 ppm; one sample contained 1.5% tin suggesting that the tin originally mined at Kestel would have been at least a 2% or higher tin-rich ore, a very good grade by today's standards. This strongly suggests that only high tin-containing material was selectively transported from Kestel mine to Göltepe for processing (grinding) and smelting purposes. The over 5,000 ground stone tools used in ore crushing from excavated contexts inside pit house structures at Göltepe support this conclusion. Perhaps the best indication of processing aims supporting tin and not iron, is the undeniable increase of tin content from samples taken from veins in the mine compared to samples from the hematite ore nodules found at Göltepe and finally compared to samples of the multicolored ground ore found stored in vessels and floors of pit house structures. It is strikingly obvious that tin-rich hematite was being enriched on its path from the mine to the smelting stage. None of the other elements analyzed showed this pattern of increase. The final production stage (refuse dump) is noticeable in the marked decrease in the tin content of powdered material from midden samples. Clearly debris from which tin had been extracted was discarded into dump areas of the site. There is no doubt that selective beneficiation of tin was the processing aim of the Göltepe industry (Yener *et al.* 2003).

Göltepe mining village is situated on top of a large natural hill facing Kestel mine. The hill measures close to 60 hectares total and is fortified at the summit with a circuit wall. The excavations uncovered 1500 m² of the settlement dating to the Late Chal-

colithic through the EB III. Radiocarbon calibrated dates of 4350-2175 BC corroborated the ceramic evidence. Göltepe is architecturally unlike any site in Turkey. The workshop/habitation units are semi-subterranean and fully subterranean pit house structures. These ovoid pit houses measuring 4-6 m. diameter were cut into the greywacke bedrock with wattle and daub superstructures. One pit house structure appeared to be a workshop as inferred from the metallurgical tool kit consisting of a moveable brazier, crucible with stone cover, ground stone ore crushers, mortars, bucking stones, kilos of ground ore and ore nodules. This pit house unit was especially significant since it contained large EBA burnished storage jars full of ground ore. Some 70 kg of ore powder and 50 kg of ore nodules were sampled for analysis. In some of the pit house units, the ground ore was arranged in cups, each with a different color from purple, reddish to pink and when analyzed each contained varying percentages of tin and iron (from 0.3-1.8%). These were subsequently identified by SIMS as unprocessed powdered ore material, tailings from an ore concentration process, and remnants such as crushed slag.

Bronze artifacts excavated at Göltepe were small pins, awls, rings and other fragments. Atomic Absorption analysis (Özbal in Yener *et al.* 2003) revealed that all contained between 4.75-12.3% tin demonstrating the high tin content of the metal unearthed at the site. Interestingly, elevated levels of gold (1.23-52.1 ppm) were also observed, suggesting the possibility that Kestel was the source of the tin used, since gold is a component of this deposit as well. Finds such as a silver-tin-zinc alloy necklace and a lead ingot demonstrate that other metals were present as well. Other indications of ore processing and metal production were a number of sandstone molds with bar-shaped beds carved on several surfaces and clay molds suggest that tin metal was being produced and poured into ingot form before being transported to locations for bronze alloying.

The single most significant find at Göltepe relating to the processing of tin has been the over one ton of vitrified earthenware bowl furnaces or crucibles with a glassy slag accretion rich in tin. Constructed with a coarse straw and grit tempered ware, they range in size from a rim size of 6 cm. in diameter to 50 cm and have vitrified surfaces (SEM) measuring

between 30-90% tin content. AAS analyses support the earlier Smithsonian results with vitrified examples ranging up to 4% tin content, a five fold increase relative to the ground ores. Verification that the crucibles were used for smelting tin metal was given by secondary ion mass spectrometer (SIMS) and microprobe analyses at the University of Chicago and Antwerp (for all residue analyses see *Adriaens et al.* 1996; 1997; 1999a, b). These results indicated that the vitrified ceramics contained a thin accretion layer of silicates with 2-3 % tin oxides. Microprobe analysis of a crucible that had a shiny green glassy material still adhering to its surface, showed that two types of crystals were present. The long thin crystals of tin oxide (SnO_2), and equiaxed crystals of iron-tin, with high tin concentrations were consistent with metallic slag. Processing involved intentionally producing tin metal by reduction firing of tin oxide in crucibles. This was achieved with repeated grinding, washing, panning and resmelting⁵. The raw materials being processed in the crucibles consisted of cassiterite in a labor intensive, multi-step, low-temperature process carried out between 800° and 950° C. (Yener and Vandiver 1993).

