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IN THE SECOND MILLENNIUM BC

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James D. Muhly

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Vasiliki Kassianidou and George Papasavvas

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3. Metallurgical production and trade on Bronze Age Cyprus: views and variations

A. Bernard Knapp

Production and Exchange: Chalcolithic and Prehistoric Bronze Age (PreBA)

The earliest known evidence of copper almost certainly produced on Cyprus stems from the Middle Chalcolithic cemetery at Souskiou-*Laona*. There, excavations in Tomb 158 produced a strip of metal twisted round in nine spiral loops and suspended from a mineralized grey strand of copper; Steel (2003–04, 110) identifies it as a spiral hair ring. Nearby were found six curved fragments of copper, perhaps all part of a single annular pendant or pin (Crewe *et al.* 2005, 51–52, 65, figs 16.2, 16.3). The spiral is nearly identical to another copper example found in the nearby cemetery of Souskiou-*Vathyrkakas* (Christou 1989, 93 and fig. 12.10; Peltenburg 2006, 99–100). Other, nearly contemporary copper pieces were found long ago at Erimi: a chisel, and what have been described as a hook and a knife (Balthazar 1990, 92–93).

Excavations at Kissonerga-*Mosphilia* have provided

crucial data for the earliest stages of indigenous metalworking and casting activities on Cyprus. From Periods 4 (Late Chalcolithic) and 5 (PreBA 1) come six metal objects, some fragments of pure smelted copper, ore consistent with production from local sources, and two possible crucibles. All these indicate that extractive metallurgy and metalworking from local ores was underway no later than the mid-3rd millennium BC (Peltenburg *et al.* 1998, 188–189; Manning and Peltenburg, in Peltenburg *et al.* 1998, 18–20). Lead isotope analysis (LIA) of one of these objects, a copper axe/adze (KM 457), and a piece of copper ore (KM 633) indicated that whilst the ore was consistent with Cypriot sources, the copper axe was not (Gale 1991); its lead isotope composition fell beyond the so-called Cypriot field (or ‘ellipse’). The use of such ‘ellipses’, it should be emphasized, has now been discredited as a means of identifying ore sources; Pollard (2009, 184–186, fig. 1) (Fig. 3.1) shows that the original Cypriot ‘field’ used by the Oxford group

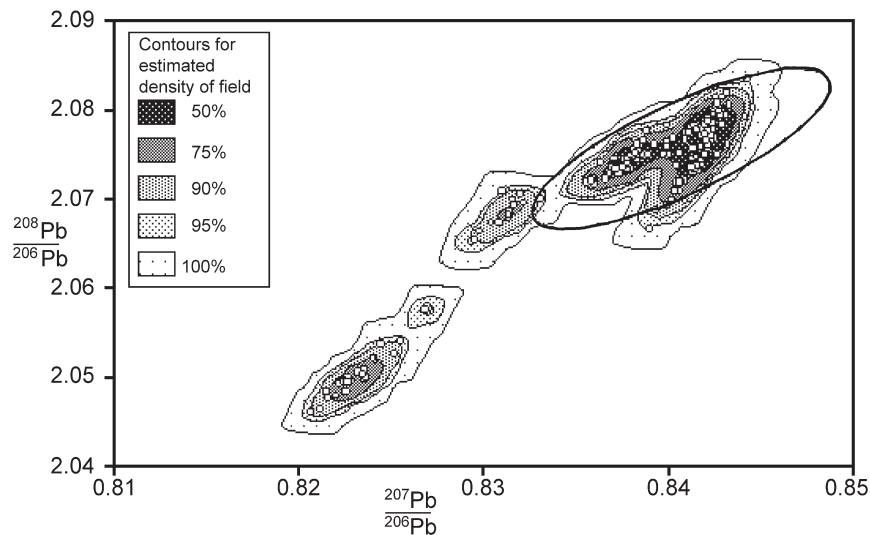


Fig. 3.1. Kernel Density Estimate (KDE) of Cypriot parent lead isotope field, with original Cypriot ‘field’ used by the Oxford group in early publications. Courtesy of Mark Pollard.



Fig. 3.2. Marki-Alonia chalk casting mould (Pre BA). Courtesy of David Frankel and Jenny Webb.

comprised less than half the extent of one based on a Kernel Density Estimate (KDE), reputedly a better estimate of the true extent of a parent lead isotope field (cf. Gale 2009).

In any case, because copper ore and minerals (chalcopyrite, malachite) outcrop along the west coast of Cyprus between Paphos and Akoursos (Zwicker 1988, 427–428), and would have been readily accessible to those who lived at *Mosphilia*, the ore found at the site need not have come from the Troodos ores used to establish the lead isotope ‘field’ for Cyprus. In other words, these local ores from the region around *Mosphilia* conceivably could have different lead isotope compositions, which could account for the distinctive LIA signature of the axe. Nonetheless, Gale concluded that this axe, or the copper from which it was made, was imported to Cyprus, perhaps from northwestern Anatolia. Peltenburg *et al.* (1998, 189) pointed out that although the form of this axe/adze could conceivably link it to other examples of PreBA 1 metal artefacts from Vasilia and Vounous thought to derive from NW Anatolian sources (Stos-Gale and Gale, in Knapp and Cherry 1994, 212), it seems patently clear that the lead isotope field that excluded axe/adze KM 457 was insufficiently defined, and today might well lie within any Cypriot field defined by KDE.

Gale (1991, 47–52) also reported on INAA (Instrumental Neutron Activation Analyses) of six Chalcolithic artefacts, which indicated they were not made from Cypriot native copper, but probably of metal smelted from copper ores. First of all, it is unclear from the publication why this smelted metal could not have come from Cypriot ores. Secondly, INAA – despite its recognised accuracy in determining the provenance of clays used in pottery – is much less accurate *on its own* as a technique to determine metals’ provenance. Based on both LIA and INAA, Gale (1991, 54) concluded that Chalcolithic metallurgy on Cyprus was ‘primitive and

provincial’, even though metallographic analyses indicated that those who made the few Chalcolithic artefacts analysed were acquainted with cold-working and annealing. If we give the indigenous Cypriots of this time any agency at all, we should assume it was they who produced these metal objects, not some ‘foreigners’ who are otherwise barely attested in the material record of the Chalcolithic period. Furthermore, fully half of the metalworking materials from *Mosphilia*, including ore, crucibles and finished products, comes from the area around the ‘Pithos House’, a concentration that may point to local knowledge of both ores and metalworking. One must also wonder why local people would bother to import ores when their own country was awash in copper deposits, or how, if they were so ‘provincial’, they had the wherewithal to conduct trade in the first place? Even if we accept the basic principles of LIA as it relates to metals’ provenance studies, in this case something was clearly amiss with the archaeological conclusions being drawn from its use.

