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COPPER SMELTING IN LATE BRONZE AGE CYPRUS

The Excavations at Politiko Phorades

by A. Bernard Knapp, Vasiliki Kassianidou and Michael Donnelly

*Now I have sent to you
500 (talents) of copper
As a present to my brother
have I sent it to you.*

*Let my brother not take it to heart
that the amount of copper is small
for in my land the hand of Nergal,
my lord, has killed all the men of
my land and so there is no one
to produce copper.*

The mid-fourteenth-century BCE royal archives of Amarna yielded a number of letters between the king of Alashiya (Cyprus) and the pharaoh in Egypt. The letter quoted to the above, known as EA (El Amarna) 35 is especially interesting because it mentions a large shipment of copper, states clearly that copper was locally produced in Cyprus, and indicates that a plague (brought by the god Nergal) had smitten the island (Knapp 1996: 22).

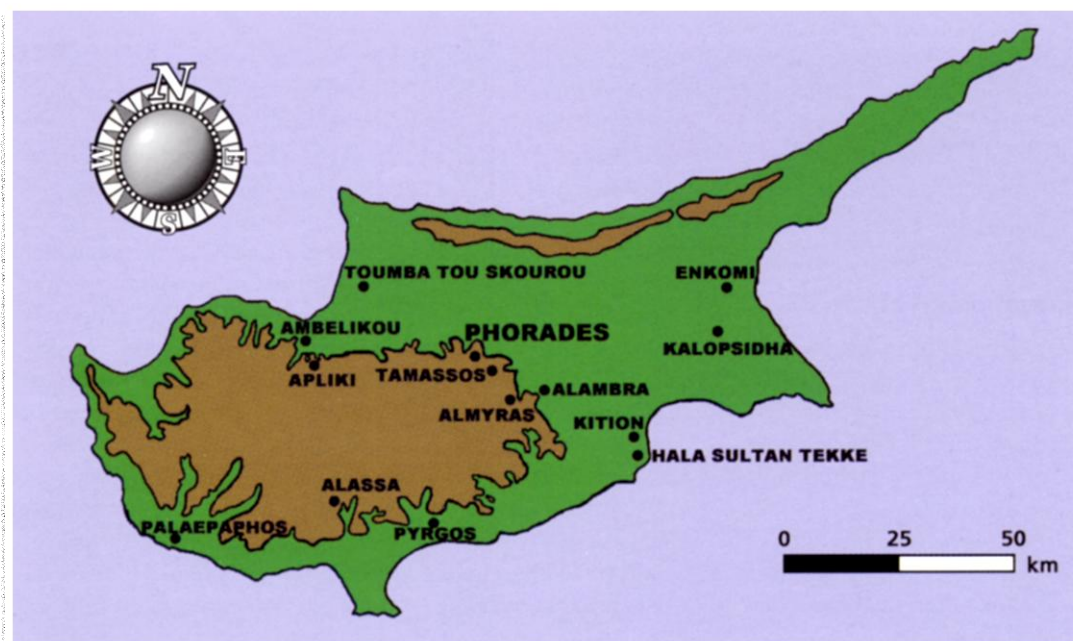
Among the earliest references to the copper and bronze of Alashiya are some cuneiform texts from Mari (on the Euphrates River in Syria) dated to the first half of the eighteenth century BCE. One of these mentions copper from the "mountain" of Alashiya, almost certainly a reference to the copper-ore deposits found in the Troodos Mountains of central and western Cyprus (T.361; Knapp 1996: 18). Production and export of Cypriot copper reached its peak in the Late Bronze Age (about 1600–1200 BCE), a time of growth, prosperity, and emerging social complexity (Knapp 1986; Muhly 1986). Urban centers like Enkomi, Hala Sultan Tekke, and Kition, with large public and ceremonial buildings and harbors, were established along the coast, their prosperity almost certainly dependent on the ever-increasing trade with the Levant and the Aegean. Cyprus's main export at