Having set the processing parameters from the archaeological and analytical information, several replication experiments tested the feasibility of the production model, the physical conditions required and the expected end products. Based on Egyptian depictions from 2500 BC, B. Earl of Cornwall and H. Özbal, successfully smelted tin metal after producing a crucible and using ground ore found in Early Bronze II/III contexts (Earl and Özbal 1996a, b). Enriching with one cup of water a low grade 1% cassiterite ore mixture to approximately 10% by vanning (panning with a shovel), this charge was then placed in a home-made crucible made with local clay and chaff temper. The charge, which was found in cups from the floor of Early Bronze Age pit structures, was placed in successive layers of charcoal and after twenty minutes of blowing through a blowpipe, tin prills entrapped inside an envelope of glassy slag emerged inside the crucible. During this experiment tin metal prills (globules) encased in glass slag were released by grinding with a lithic tool. The slag was thus in powder consistency and virtually invisible (e.g. no slag heaps) unless microscale sampling methods are introduced. Smelting thus resulted in a multistep production of tin metal with refining accomplished by washing, grinding and remelting.

Experimental trials concluded with the successful production of bronze using the results of the tin smelt which contained high levels of iron in the slag. Tin content was assayed by heating the ore sample with a weighed amount of copper to produce a bead of bronze containing nearly all the tin from the ore, leaving the iron as gangue. The melting point of iron is so much higher than that of copper (1540° C vs. 1085° C), nearly all the iron remains solid while the copper or bronze is still liquid and can be poured off. The main points drawn from this discussion is that by the end of the third millennium BC, metal production in the central Taurus range had already been transformed into a multi-tiered operation with wide networks of interaction (Yener 2007). The first tier is the extraction and smelting sites in the mountains; the second tier is the workshops found at urban sites.

OTHER NEAR EASTERN AND ASIAN SOURCES OF TIN

Central Asian sources of tin have often been cited as possible resource zones for Bronze Age tin. Deposits of tin and ancient workings have been identified near Karnab, Samarkand, Lapas, and Changali in Uzbekistan (Boroffka *et al.* 2002). As with Kestel mine, recent analyses of Karnab indicated that the ore samples had a low tin content of 1.3% or less, although according to the authors, a higher level must have existed in the upper extraction operations (Alimov *et al.* 1998). Second millennium BC Andronovo pottery was recovered in the mine as well as a settlement a kilometer away, indicating that this site was somewhat later than the technologically formative third millennium BC dates found in Anatolia. As with the special processing site of Göltepe, this settlement yielded evidence of industrial processing including ground stone tools, smelting droplets and tin ore. Similar second millennium BC workings (radiocarbon dates 1515-1265 BC) were identified at Mushiston in the Penjikent region of Tajikistan. Stannite, the complex mineral of tin and copper was reported, along with cassiterite (tin oxide) with tin contents analyzed between 50-34% (Alimov *et al.* 1998). Kaniuth (2007) correctly points out that these sources became important for the ancient Near East during the second millennium BC. For now, the production phase at Kestel and Göltepe spanning the third millennium BC remains an important earlier resource

for central and southern Anatolia, as well as northern Syria during the formative years of tin bronze production.

The aberrant result of the wars that are on-going in Afghanistan vastly reduced research of the tin sources in this region. Often cited as the source of tin for the ancient Near East (Stech and Pigott 1986; Pigott *et al.* 2003; Weeks 2003), the identified low level of tin oxide cassiterite (600 ppm) was analyzed by a French team (Cleuziou and Berthoud 1982; Berthoud *et al.* 1982) surveying the Sarkar valley, south of Herat. Although ancient workings were found, their dates could not be substantiated. Evidence of tin production and the use of tin bronze in Afghanistan during the Bronze Age await the end of hostilities there.

Although tin occurrences have been reported in Georgia in the Caucasus (Kavtaradze 1999), tin contents have not been published. Recent archaeometallurgical surveys in this country have been researching a late fourth, early third millennium BC ancient gold working site (Stöllner *et al.* 2008), which may have relevance to tin as well. During the lecture, trace levels of tin were also reported on a map. The co-occurrence of gold and other heavy metals in the Caucasus dating to the formative period of tin bronzes lends credence to contemporary, similar findings at Kestel and Göltepe.