Evidence for a local, insular metallurgical technology increases throughout the PreBA, especially during the Philia phase, with its wealth of mould-cast, copper-based artefacts (summarized in Webb and Frankel 1999, 31–33). The impurities detected in analytical work on some of these early copper-based artefacts (*e.g.* Balthazar 1990, 105, 161) suggest that existing native copper deposits were perhaps already exhausted and, like the evidence from *Mosphilia*, indicate that copper was now being mined and smelted locally (Swiny 1997, 200). Excavations at Marki-Alonia produced remarkable evidence for the casting and smelting of local ores during the PreBA, in the form of three chalk casting moulds (Frankel and Webb 2006, 216–217) (Fig. 3.2). These moulds – used to produce axes or axe-shaped ingots with parallels in Philia phase metalwork – clearly



Fig. 3.3. Sotira-Kaminoudhia dagger (M18) and 'billet' casting of a dagger blade (M12). Courtesy of Stuart Swiny.

point to the indigenous production of metal artefacts from local Cypriot ores (Fasnacht and Künzler Wagner 2001, 38–41, fig. 11). Because the smelting and casting of local copper ores were carried out at Marki, the site's location, if not its foundation, may have been based on its proximity to the nearby copper ore bodies at Mathiatis, Lythrodondas, Sia and Kambia.

Detailed archaeological and archaeometallurgical (EDXRF) analyses of the metal assemblage from Sotira-Kaminoudhia also demonstrate a precocious knowledge of metalworking during the PreBA, including the judicious use of alloys by Cypriot metalsmiths (Swiny *et al.* 2003, 380; Giardino *et al.* 2003, 392). The dagger (M18) and the small,

unforged 'billet' casting of a dagger blade (M12) produced in an open mould at Kaminoudhia (Swiny *et al.* (eds) 2003, 370–373) (Fig. 3.3), along with the surface discovery of a crucible fragment at the nearby PreBA settlement of Paramali-Pharkonia (Swiny and Mavromatis 2000, 435), both provide further evidence of local metalworking and casting activities during the PreBA.

Some 10km southeast of Marki, the site of Alambra-Mouttes divulged three further mould fragments, 16 crucible fragments, 38 pieces of ores or gossans and at least 16 pieces of slag. All this material indicates that the mining, smelting and casting of Cypriot copper ores continued during the subsequent, PreBA 2 period (Coleman *et al.* 1996, 129–137). Metal artefacts were 23 in number: four surface finds, eight from settlement contexts and 11 from tombs. LIA of 12 artefacts and nine slag samples indicated that all pure or arsenical copper objects were consistent with production from Cypriot ores, but that two bronze rings (A34, A36) and a lead metal ring (A1) fell '... well outside the Cypriot field' and so were deemed to be of foreign origin or made from imported copper or lead (Gale *et al.* 1996, 397–398, 423 table 2.24). Now that practitioners of LIA no longer use ellipses, or statistics, to analyse their data (following Pernicka *et al.* 1990), instead using two bivariate plots and point-by-point comparisons (Gale 2009, 192), would these metal rings still be regarded as 'foreign objects'? Evidence for PreBA 2 metalworking may also be seen at Ambelikou-Aletri (Merrillees 1984), Episkopi-Phaneromeni (Swiny 1986, 68, 87) and possibly Kalavassos-Laroumena (Todd 1988, 135, 139–140).

From all this material, it is evident that the earliest exploitation and subsequent production of Cyprus's copper sulphide ore deposits took place during the Late Chalcolithic and PreBA 1–2 periods in the SW (*Mosphilia*) and south central region (*Kaminoudhia*) of the island, and in the NE Troodos foothills (*Marki Alonia*). Internal demand for copper was on the rise and provided the metal for casting a range of both utilitarian and prestige items, at least some of which were removed from circulation and deposited in burials like those at Sotira-Kaminoudhia, Lapithos-*Vrysi tou Barba*, Bellapais-*Vounous* and Vasilia-*Kafkallia* (Keswani 2004, 63–71). The high costs of mortuary displays using metal objects, and the increasing importance and attendant costs of heritable property, also would have stimulated the increased production of copper (Keswani 2004, 82; 2005, 385–394).

Although material evidence for overseas contacts remains limited on Cyprus at this time, chemical and LIA analyses from 16 PreBA (EC–MC) metal artefacts found in Cypriot tomb or hoard deposits (in particular at Vasilia) now hint that these early stages in metalworking practices on Cyprus developed within a much broader regional interaction sphere in the mid to late 3rd millennium BC (Webb *et al.* 2006). These interactions involved the seaborne movement of

metals and metal artefacts between coastal Anatolia, Cyprus, the Aegean and perhaps even the southern Levant, and indicate that metalworkers from all these areas, including Cyprus, had access to the same or similar metal sources. Stos-Gale (2001, 200–201, fig. 10.2) argued in a related study that 29% of an unspecified number of copper-based metal artefacts from Pre-Palatial Crete (c. 2600–1900 BC) were consistent with production from Cypriot ores. If any of these Pre-Palatial artefacts could be dated specifically to the earlier stages of the PreBA, then during the same time span in which Webb *et al.* (2006) maintain that closely similar media of exchange (rod- or ring-shaped ingots) were being produced throughout the eastern Mediterranean, we also would have artefacts from Crete consistent with production from Cypriot copper ores.

Because only the site of Vasilia can be seen to have participated directly in such exchanges (Webb *et al.* 2006, 283), Cyprus's role remains uncertain. We cannot say, for example, whether the imported raw materials and finished artefacts analysed were brought to Cyprus by Anatolian migrants or metalsmiths, were acquired from Anatolia by Cypriot elites, or obtained through seaborne trade conducted by Cycladic or Anatolian or Cypriot mariners or traders. Equally, it remains uncertain how ores consistent with production from Cypriot sources got to Crete during the Pre-Palatial period, but it now seems possible that we may have to factor Crete into this interaction sphere as well.

Such developments transformed the island's economy, making it possible for new social groups who managed production to answer a growing external demand for Cypriot copper. About this same time, during the 19th century BC (PreBA 2), cuneiform documents from Mari in Syria provide our earliest, irrefutable evidence for the export of Cypriot ('Alashiyan') copper (Knapp 2008, 307–308). Accelerated communications and seaborne trade between Cyprus and the surrounding regions provided an opportunity for at least some people on the island to emulate or to adopt as their own some of the material innovations that characterize the PreBA. The intensification of copper production and the manufacture of metal goods also account for the practice of locating sites at or near the agricultural-mineral interface (e.g. Ambelikou-Aletri, Marki-Alonia, Sotira-Kaminoudhia).