this time was surely copper, traded in oxhide-shaped ingots that weighed approximately 65 lbs. Oxhide ingots, thought to have been an internationally accepted unit of trade during the Late Bronze Age, have been recovered in a number of sites in the Aegean and eastern Mediterranean and as far west as Sicily and Sardinia (Gale 1991; Muhly et al. 1988). Furthermore, people carrying an oxhide ingot on their shoulders are represented in Cypriot bronze stands and numerous Egyptian wall paintings. The biggest single discovery of copper oxhide ingots came from the Uluburun shipwreck off the southern coast of Turkey (Pulak 1998). The small ship was carrying almost 11 tons of pure copper that could well be of Cypriot origin. That the ship was also carrying a lot of Cypriot pottery indicates that Cyprus was at least one major port of call for the ship, perhaps its last one.

THE SYDNEY CYPRUS SURVEY PROJECT AND POLITIKO PHORADES

This historical situation is well-known among Cypriot and Mediterranean archaeologists, and the copper ingots represent the end product of a complex process involving the mining, smelting, and casting of copper. Until very recently, however, almost everything we knew of this productive process was conjectural, or reconstructed on the basis of later evidence. In 1992, the Sydney Cyprus Survey Project set out to change that situation (Given et al. 1999; Given and Knapp 2002). One of our primary goals was to consider long-term settlement patterns in relation to metallurgical and agricultural resources; we hoped to find both industrial sites (smelting areas, slag heaps, mines) and the agricultural villages that would have provided food and other resources to support them. Another goal was to understand better the relationship between metallurgical resources, agricultural production, and trade, on the one hand, and on the other, the emergence, development, and changing configurations of the complex society that had existed on Cyprus from the beginning of the Bronze Age.

Walking along a dry creek bed searching for exposed sections of stream sediments in 1996, project geomorphologist Jay Noller of Oregon State University observed a large quantity of slag and furnace material protruding from a bank, enough cultural material



Map of Cyprus showing sites mentioned in text. Contour line at 300 m.

second millennium BCE; the pottery all points to the earliest phase of the Late Bronze Age (ca. 1600 BCE), making *Phorades* the earliest primary smelting workshop yet excavated on Cyprus.

Evidence for prehistoric mining on Cyprus has until now been limited and difficult to date, as nearly all the ore bodies worked in antiquity were also worked in modern times. Miners have occasionally

to make him suspect the presence of a copper-smelting workshop. The site, now designated Politiko *Phorades*, has been the focus of our work for the past four years (Knapp et al. 1998, 1999; Kassianidou 1999). The site's geological setting and several radiocarbon dates place the *Phorades* workshop in the mid-

encountered caves or galleries filled with ancient mining waste—including wood, charcoal, and tools—but these materials were usually assigned a date in the Hellenistic–Roman era, simply because we knew that copper was exploited on a large scale at that time (Bruce 1937). The earliest archaeological evidence for mining on Cyprus comes from Ambelikou *Aletri* in the northern Troodos foothills where, in 1942, nineteenth century BCE pottery and stone axes were found in mining galleries (Merrillees 1984). The site was only briefly investigated before modern mining activities destroyed it. Rescue excavations at another mining site, discovered in the 1930s near Apliki village, revealed a few buildings with pottery from the very end of the Bronze Age, along with some blocks of slag and *tuyères* (nozzle-like ceramic pipes through which air was forced into the furnaces to facilitate combustion), in what otherwise appeared to be a domestic setting (Du Plat Taylor 1952). Unfortunately, as at Ambelikou, the site was never fully excavated or published. (James D. Muhly and Barbara Kling have undertaken the task of publishing the Apliki excavations based on Du Plat Taylor's excavation diaries and utilizing a series of new specialist reports.) Apliki, too, was subsequently destroyed by mining operations. More recently, roasting and smelting furnaces have been uncovered at the Iron Age–Hellenistic (600–150 BCE) site of Ayia Varvara *Almyras*, discovered in 1982 and excavated by a Swiss expedition off and on since 1988 (Fasnacht et al. 1992; Fasnacht 1999). Located near large copper-ore deposits south of Nicosia, it consists of a small mine and a smelting workshop, the latter atop a low hill. Although *Almyras* was the first primary smelting workshop to be discovered on Cyprus, its earliest occupation is almost a millennium after that of *Phorades*. An Italian team is currently excavating at Pyrgos *Mavroraki* where a number of features have been found in association with metallurgical slag; the reported Early–Middle Cypriot date of this site awaits confirmation (Belgiorno 1999).