Early reports (Wertime 1978; Pigott 1999) of tin occurrences in Iran especially in the Dasht-e Lut desert in eastern Iran were the first foreshadowing of this region as a possible supplier for Mesopotamia during the Bronze Age. Significant tin sources have recently been investigated Deh Hosein in central west Iran. The deposit consists of copper, tin, and gold and the workings have been dated to the late third, early second millennium BC (Momenzadeh *et al.* 2002; Nezafati *et al.* 2008). These sources in Iran have immediate relevance to the early 2nd millennium BC and later tin bronzes found in Luristan, although the earlier third millennium BC workings await clarification. PIXE spectrometry analyses (Sn from 3.5-14.8%) of excavated bronzes from these graves revealed purposefully alloyed tin bronzes (Fleming *et al.* 2005). Lead isotope analysis conducted on these and other Luristan bronzes, however, call into question the authors' conclusion that the tin and copper for these bronzes were imported

from Afghanistan and Oman respectively (Bege-mann *et al.* 2008).

Substantial evidence exists that the eastern desert of Egypt contains important deposits of tin (Rothe and Rapp 1995), although third millennium BC workings were not identified. Again limited surveys may have constrained the documentation of these hydrothermal veins of tin and tungsten, which are said to be 1.5 m in thickness (Muhly 1993). Egyptian antiquities regulations do not permit the exportation of metal samples for analysis and may have played a major role in skewing our understanding of the extent tin bronzes were used in Egypt during the third millennium BC (Old Kingdom) despite the occasional rare items. The overall impression of all this negative evidence has been to dismiss the eastern desert source of Egyptian tin as relevant only for the second millennium BC, certainly important for the rise of palace economies in the Late Bronze Age eastern Mediterranean. Geologically similar deposits of tin and tungsten were identified in Saudi Arabia at Jebel Silsilah and three other sources in western Arabia (Muhly 1993; Wertime 1978; Weeks 2003). Again, as with Egypt, Bronze Age workings were not identified, although the several percentages of tin content warrant a closer examination of this source as well⁶.

It is obvious that at the end of the third millennium BC other sources of tin, such as ones now studied in Iran and Central Asia (Weisgerber and Cierny 2002) superseded or were in competition with the Kestel tin source. Perhaps profoundly associated with the newly emerging patterns of consumption are preferences found in factors other than availability. Given the textual clues in the Kanesh cuneiform tablets, the Kanesh trading system of the early second millennium BC tapped into the resources of eastern tin, perhaps Afghanistan, Iran or Central Asia and not the local source, Kestel. Evidence of Middle Bronze Age working has not been found in Kestel. Given the labor intensive extraction of tin found at Göltepe processing site, it is not surprising that Central Anatolian Middle Bronze Age Kingdoms such as Kanesh gave preference to a ready made tin metal product brought by Assyrian merchants.

In conclusion, Early Bronze Age Kestel mine and the industrial center at Göltepe reflect the distinct strate-

gies of the first tier of processing rough metal products, that is, local ore extracted directly from the neighboring mine and smelted into rough form. It is worth reiterating obvious point that the manufacture

of metal at the mines and smelting sites are the least-studied major aspect of early states where these products are ultimately used in the production of artifacts of power and prestige.

NOTES

- ¹This information is much indebted to Kuruçayırılı (2007). I thank him for allowing me to quote from his fine master's thesis.
- ²Two radiocarbon dates run on samples from a 1995 operation at Judaidah (Edens in Yener *et al.* 2000, Beta-88280, Beta-88281; table 1) gave a date spanning 3090–2710 BC (1 S.D.). Confirming the Phase G dates, Tell Sukas yielded contemporary levels with an average of four identical dates from layers 39–38 (phase L2) in the range 2930–2650 BC.
- ³See arguments in Seeden (1980) and Marchetti (2000). Seeden (footnote 28) cites an unidentified “famous” archaeologist claiming to have visited Judaidah during the excavations, casting unnecessary doubt on direct documentation by the field archaeologists. Such unverifiable information has been the source of much misunderstanding.
- ⁴See the now irrelevant disavowals of the content and quantity of tin at Kestel mine and the processing site, Göltepe in Boroffka *et al.* 2002; Alimov *et al.* 1998; Muhly 1999; Muhly *et al.* 1991; Weeks 1999.
- ⁵Ore processing in antiquity often warranted tedious and difficult labor but valuable materials such as tin were meticulously worked such as with gold extraction.
- ⁶For tin sources in more remote areas see India (Babu 2003), Germany (Niederschlag *et al.* 2003; Weeks 2003), Spain (Muhly 1985; Weeks 2003), Yugoslavia (McGeehan-Liritzis and Taylor 1987, Glumac *et al.* 1991), and Cornwall England (Muhly 1985; Weeks 2003). These sources have also been cited as possible suppliers of Bronze Age tin, although their direct relevance to the Ancient Near East await further study.