As to Ambelikou-Aletri, another PreBA (Middle Cypriot I) site, we have only limited and quite fragmentary remains from a small-scale rescue excavation conducted there in 1942. The two areas and ten restricted trial trenches excavated produced some fragmentary wall sections, two complete, sub-rectangular buildings, and some stone foundations along with much 'debris' (Merrillees 1984, 3–4, and figs 2–4). The ground stone tools and pottery recovered within the modern mining shafts – about 250m distant from Aletri – then being explored by the 'Hellenic Company of Chemicals and Manures' included Red Polished III sherds, 19th century BC in date. These sherds came from

approximately 19m deep inside the Stoa 2 shaft and 2m deep inside the Kekleimenou 1 shaft (reachable only from within Stoa 2). Although no formal excavations were conducted in the mining shafts, these artefacts were clearly *in situ*. Thus it seems possible that marketable seams of quality ore were being recovered with very focused effort, deep inside the mines near Ambelikou.

The conspicuous metal wealth found in the cemeteries of Cyprus's north coast, and the more utilitarian copper objects found both there and at industrial sites (Ambelikou-Aletri) or in agricultural villages (Marki-Alonia, Sotira-Kaminoudhia, Alambra-Mouttes) nearer the copper sources, indicate distinctive attitudes towards metals. The composition and style of the copper-based artefacts found in mortuary contexts (Balthazar 1990, 432) point to the ceremonial consumption of metal goods, in particular their value as objects of prestige display (Giardino *et al.* 2003, 392). This picture of comparatively small-scale, local and interregional production and consumption of metals changes dramatically in the course of only a couple of centuries, at the most (*cf.* Crewe 2007, 18, who argues that localised, small-scale production of copper and metals continued until the 13th century BC – see further below).

Production and Exchange: Protohistoric Bronze Age (Pro BA)

During the ProBA, copper production expanded and intensified islandwide (e.g. Knapp 1986, 39–46, table 1). We infer these developments from copper refining installations that seem to have developed initially (ProBA I) at Enkomi (Muhly *et al.* 1988, 294–295; Muhly 1989, 299–300) and perhaps at Hala Sultan Tekke (Åström 1982), and then expanded gradually (ProBA 2) to several other sites across the island: Kalavassos-Ayios Dhimitrios, Athienou-Bamboulari *tis* Koukounninas, Maroni-Vournes, Kourion-Bamboula, Kition, Morphou-Toumba *tou* Skourou, Myrtou-Pigadhes, Pyla-Kokkinokremos, Maa-Palaeokastro, Kourion-Bamboula and Alassa-Pano Mantilares (Muhly 1989, 301–302).

Stech (1985) long ago suggested that locally controlled copper production characterized the initial stages of the island's emergent polity, and it remains an open question whether Enkomi dominated the copper industry throughout the ProBA I phase (Muhly 1989, 299). On the basis of a thorough re-examination of metalworking paraphernalia from Enkomi stored in the Cyprus Museum, Crewe (2007, 17–19) maintains that most of the early evidence for copper working at the site dates to LC IB (mid-16th century BC), and that there is no secure evidence for centrally organized, intensive production for another 250 years, *i.e.* until LC IIC. However one views Crewe's arguments, which focus solely on the site of Enkomi, there is no question that slag from

copper production litters 14th–13th century BC levels at the sites of Hala Sultan Tekke, Enkomi and Kition (Muhly 1989, 301–302), whilst metalworking installations exist at Enkomi, Kition and Atheniou. Smelting sites like Politiko-*Phorades* (ProBA 1) and mining villages like Apliki-*Karamallos* (ProBA 2) were always situated very close to the rich copper ore deposits of the Lower Pillow Lavas in the Troodos mountains.

As we might expect in a situation where centralized copper production was geared mainly for foreign consumption (Stech 1982, 112–113), few complete copper ‘oxhide’ ingots have been found on Cyprus. The roughly standardized weight, shape and purity of the ‘oxhide’ ingots, together with evidence of metallic copper re-smelting and refinement in the major coastal centres (Tylecote 1971, 53; 1985; Kassianidou 2009), suggest a regulating authority that oversaw the production of copper for export. In other words, secondary smelting and refining processes were carried out in the coastal centres, where standardized (oxhide) ingots were produced for internal consumption and external distribution. We have always assumed that copper ores in an incompletely processed state were brought to the coastal refining sites from smaller, primary production centres. And we have long known of one site – Apliki-*Karamallos* – where those who produced copper may have lived. We now have a primary production centre – Politiko-*Phorades* – that produced copper in the form of matte before shipping it to the coastal centres. Let us look more closely at these two sites, *Phorades* and Apliki, in chronological sequence, and see what further light they may shed on Late Bronze Age Cypriot copper production and exchange.

Politiko-*Phorades*

The *Phorades* excavations (Knapp and Kassianidou 2008) indicated that the metalworkers used river channel deposits to construct an artificial working platform on which they operated their smelting furnaces. On this artificial bank, we uncovered a stone-lined cavity, within which were several tuyère fragments, and around which were several almost complete tuyères (Fig. 3.4). Unlikely to be a smelting furnace, this cavity may have been a tapping pit associated with smelting activity. The slag left over from smelting was piled against the creek’s bank, and eventually formed a small heap (Fig. 3.5). Beyond a couple of possible crushing stones, there was no other evidence of ore beneficiation or the actual roasting process, both of which must have been carried out elsewhere. The concentrations of broken tuyères and furnace fragments, and the large quantities of slag (unlikely to have been transported far), indicate that the smelting of copper ores took place at *Phorades* itself. In comparison with the metallurgical remains, other finds such as pottery, chipped stone and ground stone tools were few in number. *Phorades*

thus served exclusively as a smelting workshop: once it was abandoned, whatever was left behind had no further use to the metalworkers.

The few pottery sherds – White Slip I and II (early), Base Ring I, Red Lustrous Wheelmade, Black or Red Slip Wheelmade, Plain White Handmade ware – were recovered almost exclusively within the site’s well-stratified metalworking levels. The close dating of all this pottery to a ProBA 1 (LC I–early LC II) date of deposition was confirmed by a series of radiocarbon analyses on charcoal found within the furnace walls and the slag. All analysed using AMS at the Oxford Radiocarbon Accelerator Unit, these dates confirm a calendar age range somewhere in the 16th–15th centuries BC (Fig. 3.6).

The archaeometallurgical remains consist of over 6000 fragments of furnace rims, walls and bases, 50 almost complete tuyères and up to 600 tuyère fragments. Most tuyères were cylindrical although a single elbow type was found as well as a small group of double-walled tuyères (Fig. 3.7). The *Phorades* tuyères are similar in shape and material to those from Enkomi and Apliki as well as other Late Cypriot sites. A detailed chemical and mineralogical study of the furnaces and tuyères (Hein and Kilikoglou 2007; Hein *et al.* 2007), as well as petrographic analyses, demonstrated that local clay deposits were used for their manufacture, and were specifically chosen because they contained inclusions that enabled the installations to withstand temperatures up to 1200°C. The ore smelted in the furnace was a copper sulphide and the fuel used was almost exclusively charcoal produced from *pinus brutia*, a tree that dominates the landscape today and thrives even in the lunar landscapes wrought by modern industrial mining operations.

