THE ARCHAEOLOGICAL SEASON AT GÖLTEPE, TURKEY, 1994

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Introduction

In the summer of 1994 the study season at Göltepe was aimed at continuing the investigation into the specialized production of tin metal used in making bronze. To that end a number of smelting experiments were initiated somewhat changing the parameters of the earlier experiments in 1992. These new runs were prompted by the results of intensive analysis of the excavated crucibles and ground ore and slag found in excavated contexts. Three separate teams of scientists both in this country and abroad have approached the reconstruction of Early Bronze Age technology with the use of new instrumental analysis techniques. This year further tests of the one ton of excavated metallurgical residues began with the aim of analyzing the diversity of by-products, which include chunks of ore, ground ore powder, ground slag powder, and atypical varieties of vitrified ceramic crucibles. An ongoing effort of archaeological, geomorphological survey, and modern land use studies formed the other arm of the project.

What sets the Early Bronze Age industrial/habitation site of Göltepe apart from other contemporary sites is its location within an immediate mining zone where the Kestel Tin Mine (figs. 1, 2) and other silver, gold, copper, and iron mines are situated (see illustrations on cover and title page). Not surprisingly, a preliminary spatial distribution of metallurgical debris inside pit house structure rooms at Göltepe (see illustration on page 13) reveals a special function settlement with a profound association with intensive mining and smelting. The production of metal was a critical high technology in a number of ways. Metal was the standard of value, medium of exchange, and the raw material of tool and weapon industries. Often metal was a vehicle for complex reciprocal gift exchanges. But the backbone of the industry, the technologically advanced mining and smelting operations, is often absent in the reconstruction of these processes and economies. Surely the dynamics of provisioning metal to lowland centers, and the impact of this industry upon different subsystems of Anatolian society are much more complex than the metal artifacts found during excavations lead us to believe. Clearly by the third millennium Anatolian sites were theoretically in a position to distribute wealth both internally and externally in the form of metals, a wealth finance that is mobile,

Figure 1. Extraction galleries inside Kestel Mine, Early Bronze Age

storable, and removable. Thus while the metal objects from Early Bronze Age sites highlight sophisticated metallurgical skills, their very existence at this magnitude points to a hidden production technology that operates in industrial strength in the mountain source areas. Industrial operations such as this were already in place during the previous Chalcolithic period as evidenced by metal processing at Değirmentepe and the urban metal workshops at Arslantepe, Tülintepe, Norşuntepe, and Tepecik in eastern Turkey.

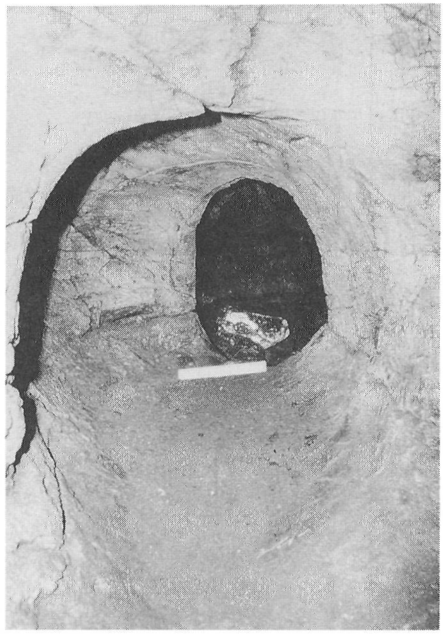
Figure 2. Extraction gallery inside Kestel Mine, Early Bronze Age

The main conclusion to be drawn is that by the end of the third millennium B.C. metal production in the central Taurus range had already been transformed into a multitiered operation with wide networks of interaction. The first tier is the extraction and smelting sites in the mountains; the second tier is the workshop production centers found at urban lowland sites. Göltepe reflects the distinct strategies of the first tier of processing rough metal products, that is, local ore extracted directly from the neighboring mine and smelted into rough form. To be sure, abundant forest supplies nearby played a large role in the transformation of tons of ore into transportable ingots or rough first-smelt metal products. The final destination of this initial stage of metal production would be the workshops in the lowland reciprocal town site assuredly situated in agriculturally fertile areas. The specialized crafts of refining the rough first-smelt metal, alloying, and then casting the molten metal into idiosyncratic shapes was done in these lowland workshops. It is worth reiterating the obvious point that the manufacture of metal at the mines and smelting sites are the least-studied major aspect of early states, leading to a perspective of metallurgical techniques skewed toward the end users.