The site of *Phorades* at the time of its discovery in 1995. Photo by V. Kassianidou.

What, then, are we to make of the Late Bronze Age, probably the earliest period in which Cypriot copper was exploited intensively, and for which we have had almost no actual evidence of mining or primary smelting? How were copper ores extracted, smelted, and distributed during that critical period in the development of the Cypriot copper industry? Before the discovery and excavation of *Phorades*, any answers to those questions were purely speculative.

THE EXCAVATIONS AT PHORADES

Phorades proved to be a small copper-smelting workshop. The excavation of the site was completed during the summer of 2000. Over three field seasons we recovered more than twenty thousand pieces of slag, weighing 3.5 tons, along with large fragments of furnace lining, *tuyères*, and gossan (an iron-rich, usually distinctively red, mineral found atop areas rich in copper sulfide deposits). The metalworkers at *Phorades* made use of river-channel deposits to construct an artificial bank. This bank is contemporary with the final phases of metallurgical production,

and occupies the channel of the ancient, most likely seasonal creek bed. Atop this bank's cobble core, layers of gravel were added to form flat surfaces upon which the metalworkers went about their work. Slag, the waste product of the smelting process, was piled against the creek's bank, eventually forming a small heap.

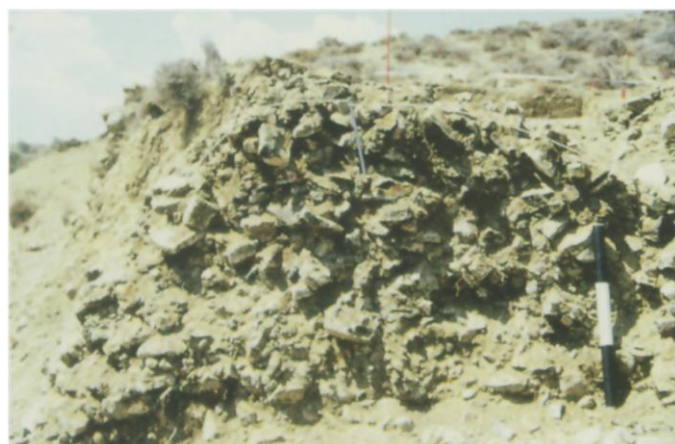
Just north of the slag heap we uncovered a large number of almost complete *tuyères* and another feature clearly constructed by the metalsmiths: a stone-lined pit within which we found *tuyère* fragments. Was this feature somehow related to the smelting activity? It is not a smelting furnace, because we know that the furnaces were made from clay and were not dug in the ground. Nonetheless, it might be a tapping pit or other installation somehow related to the smelting process. The discovery of a patch of heat-affected clay near this feature also suggests that this was once a working surface.

We are uncertain just why smelting activities would have been situated within a stream channel and why the slag heap would have been banked against the old channel walls. We would not, however, discount the possibility that this set-up had some symbolic importance to the coppersmiths. We must also consider whether the channel held water only seasonally, as is the case with most streams on Cyprus today. If so, was it empty during the actual smelting operations? The size and composite nature of the cobble bank suggest a sequence of activities as opposed to a single phase, while the discovery of numerous tiny snail shells within the bank, all post-dating its construction, suggests that the smelting operations were conducted seasonally. As is the case in so many other mining and production contexts, both ancient and modern, it seems likely that the smelting of copper took place during down time in the agricultural calendar (see various papers in Knapp, Pigott and Herbert 1998).

The pottery from *Phorades* provokes interesting questions about the status of copper workers within Cypriot Bronze Age society. The dearth of



The 2000 field season of excavation at *Phorades*. Photo by V. Kassianidou.



The ancient slag heap at *Phorades* during excavation. Photo by K. Ulrich.