We collected over 3.5 tons of slag fragments that derived from large plano-concave cakes weighing approximately 20kg. The copper content of these slags averages 2.7%, relatively high in comparison to that of slag from later periods. The *Phorades* slag differs in type and shape from all other known Late Bronze slags excavated on Cyprus, *i.e.* the large tap slags from Apliki (Muhly 1989, 306) or the plano-convex slags from Kition (Tylecote 1982, 89), both later in date by at least 300 years. Moreover, they are completely unlike the slags, small and nodular in shape, from the MBA site of Alambra-*Mouttes* (Gale *et al.* 1996, 389–390, 414, tables 2.15, 2.16), which is at least 200 years earlier. And they are quite different from the slags found at Pyrgos-*Mavrorachi*, which the excavator, at least, would date to about 1900 BC, some 300 years earlier than *Phorades* (Belgiorno 1999; 2004, 21, 31).

The metal produced in the smelter at *Phorades* was matte, which was determined not only by the presence of matte prills within the slag matrix, but also by the discovery of a small piece of matte (Fig. 3.8), silver-blue in colour: it consisted of 73.5% copper, 2.6 % iron and 23.9% sulphur. As an intermediate product in the production of copper

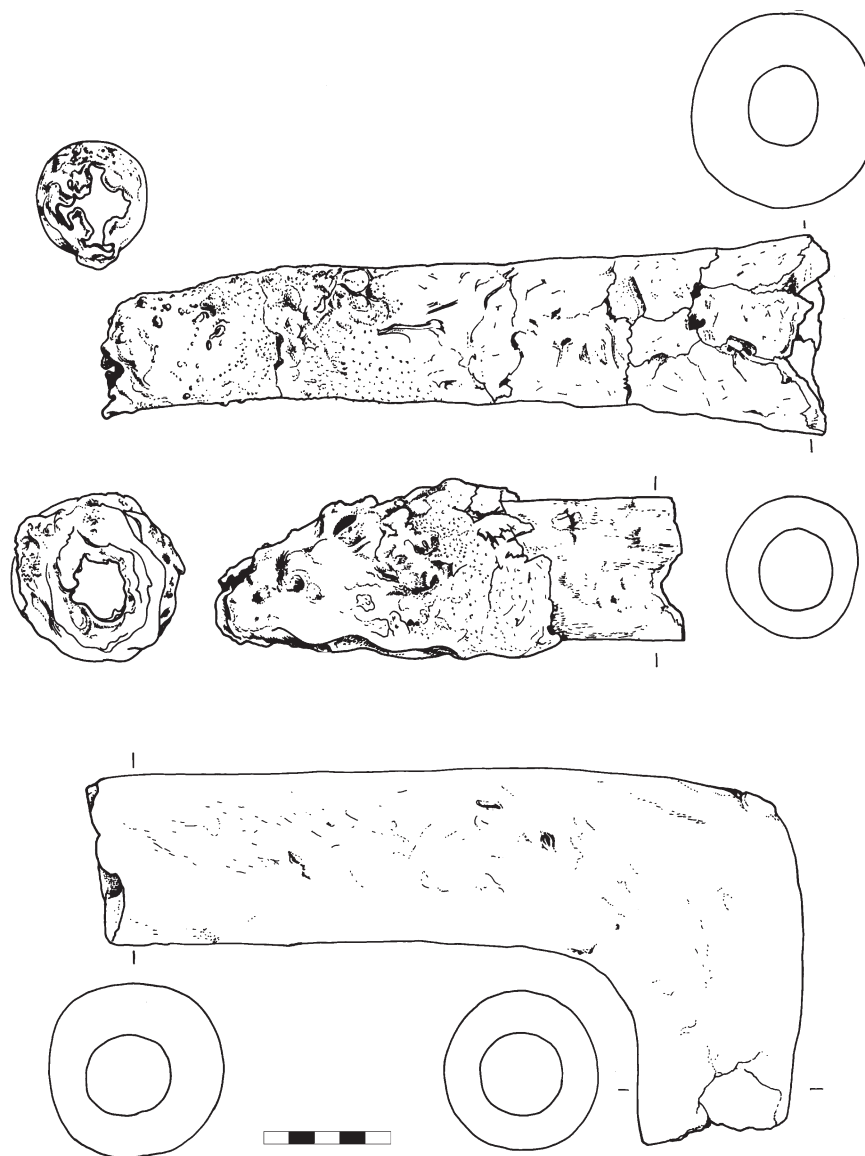


Fig. 3.4. Politiko-Phorades tuyères. Drawn by Glynnis Fawkes.



Fig. 3.5. Politiko-Phorades slag heap. Photo by Karen Ulrich.

metal, matte has always proved to be quite rare; its presence at *Phorades* is yet another indicator that this was a primary smelting workshop. In other words, and to reiterate what I said above: only the initial stage of the smelting process took place at *Phorades* whilst secondary smelting and refining were carried out at the coastal centres, where standardized (oxhide) ingots were produced for internal consumption and external distribution.

Apliki-Karamallos

Apliki-Karamallos lies on the high slopes of the Troodos foothills (Fig. 3.9) on the east bank of the Marathasa River,

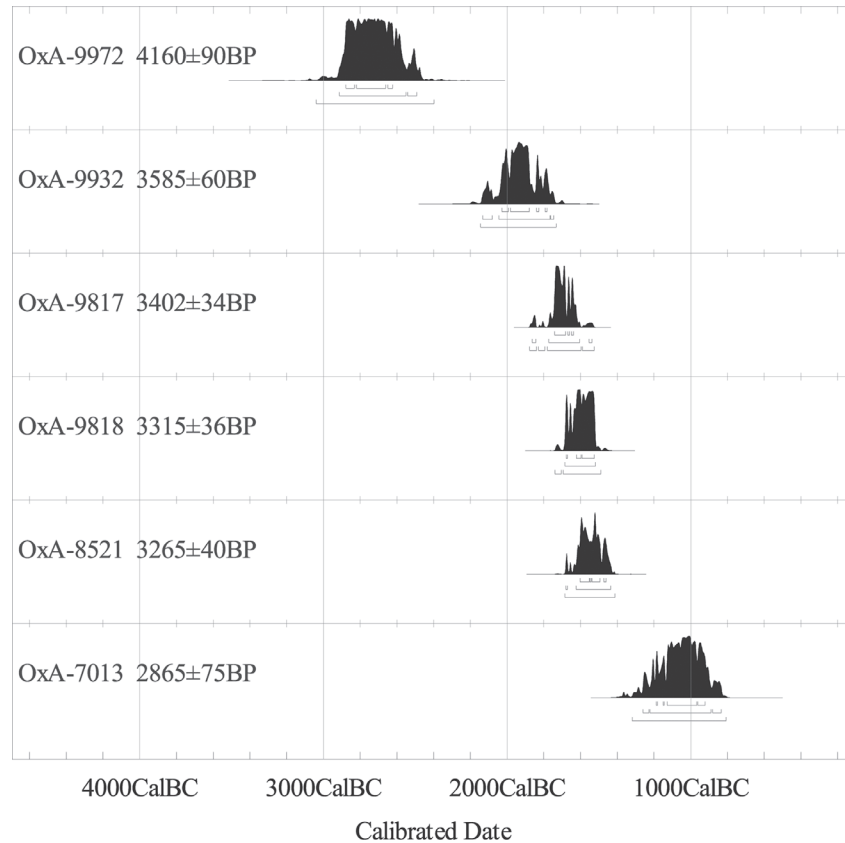


Fig. 3.6. Politiko-Phorades AMS radiocarbon dates, from charcoal found within furnace walls and slag. Oxford Radiocarbon Accelerator Unit. Courtesy of Sturt W. Manning.