To further our efforts to establish a chronological sequence for Göltepe, ten radiocarbon dates (calibrated 1 sigma) from the 1993 season were attained and the dates range from 4350 to 2175 B.C., corroborating the ceramic evidence. A dendrochronological date of 1978 +/- 37 years was obtained from a piece of charcoal in a refuse pit fill context. Seven samples of charcoal from inside Kestel Mine gave radiocarbon determinations (calibrated 1 sigma) ranging from 3625 to 2147 B.C.; three more were Byzantine and modern reflecting a use of the mine for shelter.

Analysis of Crucibles, Ore Powders, and Metallurgical Debris from Göltepe

The excavations at Göltepe yielded a variety of metallurgical residues, such as lumps of tin-rich hematite (iron oxide) ore, different grades and colors of ground ore powders, ground slag, and metal artifacts (figs. 3a–f, 4). A sampling procedure was designed to include all types, as well as the excavated crucibles, which now total a metric ton. The first step was to establish the source of the ore materials on Göltepe. To that end the ore materials were mineralogically analyzed by Bromley

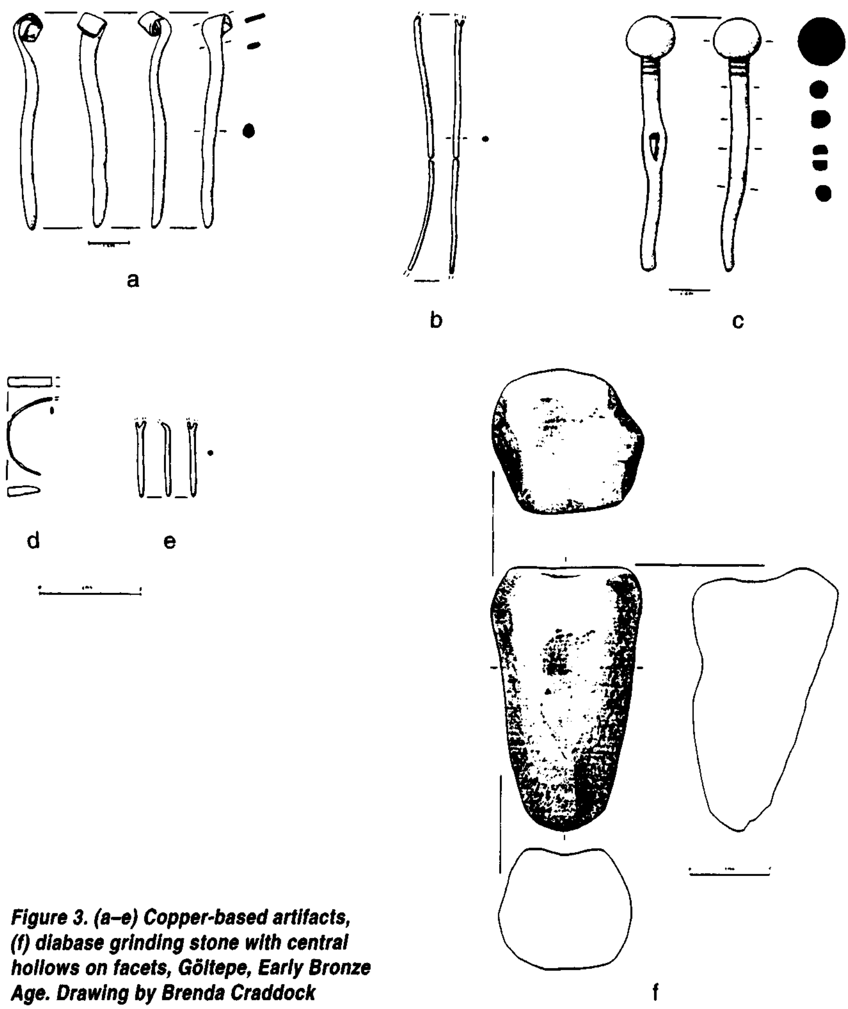

Figure 3. (a–e) Copper-based artifacts, (f) diabase grinding stone with central hollows on facets, Göltepe, Early Bronze Age. Drawing by Brenda Craddock

Petrolab at Cornwall and found to be the same as the ore from Kestel Mine. The site of Göltepe is on top of a flysch bedrock and contains no mineral bearing veins; analysis of the host rock showed that it had no resemblance to the archaeological materials and thus established that the minerals were taken to the site from its source two kilometers away. A considerable amount of hematite ore nodules were recovered during excavations at Göltepe that resemble the ore from Kestel. Analyses of these nodules yielded an average tin content of 2,080 parts per million (with a range from 14,300 to 0 parts per million), nearly three times the average now available at Kestel Mine. Analysis of one sample contained 1.5% tin, suggesting at least a 2% or higher ore mined originally at Kestel, a very good grade of ore. This strongly suggests that only high-tin containing material was selectively transported from Kestel Mine to Göltepe for processing (grinding) and smelting purposes. In order to recover the tin from the hematite matrix, the ore must have been crushed to powder consistency. The over 5,000 ground stone tools (fig. 3f) used in ore crushing from excavated contexts inside pit house structures at Göltepe support this conclusion.