REFERENCES

- Adriaens, A., K.A. Yener and F. Adams 1996
 “Surface Analysis of Early Bronze Age Ceramic Crucibles from Göltepe, Turkey”, H.J. Mathieu, B. Reihl and D. Briggs (eds.) *The Proceedings of the 6th European Conference on Applications of Surface and Interface Analysis*: 123-126. Wiley, Chichester and New York.
- Adriaens, A., K.A. Yener and F. Adams 1999
 “An Analytical Study Using Electron and Ion Microscopy of Thin-Walled Crucibles from Göltepe, Turkey”, *Journal of Archaeological Science* 26: 1069-1073.
- Adriaens, A., B. Earl, H. Özbal and K.A. Yener 2002
 “Tin Bronze Metallurgy in Transformation: Analytical Investigation of Crucible Fragments from Tell al-Judaidah, Amuq (Turkey) Dating to Circa 3000-2900 BC”, E. Jerem and K.T. Biro (eds.) *Archaeometry* 98: 273-277. BAR International Series 1043 (II). Archaeopress, Oxford.
- Adriaens, A., K.A. Yener, F. Adams and R. Levi-Setti 1997
 “SIMS Analyses of Ancient Ceramic Crucibles and Slags from Turkey”, A. Benninghoven, B. Hagenhoff and H.W. Werner (eds.) *Tenth International Conference on Secondary Ion Mass Spectrometry SIMS X*: 877-880. Wiley & Sons, Chichester and New York.
- Adriaens, A. et al. 1999
 “Analytical Investigation of Archaeological Powders from Göltepe (Turkey)”, *Archaeometry* 41: 81-90.
- Alimov, K. et al. 1998
 “Prähistorischer Zinnbergbau in Mittelasien. Vorbericht der ersten Kampagne 1997”, *Eurasia Antiqua* 4: 137-199.
- Babu, T.M. 2003
 “Advent of the Bronze Age in the Indian Subcontinent”, P. Craddock and J. Lang (eds.) *Proceedings of the Conference of Ancient Mining and Metallurgy*: 174-180. British Museum Occasional Publications, London.
- Begemann, F. et al. 2008
 “An Archaeo-Metallurgical Study of the Early and Middle Bronze Age in Luristan, Iran”, *Iranica Antiqua* 43: 1-66.
- Bengliyan, A. 1985
Trace Element Analysis of Metal Artifacts from Gedikli Hoard by Atomic Absorption Spectroscopy. Yayınlanmamış Yüksek Lisans Tezi, Kimya Bölümü, Boğaziçi Üniversitesi, İstanbul.
- Berthoud, T. et al. 1982
 “Cuivres et Alliages en Iran, Afghanistan, Oman au Cours des IVe et IIIe Millénaires”, *Paléorient* 8: 39-54.
- Boroffka, N. et al. 2002
 “Bronze Age Tin in Central Asia”, K. Bole, C.