Fig. 3.7. Politiko-Phorades double-walled tuyères. Photo by Christopher Parks.

in the midst of the richest mining district on Cyprus. This district extends from Skouriotissa (in the east) to Ambelikou and Mavrovouni (in the west) (Constantinou, in Kling and Muhly 2007, 339). The site was discovered in 1938 by a mining engineer during opencast explorations for gold and silver at the Apliki ore body, near the modern village of the same name. Two weeks of rescue excavations were conducted shortly afterward, and were followed by five intensive weeks of excavations in 1939 (Taylor 1952; Muhly 1989, 306–10). Both undertakings in the ‘neck’ of the South Hill (Taylor 1952, fig. 2 and pl. XXIV) indicated a 13th–12th century BC date for the site, now reconfirmed and refined by radiocarbon dating: House A at Apliki was built about 1300 BC and destroyed c. 1200–1156 BC (Manning and Kuniholm, in Kling and Muhly 2007, 328).

House A at Apliki was the only one of several structures to be fully excavated. From the many spindle-whorls and loom weights recovered, Smith (in Kling and Muhly 2007, 233) concluded that spinning and weaving – probably for local use – took place in House A. Metal objects from Apliki included a bronze chisel, drills, awls, a knife, some bronze leaf, two objects of lead, and a gold earring (Kling, in Kling and Muhly 2007, 311–313; see also Taylor 1952, 152). The

Apliki excavations, however, produced no physical evidence for ore dressing activities (Kassianidou, in Kling and Muhly 2007, 283), something that puzzled Taylor (1952, 150). Detailed study of the ground stone tools (pestles, rubbers, and querns) has provided some further indicators of metallurgical activities in House A (rooms A.2, A.3, A.5, A.7). From this study, Kassianidou (in Kling and Muhly 2007, 277) concluded that Apliki was a settlement with storage facilities for food or other commodities to be used by the workforce, as well as an industrial centre where copper metal was extracted from sulphide ores. Some of the faunal remains (sheep, goat, ox) were stained green and were most likely impregnated with metal ‘salts’ (copper, iron) (Croft, in Kling and Muhly 2007, 321).

Karamallos lies only two miles from the ore body at Apliki, but Taylor (1952, 150) was concerned that ‘...the evidence for the mining of copper ore by the occupants of this site is tentative’. No copper ores were found at the site itself, and Taylor (1952, 164) sought to explain its function by noting that its foundation coincided with the height of the ‘Mycenaean’ period, ‘... when one might expect to find new workers’ settlements in the mining district, necessitated by the expansion of the copper trade’. Nobody today would link the operation at Apliki to a Mycenaean presence, but most scholars would agree that Apliki was a miners’ community that included not only living space for the miners who worked the ore body but many of the accoutrements of daily life. The presence of tuyères (House A, a pit in trench B) – some with flat sides, others round in section, and at least one ‘elbow’ tuyère – along with fragments of crucibles, stone hammers and the abundant slag, suggests that those who lived at *Karamallos* were involved in

preparing and processing ores, work that was probably carried out near the village. No traces of furnaces were found but explorations by the Cyprus Mines Corporation found remnants of discarded furnaces at the ‘North Hill’ of Apliki, which at the time was covered in slag heaps (Taylor 1952, 152). Most important, however, was the quantity of large blocks of a black ropy slag, said to be present in all the rooms of House A (Muhly 1989, 306–307, fig. 35.1; Taylor 1952, 142). Muhly (1989, 307) felt that these slags as well as the massive size of the tuyères known from the site were enough to confirm that ‘... extensive mining and smelting operations were carried out at Apliki during the 13th and 12th centuries BC’. Quite how this tallies with Taylor’s statement that the evidence for copper mining at Apliki-*Karamallos* was ‘tentative’ will have to be judged when we have the final publication of the metallurgical remains from this crucial Late Bronze Age site.

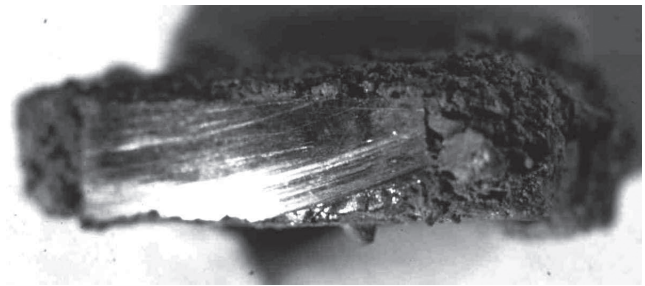


Fig. 3.8. Politiko-Phorades, small piece of silver-blue matte. Photo by Christopher Parks.



Fig. 3.9. (Colour Plate 3) Apliki landscape, with modern spoil heap in centre of image. Photo by Bernard Knapp.

Discussion

Evaluating the diverse evidence from the sites of Ambelikou-Aletri, Politiko-Phorades, and Apliki-Karamallos, spread over a period of some 700 years during the MBA-LBA, presents a challenge. The finds from Ambelikou are quite limited and at most indicate a few structures that may have served either to facilitate the production of ores (storage or work rooms) or to shelter those working deep inside the mining shafts (Stoas 1 and 2 and Kekleimenou 1). The finds from Apliki would seem to demonstrate that miners were living in close proximity to the still unlocated industrial area where they worked. Because the storeroom in House A could have contained up to 15 large pithoi, this room alone may have had a storage capacity of up to 7500 litres, presumably for olive oil. House A also contained a gold earring, a Mycenaean granary style krater, an ivory cylinder and a steatite cylinder seal. Based on these finds, Keswani (1993, 77) suggested that House A should be regarded as an ‘official residence’ and workplace where local mining and the primary production of copper ores were controlled, and whence subsistence commodities were redistributed to other residents.

All this points to a complex pattern of community relations during the 13th century BC, when copper production had reached its Bronze Age zenith on the island. In comparison with Apliki and Ambelikou-Aletri, *Phorades* stands apart, with no architectural remains, and little evidence beyond pottery and a few faunal data that can tell us anything about the people who worked at the site. Apliki, of course, has now been obliterated by modern mining operations, and in any case lies in the buffer zone between the Republic of Cyprus and the Turkish-occupied sector of the north, a situation that has prevented most scholars, including myself, from visiting the site or its surroundings. This has not stopped others from visiting the area, however, and I turn now to consider the implications of some provenance studies that have resulted from those visits.