Pit house floor assemblages at Göltepe often yielded dense concentrations of variously colored ground ore powder, often in excess of ten kilograms, and at times stored as the contents of vessels (fig. 5). The colors ranged from purple/burgundy, pink, black to beige and each had varying tin and iron contents. Their composition was similar to the hematite ore from Kestel which suggests that they must have had the same origin. Analyses by Hadi Özbal, Mieke Adriaens, Effie Photos-Jones, and others clearly indicate that there are three groups of powders: *Group 1* is unprocessed ground ore material, *Group 2* may be the residue from an ore concentration process (the enriched portion having been extracted), and *Group 3* may be ground slag from which the tin metal product has been removed.

The scholarly debate over the original amount of tin at Kestel Mine has continued unabated and has gained impetus as a result of the new archaeometallurgy discussion group on the Internet. Skeptics primarily point to the relatively small amounts of tin ore left in Kestel today and suggest the mining of other minerals such as iron or gold. Although the evidence is inconclusive since the mine was exhausted in antiquity, the more convincing arguments about the object of processing stem from archaeological finds at Göltepe. Aside from the tin-rich crucibles (fig. 6), perhaps the best indication of processing aims is the undeniable increase of tin content in a flow pattern starting from vein samples taken in the mine, samples from the hematite ore nodules found at Göltepe, the tin content in the crucibles, and finally samples taken of the multicolored ground and pulverized ore found stored in vessels and floors of pit house structures. It is strikingly obvious that tin-rich hematite was being enriched between its path from the mine to the smelting crucible. None of the other elements analyzed showed this patterned increase.

Figure 4. Lead Ingot, Göltepe, Early Bronze Age

The crucibles themselves at Göltepe had high concentrations of tin on the inner vitrified surface. Recent atomic absorption analyses support the earlier Smithsonian results with vitrified examples ranging up to 4% tin content (four of the new samples of crucible tested yielded tin content above 1% (1.009%, 2.09%, 2.21%, and 3.65%), a fivefold increase relative to the powders. 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.