- Renfrew and M. Levine (eds.) *Ancient Interactions: East and West in Eurasia*: 135-159. Cambridge University Press, Cambridge.
- Charles, J.A. 1967
“Early Arsenical Bronzes-A Metallurgical View”, *American Journal of Archaeology* 71: 21-26.
- Cleuziou, S. and T. Berthoud 1982
“Early Tin in the Near East: A Reassessment in the Light of New Evidence from Western Afghanistan”, *Expedition* 25: 14-19.
- Çopuroğlu, İ. and M.G. Yalçın 2000
“Niğde Masifi Metalik Maden Yatakları, Metalic Ore Deposits of Niğde”, 53. *Türkiye Jeoloji Kurultayı* (53. *Geological Congress of Turkey*): 16-17. Jeoloji Mühendisleri Odası (Chamber of Geological Engineers of Turkey), Ankara.
- Craddock, P.T. 1995
Early Metal Mining and Production. Edinburgh University Press, Washington.
- Dercksen, J.G. 2005
“Metals According to Documents from Kültepe-Kanish Dating to the Old Assyrian Colony Period”, *Anatolian Metal III* (Der Anschnitt, Beiheft 18): 17-34.
- Duru, R. 2006
Gedikli Karahöyük I. The Results of Excavations Directed by Prof. U. Bahadır Alkım in the Years 1964-1967. Türk Tarih Kurumu, Ankara.
- Earl, B. and H. Özbal 1996a
“Early Bronze Age Tin Processing at Kestel/ Göltepe, Anatolia”, *Archaeometry* 38: 289-303.
- Earl, B. and H. Özbal 1996b
“Early Bronze Age Tin Processing at Kestel-Göltepe”, S. Demirci, A.M. Özer and G.D. Summers (eds.) *Archaeometry 94. Proceedings of the 29th International Symposium on Archaeometry*: 447-449. Tübitak, Ankara.
- Fleming, S.J., V.C. Pigott, C.P. Swann and S.K. Nash 2005
“Bronze in Luristan: Preliminary Analytical Evidence from Copper/Bronze Artifacts Excavated by the Belgian Mission in Iran”, *Iranica Antiqua* 40: 35-64.
- Friedman, E.S. et al. 1999
“Archaeology at the APS: Illuminating the Past”, *Advanced Photon Source Research* 2/1: 12-16.
- Glumac, P.D. and J.A. Todd 1991
“Early Metallurgy in South-East Europe: The Evidence of Production”, D. Glumac (ed.) *Recent Trends in Archaeometallurgical Research*: 8-19. MASCA Research Papers in Science and Archaeology 8, Philadelphia.
- Kaniuth, K. 2007
“The Metallurgy of the Late Bronze Age Sapalli Culture (Southern Uzbekistan) and its Implications for the ‘Tin Question’”, *Iranica Antiqua* 42: 23-40.
- Kaptan, E. 1995
“Tin and Ancient Tin Mining in Turkey”, *Anatolica* 21: 197-203.
- Kavtaradze, G.L. 1999
“The Importance of Metallurgical Data for the Formation of Central Transcaucasian Chronology”, A. Hauptmann et al. (eds.) *The Beginnings of Metallurgy*: 67-103. Der Anschnitt Beiheft 9, Bochum Bergbau Museum, Bochum.
- Kuruçayırılı, E. 2007
Tin and Tin-Bronze in the Bronze Age: Their Use, Sources and Trade from the Balkans to India. Unpublished MA thesis, Bryn Mawr University.
- Kuruçayırılı, E. and H. Özbal 2005
“New Metal Analysis from Tarsus-Gözlükule”, A. Özyar (ed.) *Field Seasons 2001-2003 of the Tarsus-Gözlükule Interdisciplinary Research Project*: 177-195. Ege Yayınları, İstanbul.
- Lechtman, H. 1996
“Arsenic Bronze: Dirty Copper or Chosen Alloy? A View from the Americas”, *Journal of Field Archaeology* 23: 477-514.
- Marchetti, N. 2000
“A Middle Bronze I Ritual Deposit from the ‘Amuq Plain: Note on the Dating’ and Significance of the Metal Anthropomorphic Figurines from Tell Judaidah”, *Vicino Oriente* 12: 117-132.
- Mcgeehan-Liritzis, V. and J.W. Taylor 1987
“Yugoslavian Tin Deposits and the Early Bronze Age Industries of the Aegean Region”, *Oxford Journal of Archaeology* 6: 287-300.
- Momenzadeh, M., N. Nezafati and E. Pernicka 2002
“First Indication of Tin at the Ancient Mining Site near Deh Hosein, West-Central Iran: A Possible Source for Luristan Bronze?”, *Paper presented at the*