A comprehensive and long-term programme of LIA conducted on oxhide ingots found widely throughout the Mediterranean has suggested – at least to those that carried out the analyses – that the copper used for making *all* oxhide ingots after 1250 BC (some 180 examples) came from only one mine, that of Apliki (Stos-Gale *et al.* 1997; Gale 1999, 116; Gale, this volume). Yet this same copper was almost never used to make bronze or copper artefacts. As Kassianidou (2009; see also Kassianidou 2001, 110) has outlined very clearly in a recent paper, many archaeologists found this suggestion hard to accept. For example, Muhly (2003, 144–145) suggested that it was ‘... a theory of improbably grandiose proportions’, whilst I was even more vocal (Knapp 1999, 106): ‘The cultural and economic model proposed – namely that a single site and a single ore deposit was producing all or most of the copper oxhide ingots found in

the Bronze Age Mediterranean – whilst bold and provocative, and coherent in analytical terms, makes little sense in economic, social, spatial or even mineralogical terms, contradicts the model we can now propose on the basis of our work at *Phorades*, and represents a marked change from earlier interpretations that proposed exploitation of multiple ore deposits around the Troodos’.

Even if, as already emphasized above, the copper ore deposits from the area between Skouriotissa and Mavrovouni are the most substantial on Cyprus and amongst the largest in the Mediterranean region, we still need to understand why countless other ore deposits scattered throughout the Lower Pillow Lavas of the Troodos complex, or even in this same area, were not exploited to produce oxhide ingots. Apliki, of course, is the only ore deposit closely associated with an excavated LC settlement (*Karamallos*) dating to the ProBA 2 period (13th century BC). But we also have to take into account *Phorades*, an excavated metallurgical production site located in close proximity to another ore body, *Kokkinorotsos*, only 500m distant from the site. Although *Phorades* dates to an earlier period (ProBA 1, 16th century BC), it is hard to conceive of a well developed export-oriented economy in which those who controlled the production and export of copper during any stage of the ProBA would have limited their activities to the Apliki mine, or preferred it over all others. We have argued that sites like *Phorades* must have once been ubiquitous throughout the mining areas that encircle the Troodos mountains (Knapp 2003, 564); most have now been destroyed by modern mining operations. As we demonstrated in our work at *Agrokipia-Kriadis*, however, ancient beneficiation and ore preparation activities can be found deeply buried within modern spoil heaps (Kassianidou, in Given and Knapp 2003, 60–74), and there are other examples around the Mitsero ore body (Given and Knapp 2003, 82–118).

As Kassianidou (2009) argues, Apliki’s location is not a favourable one, far from the sea and with ores at a level so deep that it could not have been advantageous for ancient miners. Furthermore Apliki, like all the other mines of the ‘Solea Axis’ and those at Limni, are the ones farthest from the workshops in coastal sites where the final refinement of copper ores (from matte or ‘black copper’) took place. In order to refine enough metal to cast an ingot, metal from several smelting charges had to be melted together. If, as LIA suggests, the metal from a single mine at Apliki was used solely for casting ingots, the first question that arises is: which mines were producing the copper used to produce bronze artefacts? This is but one of several questions that arise but are never considered (Gale 2001, 116; Gale and Stos-Gale 2002, 290).

If only the Apliki ores were used to produce ingots, while ores from other mines were used to produce copper or bronze artefacts, how are we to understand the oxhide ingots and

ingot fragments found in archaeometallurgical or hoarding contexts at Enkomi, Maroni-Tsaroukkas and Vournes, Kalavassos-Ayios Dhimitrios, Pyla-Kokkinokremos and Maa-Palaeokastro, and in less secure contexts at Mathiatis and Skouriotissa? Were all the metalworkers around the island supplied with copper oxhide ingots coming from Apliki? As is often the case with scientific analysis, the results of LIA seem to raise more questions than they answer.

Conclusions

As Kassianidou (2009) notes: 'What it comes down to, I think, is whether we accept the analytical data as "objective" and, therefore, correct, or whether we question the ability of this analytical technique to detect provenance correctly, even for unalloyed copper metal'. Muhly (2003, 145) has also pointed out that the LIA of artefacts characterizes the source of lead in them, not the source of the copper; he states unequivocally that '... this constitutes the fatal flaw in all the research published by the Gales, going back to 1982'. He contends, further, that although some LC artefacts must have been made from Apliki copper, the miniscule amount of Apliki lead in the Apliki oxhide ingots would have been overshadowed by the melange of ingot and bun fragments, and recycled scrap metal that went into the crucible to produce copper-based artefacts (Muhly 2003, 145). Finally, Muhly asks what are we to make of the Late Minoan I artefacts (*i.e.* 16th century BC) from Khania on Crete which, according to LIA, were made from Apliki copper (Stos-Gale *et al.* 2000, 209), even though the same team has insisted in every other publication that Apliki copper only came into use *c.* 1250 BC?

Along with other archaeologists who have worked most closely trying to understand the role of Cyprus in the Late Bronze Age metals trade within and beyond the Mediterranean, I have little doubt that the data derived from LIA analyses are 'objective'. The problems arise with the consistency of LIA analyses, and the archaeological interpretations that have been inferred on the basis of lead isotope data, in particular concerning artefacts (or ingots) made of alloyed copper.

It must be emphasized that this debate is not solely the domain of archaeologists. Above and beyond all past exchanges (e.g., Budd *et al.* 1995; Gale 1999, 2001; Knapp 2000; Muhly 1985, 1995; Stos-Gale *et al.* 1997), Pollard (2009) has now argued that for several analytical and archaeological reasons, we should not attempt to pin down the exact source of raw materials to particular mines. He notes how difficult it is to obtain ores that reflect with any accuracy the ores used in antiquity (in this case, the Bronze Age), and tries to suggest a way forward using High Resolution ICP-MS (Inductively Coupled Plasma Mass Spectrometry) technology. In a brief response, Gale (2009)

charges Pollard with making complaints without using any data to back them up. Gale reiterates, as he has done in this conference, that the majority of oxhide ingots found in the Mediterranean dated after 1250 BC and analysed by lead LIA shows that they were made only from copper from the Apliki ore deposit.