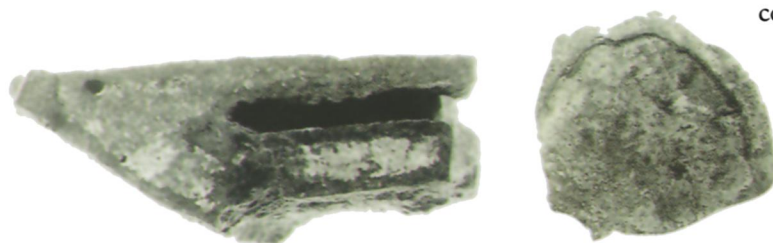


The stone lined feature and concentration of *tuyères* during excavations. Photo by V. Kassianidou.

coarse wares and the presence of “elite” pottery styles (e.g., White Slip, Base Ring, Black Slip, Red Lustrous, and one possible Aegean import) suggest that somebody at *Phorades* had access to what we regard as high-status goods. Although, hypothetically, such items might derive from another site or tomb upstream (only later becoming embedded in our site), these pottery sherds are in good condition, with sharp breaks still visible, and thus not at all what one would expect from material washed downstream. Furthermore, these sherds are found almost exclusively within the site’s metalworking levels. Later sherds—Iron Age to Roman in date—found on the surface and in the uppermost levels of the site, are worn, consistent with river deposition.

ARCHAEOMETALLURGY AT PHORADES

All the slags recovered from *Phorades* derive from large cakes that were flat on top and concave on the bottom (“plano-concave”), a type previously unknown on Cyprus. They would have had a maximum diameter of 17.3 inches at the top and a weight of about 44 lbs. What can these unique slags from *Phorades* tell us about copper production practices? The slag cakes’ concave bottom suggests that they may have cooled on top of a



Fragments of a typical slag cake from *Phorades*. Photo by X. Michael.

layer of molten metal. The edges of the slag pieces often contain small gravels, and it is possible that the people running the smelter emptied the furnace into a pit lined with clay or gravel.

Preliminary metallurgical analyses indicate that the slags contain a large amount of metallic copper sulfides. In turn this suggests that they derive from an initial phase of smelting that would have yielded matte (a copper-iron sulfide), not copper. A small piece of matte found during the 1998 season therefore assumes a very important place in our interpretation of *Phorades*. Matte is an intermediate product and thus extremely rare in archaeological excavations; it would have had to undergo further treatment before being converted into black copper. The black copper would then have to be refined, probably several times, in order to produce copper metal of the purity found in the oxhide ingots. The presence of matte signals clearly that *Phorades* was a primary smelting workshop. Secondary smelting and refining may have taken place at the site or elsewhere.

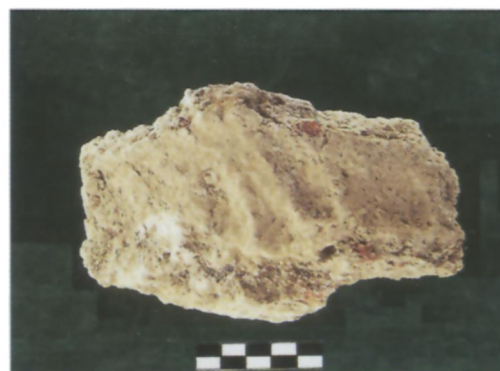
We have collected more than six thousand fragments of smelting furnaces—rims, walls and bases—all made of coarse refractory clay mixed with a large amount of organic material.