- 33rd *International Archaeometry Symposium*, Amsterdam. <http://www.geo.vu.nl/archaeometry/abstracts/metalgeneral.pdf>
- Montero Fenollós, J.-L. 1996
“Metallurgia en el Proximo Oriente Antiguo. El Ejemplo de Siria”, *Revista de Arqueología* 178: 14-23.
- Moorey, P.R.S. 1994
Ancient Mesopotamian Materials and Industries: the archaeological evidence. Eisenbrauns, Winona Lake.
- Muhly, J.D. 1985
“Sources of Tin and the Beginning of Bronze Metallurgy”, *American Journal of Archaeology* 89: 275-291.
- Muhly, J.D. 1993
“Early Bronze Age Tin and the Taurus”, *American Journal of Archaeology* 97/2: 239-253.
- Muhly, J.D. 1999
“Copper and Bronze in Cyprus and the Eastern Mediterranean”, V.C. Pigott (ed.) *The Metallurgy of the Asian Old World*: 15-26. MASCA Volume 16, Philadelphia.
- Muhly, J.D. et al. 1991
“The Bronze Age Metallurgy of Anatolia and the Question of Local Tin Sources”, E. Pernicka and G. A. Wagner (eds.) *Archaeometry* '90: 209-220. Proceedings of the 27th Symposium on Archaeometry held in Heidelberg, Basel.
- Nezafati, N., M. Momenzadeh and P. Pernicka 2008
“New Insights into the Ancient Mining and Metallurgical Researches in Iran”, Ü. Yalçın, H. Özbal and A.G. Paşamehmetoğlu (eds.) *Ancient Mining in Turkey and the Eastern Mediterranean*: 329-350. Atılım Üniversitesi, Ankara.
- Niederschlag, E., E. Pernicka, T. Seifert and M. Bartelheim 2002
“The Determination of Lead Isotope Ratios by Multiple Collector ICP-MS: A Case Study of Early Bronze Age Artifacts and Their Possible Relation with Ore Deposits of the Erzgebirge”, *Archaeometry* 45: 61-100.
- Northover, J.P. 1989
“Properties and Use of Arsenic-Copper Alloys”, A. Hauptmann and E. Pernicka (eds.) *Old World Archaeometallurgy*: 111-118. G.A. Wagner, Bochum.
- Pehlivan, N.A. et al. 2005
“Kıranardı (Kayseri) Kalay Cevherleşmesine ait ilk Jeolojik ve Arkeojeolojik Bulgular (Geological and Archaeological Finds at the Kıranardı (Kayseri) Tin Mineralization, 58)”, *Türkiye Jeoloji Kurultayı* (58. *Geological Congress of Turkey*). Jeoloji Mühendisleri Odası (Chamber of Geological Engineers of Turkey), Ankara.
- Pigott, V.C. 1999
The Metallurgy of the Asian Old World. 15-26. MASCA Vol. 16, Philadelphia.
- Pigott, V.C., H.C. Rogers and S.K. Nash 2003
“Archaeometallurgical Investigations at Malyan: The Evidence for Tin-Bronze in the Kaftari Phase”, N.F. Miller and K. Abdi (eds.) *Yeki Bud, Yeki Nabud. Essays on the Archeology of Iran in Honor of William M. Sumner*: 161-176. Cotsen Institute of Archaeology, Los Angeles.
- Rothe, R.D. and G.R. Rapp Jr. 1995
“Trace Element Analysis of Egyptian Eastern Desert Tin and its Importance to Egyptian Archaeology”, A.A.H. Abdel, M. Miele and S. Riad (eds.) *Proceedings of the Egyptian-Italian Seminar on Geosciences and Archaeology in the Mediterranean Countries*: 229-244. Geological Survey of Egypt, Cairo.
- Sarp, H. and R. Cerny 2005
“Yazganite, NaFe₃+2 (Mg,Mn)(AsO₄)₃.H₂O, a New Mineral: Its Description and Crystal Structure”, *European Journal of Mineralogy* 17: 367-374.
- Sayre, E.V., K.A. Yener, E.C. Joel and I.L. Barnes 1992
“Statistical Evaluation of the Presently Accumulated Lead Isotope Data from Anatolia and Surrounding Regions”, *Archaeometry* 34: 73-105.
- Sayre, E.V. et al. 2001
“Stable Lead Isotope Studies of Black Sea Anatolian Ore Sources and Related Bronze Age and Phrygian Artefacts from Nearby Archaeological Sites. Appendix: New Central Taurus Ore Data”, *Archaeometry* 43: 77-115.
- Seeden, H. 1980
The Standing Armed Figurines in the Levant. Prähistorische Bronzefunde. Abteilung I, Band I, Beck, Munich.
- Snow, H. 2005
The Role of Metals in the Early Bronze Age Economies of North Syria and Anatolia. Unpublished dissertation, Department of Near and Middle Eastern Civilizations, University of Toronto.