In this paper, I have made extensive use of the Cypriot archaeological record to make my own arguments, even if the data are not quantified in the manner scientists prefer. On the one hand, the 'scientific' evidence that suggests all oxhide ingots produced on Cyprus after 1250 BC had to come from Apliki seems to me to be as contrary to the material, social, economic and spatial evidence as it did 20 years ago. On the other hand, I would emphasize and acknowledge that virtually all of the lead isotope analyses carried out on Cypriot ingots and at least some artefacts have tended to confirm that they are consistent with production from Cypriot ores. Moreover, as Muhly (2003, 150) recently emphasized, ingots of unalloyed copper group have a lead isotope signature that is not only remarkably consistent within and between different laboratories, but also points to a Cypriot ore source. The bulk of this work was carried out at the Oxford laboratories under the direction of Noël Gale. This body of work has done more than any other to substantiate virtually all the hypotheses I have proposed, or the arguments I have made over the years in several papers and books about the centrality of Cyprus to copper production and trade in the Late Bronze Age Mediterranean. How can I look such a gift horse in the mouth? Yet another unanswered question

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Bibliography

- Åström, P. (1982) The bronzes of Hala Sultan Tekke. In J. D. Muhly, R. Maddin and V. Karageorghis (eds) *Early Metallurgy in Cyprus, 4000–500 BC*, 177–183. Nicosia, Pierides Foundation.
- Balthazar, J. Weinstein (1990) *Copper and Bronze Working in Early through Middle Bronze Age Cyprus*. Studies in Mediterranean Archaeology and Literature Pocket-book 84. Jonsered, Paul Åströms Förlag.
- Belgiorno, M. R. (1999) Preliminary report on Pyrgos excavations 1996, 1997. *Report of the Department of Antiquities Cyprus*, 71–86.
- Belgiorno, M.R. (2004) *Pyrgos-Mavroraki: Advanced Technology in Bronze Age Cyprus*. Nicosia, CNR-ITABC, Archaeological Mission at Pyrgos.
- Budd, P., Pollard, A. M., Scaife, B. and Thomas, R. G. (1995) Oxhide ingots, recycling and the Mediterranean metals trade. *Journal of Mediterranean Archaeology* 8, 1–32.
- Christou, D. (1989) The Chalcolithic cemetery at Souskiou-Vathyrakakas. In E. J. Peltenburg (ed.) *Early Society in Cyprus*, 82–94. Edinburgh, Edinburgh University Press.
- Coleman, J. E., Barlow, J. A., Mogelonsky, M. K. and Schaar, K. W. (1996) *Alambra: A Middle Bronze Age Site in Cyprus. Investigations by Cornell University, 1975–1978*. Studies in Mediterranean Archaeology 118. Jonsered, Paul Åströms Förlag.
- Crewe, L. (2007) *Early Enkomi. Regionalism, Trade and Society at the Beginning of the Late Bronze Age on Cyprus*. British Archaeological Reports, International Series 1706. Oxford, Archaeopress.
- Crewe, L., Lorentz, K., Peltenburg, E. and Spanou, S. (2005) Treatments of the dead: preliminary report of investigations at Souskiou-Laona Chalcolithic cemetery, 2001–2004. *Report of the Department of Antiquities, Cyprus*, 41–67.
- Fasnacht, W. and Künzler Wagner, N. (2001) Stone casting moulds from Marki-Alonia. *Report of the Department of Antiquities, Cyprus*, 38–41.
- Frankel, D. and Webb, J. M. (2006) *Marki Alonia: An Early and Middle Bronze Age Settlement in Cyprus. Excavations 1995–2000*. Studies in Mediterranean Archaeology 123:2. Sävedalen, Paul Åströms Förlag.
- Gale, N. H. (1991) Metals and metallurgy in the Chalcolithic period. *Bulletin of the American Schools of Oriental Research* 282/283, 37–62.
- Gale, N. H. (1999) Lead isotope characterization of the ore deposits of Cyprus and Sardinia and its application to the discovery of the sources of copper for Late Bronze Age oxhide ingots. In S. M. M. Young, A. M. Pollard, P. Budd and R. A. Ixer (eds) *Metals in Antiquity*. British Archaeological Reports, International Series 792, 110–121. Oxford, Archaeopress.
- Gale, N. H. (2001) Archaeology, science-based archaeology and the Mediterranean Bronze Age metals trade: a contribution to the debate. *European Journal of Archaeology* 4, 113–130.
- Gale, N. H. (2009) A response to the paper of A. M. Pollard: What a long, strange trip it's been: lead isotopes and archaeology. In A. J. Shortland, I. C. Freestone and T. Rehren (eds) *From Mine to Microscope: Advances in the Study of Ancient Technology*, 191–196. Oxford, Oxbow Books.
- Gale, N. H. and Stos-Gale, Z. A. (2002) Archaeometallurgical research in the Aegean. In M. Bartelheim, E. Pernicka and R. Krause (eds) *The Beginnings of Metallurgy in the Old World*, 277–302. Rahden/Westfallen, Verlag Marie Leidorf.
- Gale, N. H., Stos-Gale, Z. A. and Fasnacht, W. (1996) Copper and copper working at Alambra. In J. E. Coleman, J. A. Barlow, M. K. Mogelonsky and K. W. Schaar *Alambra: A Middle Bronze Age Site in Cyprus. Investigations by Cornell University, 1974–1984*. Studies in Mediterranean Archaeology 118, 359–426. Jonsered, Paul Åströms Förlag.
- Giardino, C., Gigante, G. E. and Ridolfe, S. (2003) Archaeometallurgical studies. Appendix 8.1 in S. Swiny, G. Rapp and E. Herscher (eds) *Sotira Kaminoudhia: An Early Bronze Age Site in Cyprus*. Cyprus American Archaeological Research Institute, Monograph 4, 385–396. Boston, American Schools of Oriental Research.
- Given, M. and Knapp, A. B. (2003) *The Sydney Cyprus Survey Project: Social Approaches to Regional Archaeological Survey*. Monumenta Archaeologica 21. Los Angeles, Cotsen Institute of Archaeology, UCLA.
- Hein, A. and Kilikoglou, V. (2007) Modeling of thermal behavior of ancient metallurgical ceramics. *Journal of the American Ceramic Society* 90, 878–884.
- Hein, A., Kilikoglou, V. and Kassianidou, V. (2007) Chemical and mineralogical examination of metallurgical ceramics from a Late Bronze Age copper smelting site in Cyprus. *Journal of Archaeological Science* 34, 141–154.
- Kassianidou, V. (2001) Cypriot copper in Sardinia: yet another case of bringing coals to Newcastle? In L. Bonfante and V. Karageorghis (eds) *Italy and Cyprus in Antiquity: 1500–450 BC*, 97–119. Nicosia, The Costakis and Leto Severis Foundation.
- Kassianidou, V. (2009) Oxhide ingots in Cyprus. In F. Lo Schiavo, J. D. Muhly, R. Maddin and A. Giumlia Mair (eds) *Oxhide Ingots in the Central Mediterranean*. Biblioteca di Antichità Cipriote 8, 41–81. Rome, A. G. Leventis Foundation, CNR Istituto di Studi sulle Civiltà dell'Egeo e del Vicino Oriente.
- Keswani, P. S. (1993) Models of local exchange in Late Bronze Age Cyprus. *Bulletin of the American Schools of Oriental Research* 292, 73–83.
- Keswani, P. S. (2004) *Mortuary Ritual and Society in Bronze Age Cyprus*. Monographs in Mediterranean Archaeology 9. London, Equinox.
- Keswani, P. S. (2005) Death, prestige, and copper in Bronze Age Cyprus. *American Journal of Archaeology* 109, 341–401.
- Kling, B. and Muhly, J. D. (2007) *Joan du Plat Taylor's Excavations at the Late Bronze Age Mining Settlement at Apliki Karamallos, Cyprus*. Studies in Mediterranean Archaeology 134:1. Sävedalen, Paul Åströms Förlag.
- Knapp, A. B. (1986) Production, exchange and socio-political complexity on Bronze Age Cyprus. *Oxford Journal of Archaeology* 5, 35–60.
- Knapp, A. B. (1999) The archaeology of mining: fieldwork perspectives from the Sydney Cyprus Survey Project. In S. M. M. Young, A. M. Pollard, P. Budd and R. A. Ixer (eds) *Metals in Antiquity*. British Archaeological Reports, International Series 792, 98–109. Oxford, Archaeopress.
- Knapp, A. B. (2000) Archaeology, science-based archaeology and