The furnaces appear to have been cylindrical structures (average outer diameter of 16.5–17.3 inches) with a flat base and well-defined rims. Some of the fragments are large enough to enable us to estimate the dimensions and form of the furnace, as well as their method of construction. Fingerprint impressions around the bases indicate that the clay was pushed down and against the outer surface of the base; they also serve as vivid reminders that these are human artifacts. Whenever preserved, the outer surface of the furnace is smooth and well-shaped, and the base is perfectly flat. The fragments clearly show that the furnaces were constructed in the round, not in a pit or against a stone wall. Had this been the case, the outer surface would not have been so smooth and finger impressions would have been on the interior surface where the maker would have pushed the clay against the pit or the stone structure, as was the case at Timna (Rothenberg 1990: 12 and fig. 25). The furnaces from *Phorades* are very similar to one from Enkomi, a key Late Bronze Age port on the east coast of Cyprus. There, a cylindrical coarse ceramic vessel with a slagged inner surface was first thought to be a crucible, but Ronald Tylecote (the eminent British archaeometallurgist) recognized it as a smelting furnace (Tylecote 1982); indeed, analyses on a small slag sample from the bottom of that “crucible” detected the presence of small prills (spherical pellets) of copper sulfides. A small hole seems to have been pierced through the walls so that the contents could be emptied.

We have recovered fifty almost complete *tuyères* and over 600 fragments. Made of highly refractory clay, *tuyères* force air into the furnace, making possible the extreme temperatures, usually 1200–1300° C, required to smelt copper ore. Most of the *tuyères* are cylindrical and many are slagged and highly vitrified. One of the best examples has a



Fragments of furnace lining from *Phorades*. Photo by X. Michael.



Fingerprint impressions on a furnace from *Phorades*. Photo by K. Ulrich.



Well-preserved slagged *tuyère* (a nozzle-like ceramic pipe through which air is forced into the furnace to facilitate combustion) from *Phorades*. Photo by V. Kassianidou.



Elbow *tuyère* at the time of discovery. Photo by P. Duffy.

preserved length of about 30 cm. During the 2000 season, we also recovered an “elbow” *tuyère*, a well-known type from other Late Bronze Age sites on Cyprus. Apart from the cylindrical and elbow *tuyères* we also have four double *tuyères*, a type previously unknown on the island. In five well-preserved examples, a layer of clay seems to have been wrapped around what appears to be a used *tuyère* (identified as such from its slagged surface). This suggests that the purpose of these double *tuyères* was not to protect the inner part with a second or outer part made of more refractory clay (as is the case with examples from Timna, dating to the New and Late New Kingdom; Rothenberg 1990: 8), but rather to repair and re-use a *tuyère* that had somehow become damaged. The position of the *tuyères* in use is problematic. We have found no furnace-lining pieces containing a hole for the *tuyères*, and the diameter of the *tuyères* (2.75–4.0 inches) argues against the notion that they would have been inserted through holes in the furnace walls. (The Enkomi furnace also lacks holes for *tuyères*.) We therefore surmise that the *tuyères* were placed directly into the open mouth of the furnace. We have no material evidence for bellows, but we know from Egyptian wall paintings and excavations elsewhere on Cyprus that, at least in the later

Bronze Age, ceramic bellows were used in conjunction with *tuyères* (Tylecote 1981). The possibility exists that the *Phorades* metalsmiths used bellows made from organic materials, such as leather. If the *tuyères* were set in the furnaces from the top, workers may have blown air (using their mouths) into the furnaces without bellows, a practice seen in nearly contemporary Egyptian wall paintings.

PHORADES IN CONTEXT

Kokkinorotsos (“red rock”), the probable source of the ores smelted at *Phorades*, is visible from the site, and lies about one-half mile (thirty minutes on foot) to the northwest. A couple of possible crushing stones have been found at *Phorades*, but there are no other remains

clearly connected with the beneficiation process. Either ore preparation and roasting took place in some part of the site that has since eroded away, or else it occurred nearer the mine.

Among the most important factors in deciding where to establish a smelting workshop in antiquity were proximity to ore and deposits of flux (a mineral added to a furnace charge to produce a more fluid slag which will melt at lower temperatures), fuel, water, and refractory clay. Of course, social and economic factors will also have influenced site location. As the ore, the flux, and the fuel are equally available in the direct vicinity of the mines around *Kokkinorotsos*, the workshop’s location may have been chosen in part because of the creek, which would have provided the clay and water required for construction of the furnaces. A spring near the site would have provided drinking water for the workers even in the hottest months, and thus was also a critical factor in choosing a location for the smelter.