- Stech, T. and V.C. Pigott 1986
“The Metals Trade in Southwest Asia in the Third Millennium B.C.”, *Iraq* 48: 39-64.
- Stöllner, Th., I. Gambaschidze and A. Hauptmann 2008
“The Earliest Gold Mining of the Ancient World?”, Ü. Yalçın, H. Özbal and A.G. Paşamehmetoğlu (eds.) *Ancient Mining in Turkey and the Eastern Mediterranean*: 271-288. Atılım Üniversitesi, Ankara.
- Weeks, R.L. 1999
“Lead Isotope Analysis from Tell Abraq, United Arab Emirates: New Data Regarding the ‘Tin Problem’ in Western Asia”, *Antiquity* 73: 49-64.
- Weeks, R.L. 2003
Early Metallurgy of the Persian Gulf. Brill Academic Publishers, Boston and Leiden.
- Weisgerber, G. and J. Cierny 2002
“Tin for Ancient Anatolia?”, *Anatolian Metal II* (Der Anschnitt, Beiheft 15): 179-187.
- Wertime, T.A. 1978
“The Search for Ancient Tin: The Geographic and Historic Boundaries”, A.D. Franklin, J.S. Olin and T.A. Wertime (eds.) *The Search for Ancient Tin*: 1-6. Smithsonian Institution Press, Washington.
- Yalçın, Ü. 2000
“Anfänge der Metallverwendung in Anatolien”, *Anatolian Metal I* (Der Anschnitt, Beiheft 13): 17-30.
- Yalçın, Ü. (ed.) 2002
Anatolian Metal II. Der Anschnitt, Beiheft 15. Bochum Bergbau Museum, Bochum.
- Yalçın, Ü. (ed.) 2005
Anatolian Metal III. Der Anschnitt, Beiheft 18. Bochum Bergbau Museum, Bochum.
- Yener, K.A. 2000
The Domestication of Metals: The Rise of Complex Metal Industries in Anatolia (c. 4500-2000 B.C.). E.J. Brill, Leiden.
- Yener, K.A. 2007
“The Anatolian Middle Bronze Age Kingdoms and Alalakh: Mukish, Kanesh, and Trade”, *Anatolian Studies* 57: 151-170.
- Yener, K.A. 2008
“Revisiting Kestel Mine and the Dynamics of Local Provisioning of Tin during the Early Bronze Age”, Ü. Yalçın, H. Özbal and A.G. Paşamehmetoğlu (eds.) *Ancient Mining in Turkey and the Eastern Mediterranean*: 57-64. Atılım Üniversitesi, Ankara.
- Yener, K.A. and H. Özbal 1987
“Tin in the Turkish Taurus Mountains: The Bolkardag Mining District”, *Antiquity* 61: 64-71.
- Yener, K.A. and P.B. Vandiver 1993
“Tin Processing at Göltepe, an Early Bronze Age Site in Anatolia”, *American Journal of Archaeology* 97: 207-238.
- Yener, K.A., A. Adriaens, B. Earl and H. Özbal 2003
“Analyses of Metalliferous Residues, Crucible Fragments, Experimental Smelts, and Ores from Kestel Tin Mine and the Tin Processing Site of Göltepe, Turkey”, P. Craddock and Janet Lang (eds.) *Proceedings of the Conference of Ancient Mining and Metallurgy*: 181-197. British Museum Occasional, London.
- Yener, K.A. et al. 1989
“Kestel: An Early Bronze Age Source of Tin Ore in the Taurus Mountains, Turkey”, *Science* 244: 200-203.
- Yener, K.A. et al. 1991
“Stable Lead Isotope Studies of Central Taurus Ore Sources and Related Artifacts from Eastern Mediterranean Chalcolithic and Bronze Age Sites”, *Journal of Archaeological Science* 18: 541-577.

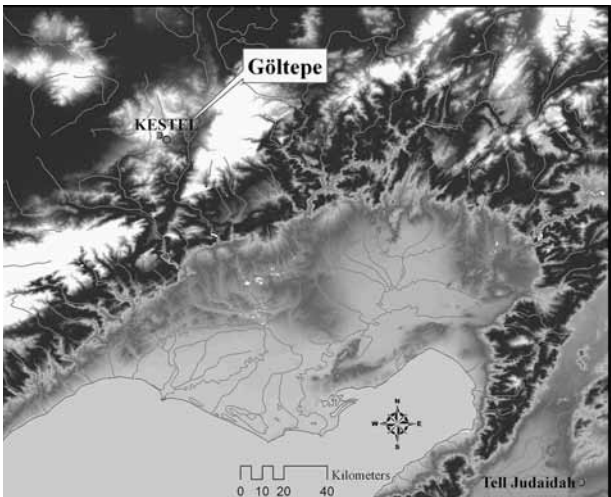


Fig. 1: Map of the Northeastern Mediterranean

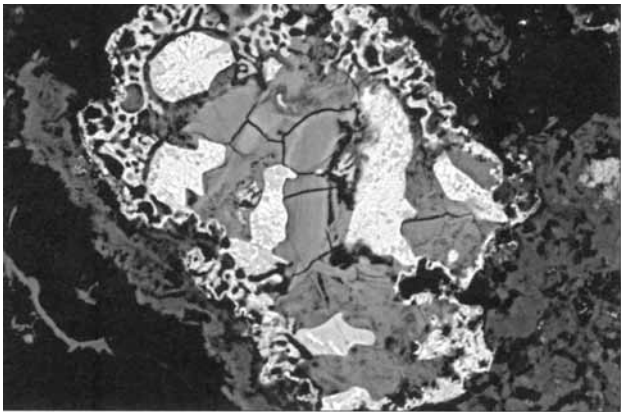


Fig. 2a: Backscattered electron image of residue in Judaidah crucible c. 3000 BC. Mag 720 x (Adriaens et al. 2002: Fig. 5).