This aim is also verified by a series of new analyses using microprobe and secondary ion mass spectrometer (SIMS) at the University of Chicago Fermi Institute and Antwerp University. The microprobe indicates that these vitrified ceramics contain a thin accretion layer of silicates with 2–3% tin oxides. A shiny layer rich in tin

Figure 5. Ground ore stored in jars, Pit house A15-0100-006, Göltepe, Early Bronze Age

in a back scattered electron image is shown in the illustration on page 1. Small inclusions in this material contain up to 65% tin oxides. SIMS analysis of a crucible that had a shiny green glassy material still adhering to its surface showed that two types of crystals were present: long thin crystals of tin oxide (SnO_2) and equiaxed crystals of iron-tin, with high tin concentrations that were consistent with metallic slag. Similar methods were used to test a sample of powdered ore material found in a pit house structure. Interestingly, one of the crystals was iron-tin and was of a structure suggesting that heat had been applied and that the result was man-made. This suggests that some of the powdered materials found at Göltepe were ground slag with the tin metal already removed.

Establishing Production Yields

Given the results of the analyses of the archaeological materials, several experimental smelting procedures were tested both in the field at Celaller (a mountain village near Göltepe) and at the University of Chicago by our tin specialist, Bryan Earl from Cornwall. These and other experimental products were tested using atomic absorption spectography by Hadi Özbal of Boğaziçi University in Istanbul. A video camera documented these replication experiments, while prints and slides were taken for future publication of the process. A total of four experiments were conducted, one in Cornwall, two in Turkey, and a fourth in Chicago. The courtyard of the Oriental Institute served as the setting for the Chicago smelting experiment, which was widely witnessed by faculty, staff, and students from the University of Chicago (see illustration on page 131). Scientists from various departments of the University of Chicago (such as chemistry and geophysics), staff from the Enrico Fermi Institute, as well as researchers from the Field Museum and the Illinois Institute of Technology joined the demonstration. Bryan Earl successfully obtained tin metal prills (globules) from ore powder found on the excavations at Göltepe.

The experiments were aimed at establishing production techniques and were designed to determine the magnitude of tin production at the site, a question that still eludes us. Processing involved intentionally producing tin metal by reduction firing of tin oxide (cassiterite) in crucibles—with repeated grinding, washing, panning, and resmelting. The first experimental crucibles were fabricated from local Celaller Turkish clays. Using a slab construction technique, three crucibles were made replicating some of the range of sizes and techniques of the actual crucibles recovered during archaeological excavations.

The charge feed utilized in the experiment was ground ore powder excavated from Early Bronze Age pit house structures at Göltepe. Three separate qualities of charge were tested, (a) a fine ground ore with relatively high tin content but unvannable because of iron contamination, (b) ground ore as found in its original state without beneficiation with a vanning shovel, and (c) a very small sample, enriched and placed into a micro-crucible in a larger crucible imitating a bowl furnace and crucible.

Other variables during these tests were the use of simultaneous blow pipes (up to three), the crucible with or without cover, and the nature of the fuel used. The experiment with three blowpipes (fig. 7) made the fire so hot that it melted the metal blowpipe and vitrified the micro-crucible. This indicated a temperature in excess of 1100° C. Variation in the charcoal effected the success of the smelt tremendously. The use of commercial charcoal briquettes resulted in an unsuccessful smelt in Cornwall, while wood charcoal completed the smelt efficiently and resulted in tin metal prills (globules) in Chicago. The test run utilizing a micro-crucible was only partially successful. Even though we did manage to produce prills, they penetrated the fabric of the micro-crucible and were extracted with effort. This dramatically pointed out why the archaeological crucibles had a layer of dense, fine, well levigated clay on the interior surface. The charge sample with high levels of iron that was not enriched fared poorly as well. Trial and error revealed that a simple formula for the production of tin metal prills is to use a simple blowpipe and wood charcoal, after having enriched the ore to approximately 10% tin content with a vanning shovel.