It is hard to calculate the amount of copper produced at the workshop when we do not know the copper content of the smelted ore (no examples of ore were found during the excavations). Nonetheless, based on the amount of slag recovered from *Phorades* and the information gained from smelting experiments, we estimate that the smelting furnaces

from our site would have produced something on the order of 650 pounds of copper (the equivalent of ten oxhide ingots). When we compare this to the amount of copper carried by the ship that sunk at Uluburun (about 350 oxhide ingots), it becomes clear that the level of production at *Phorades* was limited, especially if we take into account the likelihood that some of the metal produced would have been for local use. We thus suggest that *Phorades* was likely to have been only one of many similar sites in the Troodos foothills, each supported by one or more agricultural villages.

Metalsmiths may have had a high status throughout the Early and Middle Cypriot periods and into the beginning of the Late Cypriot, that is from about 2500 to 1600 BCE. Later, as copper production increasingly came under centralized control, metalsmiths became specialized craftsmen dominated by regional or local elites. If so, the seasonal activities that we seem to be witnessing at sites such as *Phorades* would have changed to a fulltime enterprise.

One important implication of the *Phorades* excavations is that we must reconsider the overall economic constellation of Late Cypriot mining and production sites, agricultural villages, rural sanctuaries, and secondary towns (inland) or primary distribution centers (coastal ports like Enkomi) (Knapp 1997). Based on intensive survey and careful consideration of the region surrounding *Phorades*, we can offer a preliminary reconstruction of this Bronze Age industrial landscape. The ore itself would have come from mines on the gossan ridge one-half mile northwest of the site. The preparation of the ores would have been carried out near these ores. Overall what we can envision is a self-contained metallurgical area with all the essential raw materials, social organization, and communications necessary for small-scale, localized production that may have been integrated into a broader economic and ideological system. The patterning of sites in and around our survey area leads us to think that a Bronze Age smelting site like *Phorades*, along with its agricultural support village, would have been linked to a network of sites running in a northwesterly direction to a coastal site on Morphou Bay. Such a site was perhaps associated in part with *Toumba tou Skourou* (another Late Cypriot town and possible distribution center located very near the coast) (Vermeule and Wolsky 1991). Equally it might have been linked to the key site of Kalopsidha, which lies directly to the east and on the banks of the same river as *Phorades* (Åström 1966).

FUTURE WORK

On the broader level of Mediterranean Bronze Age metals trade, the excavations at *Phorades* have taught us a great deal about previously unknown copper production processes as well as their ultimate product, the copper oxhide ingots. These slabs of nearly pure copper are found throughout much of the eastern and central Mediterranean, and form a prominent part of the cargoes on the Bronze Age shipwrecks discovered at Uluburun and Cape Gelidonya (Turkey). The lead-isotope composition of many ingots from these shipwrecks visually matches that of Cypriot ore bodies (although this analytical technique cannot be regarded as definitive on metal provenience).

After three seasons of excavation, we have recovered an impressive array of archaeometallurgical finds in direct association with pottery dated to the earliest part of the Late Bronze Age. This is confirmed by several radiocarbon analyses. The nature of the finds as well as the location of the site point to a primary smelting workshop. Having now demonstrated the existence of a copper-sulfide smelting workshop on prehistoric Cyprus, we still need to consider the social context in which this method of production was adopted, to reconstruct the smelting technology of the early-mid second millennium BCE, and to try and understand how these unprecedented technological developments led to the kingdom of Alashiya becoming known far and wide as one of the main purveyors of copper in the Bronze Age Mediterranean world.

NOTE

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Michael Donnelly received his B.Sc. (honours) in Archaeology from the Department of Archaeology, University of Glasgow, in 1992. He is an experienced field archaeologist, working most recently as Field Project Officer in GUARD (Glasgow University Archaeological Research Division), a field unit directly linked to Glasgow University's Department of Archaeology. His research interests lie in lithic analysis, material culture studies and social archaeology, in particular as it relates to northwest European early prehistory. He has worked at several iron smelting sites in the Scottish highlands and served as Field Director of the excavations at Phorades.