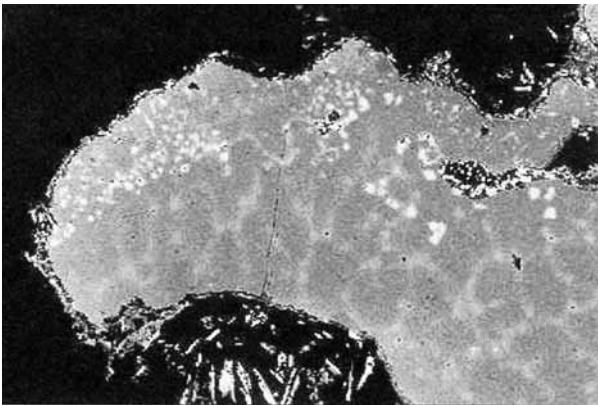


Fig. 2b: Backscattered electron image of residue in Judaidah crucible c. 3000 BC. Mag 440 x (Adriaens et al. 2002: Fig. 4)

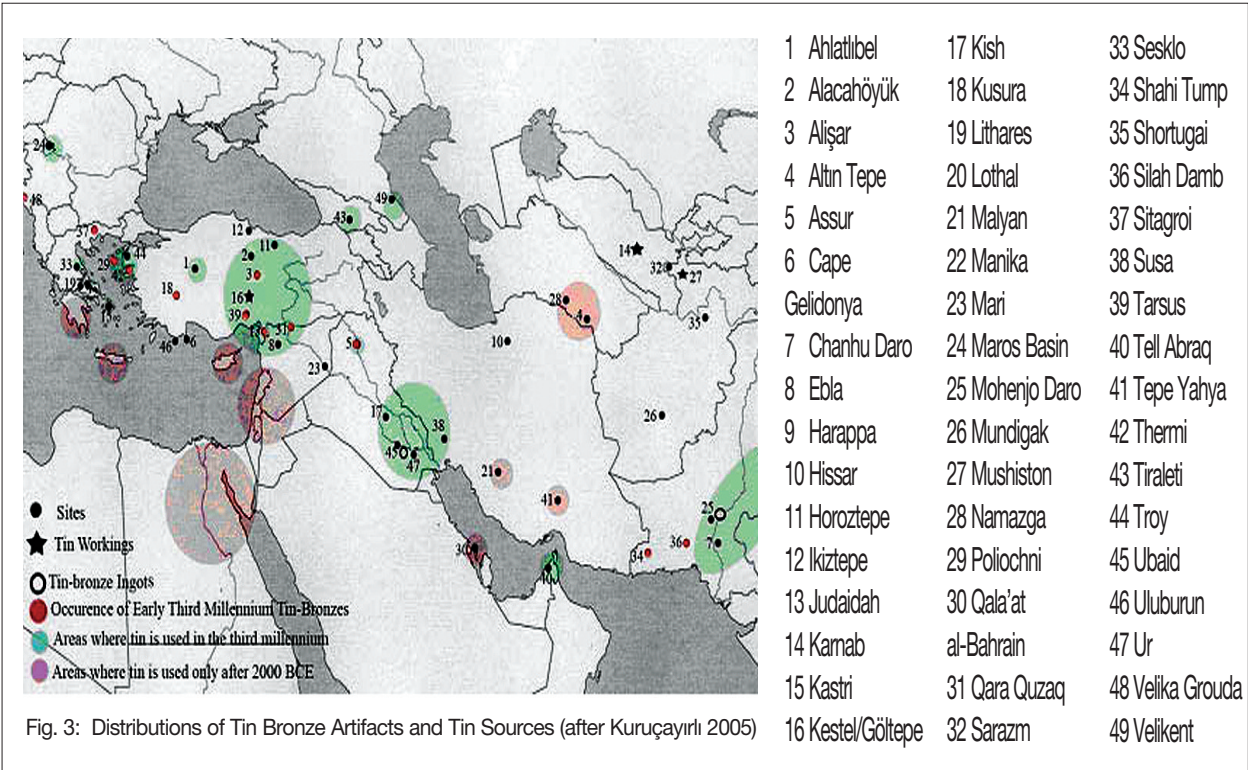


Fig. 3: Distributions of Tin Bronze Artifacts and Tin Sources (after Kuruçayırılı 2005)