Having produced small, sand-sized globules of tin metal and small amounts of slag, the next step was to attempt to make a tin bronze using this experimentally smelted material. This was accomplished at Cornwall and Istanbul using the experimental tin prills that had been manufactured in Turkey. While the tin in prill form could have been remelted and the metal poured into a mold producing an ingot, the alternative for alloying copper would be to utilize the prill-iron mixture by pouring into molten copper. The iron content of the tin produced in this manner would be rejected into a dross, producing a good bronze.

Land Use Patterns

Geomorphological and archaeological research was directed by Tony Wilkinson (Research Associate at the Oriental Institute), who surveyed the hillside terraces surrounding the sites during the summer of 1994. His work will ultimately help us determine land use patterns, agricultural production strategies, and carrying capacities. The foregoing is aimed at the documentation of changing patterns of urban land use and ecology and the principal components of this change. Changes are predicted especially in the realm of agricultural fields. Quite useful models can be found in

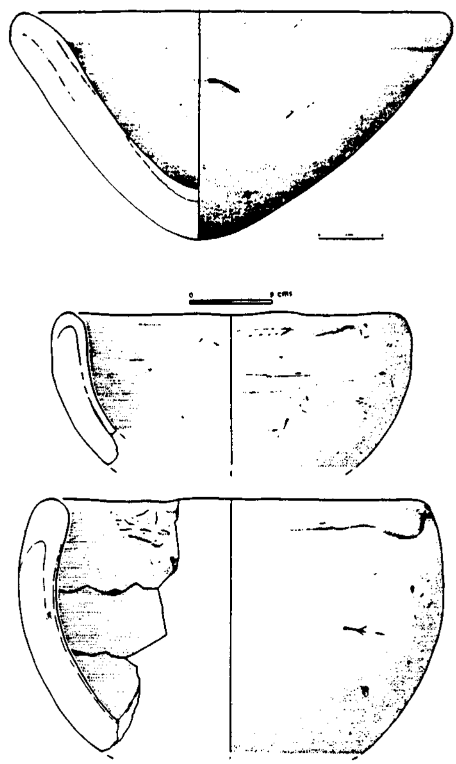

Figure 6. Crucibles, Göltepe, Early Bronze Age. Drawing by Brenda Craddock

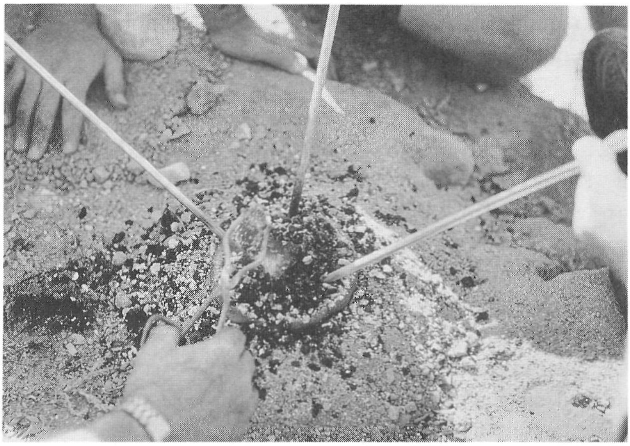

Figure 7. Tin smelting experiment using three blowpipes, ground powdered ore dating to the Early Bronze Age found at Göltepe, and crucible made from local clay, Çamardı, Turkey, 1994

Yemen and Jordan, where in order to meet the increasing demands of foodstuffs in antiquity, terraces were built into the hillsides and used for agricultural purposes. Hitherto unused higher mountain altitudes were also integrated into the growing demand for provisioning the increase in population. Since the greatest activity of mining extraction and smelting industries date to the Early Bronze Age, a larger population is predicted at that time around the Göltepe area and would necessitate terracing the mountain. It was to obtain data supporting this idea that an archaeological and geomorphological survey as well as pollen, palaeobotanical, and phytolith analyses were initiated. Relic forests and traces of ancient terracing were mapped onto a 1:20,000 map and digitized using AutoCAD version 11 on an IBM-compatible computer by John and Peggy Sanders of the Oriental Institute Computer Laboratory. At this point the plans of the excavation are being plotted in AutoCAD as well, whereas the large-scale surface terrain of the entire mountainous region around the site is being produced with the ARRIS program and its Topographer module on a Sun SPARCstation computer.

Ethnographic Research

The village of Celaller provided us with rich ethnographic examples of ongoing transhumance practices. Originally Yörük nomads migrating from the lowland Cilicia and Syrian coastal littoral, the local population was settled into the present village when the border between Turkey and Syria was established prior to the Second World War. The central Taurus mountainous area (1,600–3,000 meters altitude) was originally the summer pasturage of these nomads and when given the choice of land, they chose an area more conducive to the livelihood of their camels and herds of sheep and goat. Their economy today is still based on pastoralism, carpet weaving, and limited agriculture. The village owns vast hectares of pasture lands in the Niğde Massif mountains and continues to migrate further upland every year thus continuing the transhumance legacy. Notably, this is a local transhumance pattern that was adapted regionally and carried out by a splinter segment of the society, the women. For six months out of the year, the women of the village take a few children and go upland to the even higher altitudes (2,000–2,500 meters) with their herds. The men generally stay in the village working on the meager agriculture or hire out as cooks throughout Turkey. The highland dairy industry run by the women consists of making yogurt, cheese, and dairy products, and shearing the sheep for eventual use in their carpet industry that occupies them during the winter months. These local patterns of pastoral nomadism were investigated in 1994 by interviewing and mapping the uniquely idiosyncratic transhumance systems of the women in the village.

In 1996 a final campaign to excavate the series of graves in the Kestel mortuary chamber of an abandoned mine shaft will define a formerly mute industrial system of antiquity.

Acknowledgments

The 1994 study season was conducted under the auspices of the Turkish Ministry of Culture, Directorate General of Monuments and Museums, and the Niğde Museum. Work on the site was generously supported by the National Endowment for the Humanities, the National Geographic Society, and the Institute of Aegean Prehistory. The author wishes to express her gratitude here to both the Oriental Institute and its members—Mr. and Mrs. Albert F. Haas, Mr. and Mrs. M. D. Schwartz, Elizabeth B. Tieken, and Melanie Ann Weill—who financially contributed to the success of the excavation. The team was led by Aslıhan Yener, the director, with Metin Gökçay as the representative of the Ministry of Culture, Directorate of Monuments and Museums. Fine tuning the ceramics was tackled by Dr. Sylvestre Duprés and Behin Aksoy. Conservation was ably managed by Fazıl Açıkgöz. Replication smelting experiments and analyses of metallurgical debris were undertaken by Bryan Earl of Cornwall and Hadi Özbal of Boğaziçi University. Alan McCune, graduate student in the Department of Near Eastern Languages and Civilizations, helped with the topographical mapping of Kestel slope and Gül Pulhan from Yale University aided the efforts of ceramic typology. Gül Pulhan also investigated transhumance patterns of Celaller women in an ethnographic study of localized nomadism. Allan Gilbert and Patience Ann Freeman of Fordham University continued the faunal analysis while Mark Nesbitt of Cambridge University, England, completed the palaeobotanical report. Analyses of the one ton of crucible slag and residues were further advanced by Dr. Ian Steele of the University of Chicago, Laura D'Alessandro of the Oriental Institute, and Mieke Adriaens of Antwerp University, Belgium. Effie Photos-Jones, Alan Hall, and Alan Hendry of Strathclyde Universities in Scotland undertook the analysis of metallurgical debris. Alan Bromley of Petrolab, Cornwall, reported on the mineralogy of Kestel tin ores. Brenda Craddock and Ayşe Özkan were the architect and illustrators. Tony Wilkinson of the Oriental Institute researched land use patterns and located ancient agricultural terracing systems. John and Peggy Sanders of the Oriental Institute Computer Laboratory digitally rendered the topographical maps and plans. Edward Sayre and Emile Joel from the Conservation Analytical Laboratory of the Smithsonian Institution worked with the author on the next stage of lead isotope research.