- the Mediterranean Bronze Age metals trade. *European Journal of Archaeology* 3, 31–56.
- Knapp, A. B. (2003) The archaeology of community on Bronze Age Cyprus: Politiko Phorades in context. *American Journal of Archaeology* 107, 559–580.
- Knapp, A. B. (2008) *Prehistoric and Protohistoric Cyprus: Identity, Insularity and Connectivity*. Oxford, Oxford University Press.
- Knapp, A. B., and Cherry, J. F. (1994) *Provenance Studies and Bronze Age Cyprus: Production, Exchange, and Politico-Economic Change*. Monographs in World Archaeology 21. Madison, Prehistory Press.
- Knapp, A. B., and Kassianidou, V. (2008) The archaeology of Late Bronze Age copper production: Politiko Phorades on Cyprus. In Ü. Yalçın (ed.) *Anatolian Metal IV*. Die Anschnitt, Beiheft 21, 135–147. Bochum, Deutsches Bergbau-Museum.
- Merrillees, R. S. (1984) Ambelikou-Aletri: a preliminary report. *Report of the Department of Antiquities Cyprus*, 1–13.
- Muhly, J. D. (1985) Lead isotope analysis and the problem of lead in Cyprus. *Report of the Department of Antiquities Cyprus*, 78–82.
- Muhly, J. D. (1989) The organisation of the copper industry in Late Bronze Age Cyprus. In E. J. Peltenburg (ed.) *Early Society in Cyprus*, 298–314. Edinburgh, Edinburgh University Press.
- Muhly, J. D. (2003) Trade in metals in the Late Bronze Age and the Iron Age. In N. C. Stampolidis and V. Karageorghis (eds) *Sea Routes...Interconnections in the Mediterranean 16th–6th c. BC*, 141–150. Athens: University of Crete and the A. G. Leventis Foundation.
- Muhly, J. D., Maddin, R. and Stech, T. (1988) Cyprus, Crete and Sardinia: copper oxhide ingots and the metals trade. *Report of the Department of Antiquities Cyprus*, 281–298.
- Peltenburg, E. J. (and project members) (1998) *Lemba Archaeological Reports*. Volume 2:1A. *Excavations at Kissonerga-Mosphilia*. Studies in Mediterranean Archaeology 70:2. Göteborg, Paul Åströms Förlag.
- Peltenburg, E. J. (co-ordinator) (2006) *The Chalcolithic Cemetery at Souskiou-Vathykakas, Cyprus. Investigations of Four Missions, from 1950 to 1997*. Nicosia, Department of Antiquities.
- Pernicka, E., Begemann, F., Schmitt-Strecker, S. and Grimanis, A. P. (1990) On the composition and provenance of metal artefacts from Poliochni on Lemnos. *Oxford Journal of Archaeology* 9, 263–298.
- Pollard, M. (2009) What a long, strange trip it's been: lead isotopes and archaeology. In A. J. Shortland, I. C. Freestone and T. Rehren (eds) *From Mine to Microscope: Advances in the Study of Ancient Technology*, 181–189. Oxford, Oxbow Books.
- Stech, T. (1982) Urban metallurgy in Late Bronze Age Cyprus. In J. D. Muhly, R. Maddin and V. Karageorghis (eds) *Early Metallurgy in Cyprus, 4000–500 BC*, 105–115. Nicosia, Pierides Foundation.
- Stech, T. (1985) Copper and society in Late Bronze Age Cyprus. In A. B. Knapp and T. Stech (eds) *Prehistoric Production and Exchange: The Aegean and East Mediterranean*. UCLA Institute of Archaeology, Monograph 25, 100–105. Los Angeles, UCLA Institute of Archaeology.
- Steel, L. (2003–04) Archaeology in Cyprus, 1997–2002. *Archaeological Reports* 50, 93–111.
- Stos-Gale, Z. (2001) Minoan foreign relations and copper metallurgy in Protopalatial and Neopalatial Crete. In A. Shortland (ed.) *The Social Context of Technological Change in Egypt and the Near East, 1650–1550 BC*, 195–210. Oxford, Oxbow Books.
- Stos-Gale, Z. A., Malietis, G., Gale, N. and Annetts, N. (1997) Lead isotope characteristics of the Cyprus copper deposits applied to provenance studies of copper oxhide ingots. *Archaeometry* 39, 83–124.
- Stos-Gale, Z. A., Gale, N. H. and Evelyn, D. (2000) An interpretation of the metal finds, using lead isotope and chemical analytical procedures. In E. Hallager and B. P. Hallager (eds) *The Greek-Swedish Excavations at the Agia Aikaterini Square, Kastelli, Kania. 1970–1987*. Volume II: *The Late Minoan IIIC Settlement*, 206–214. Stockholm, Paul Åströms Förlag.
- Swiny, S. (1986) *The Kent State University Expedition to Episkopi Phaneromeni*. Studies in Mediterranean Archaeology 74:2. Göteborg, Paul Åströms Förlag.
- Swiny, S. (1997) The Early Bronze Age. In T. Papadopoulos (ed.) *A History of Cyprus*, Volume 1 [in Greek], 171–212. Nicosia, Archbishop Makarios III Foundation.
- Swiny, S. and Mavromatis, C. (2000) Land behind Kourion: results of the 1997 Sotira Archaeological Project Survey. *Report of the Department of Antiquities Cyprus*, 433–452.
- Swiny, S., Rapp, G. and Herscher, E. (eds) (2003) *Sotira Kaminoudhia: An Early Bronze Age Site in Cyprus*. Cyprus American Archaeological Research Institute, Monograph 4. Boston, American Schools of Oriental Research.
- Taylor, J. du Plat. (1952) A Late Bronze Age settlement at Apliki, Cyprus. *Antiquaries Journal* 32, 133–167.
- Todd, I. A. (1988) The Middle Bronze Age in the Kalavassos area. *Report of the Department of Antiquities Cyprus*, 133–140.
- Tylecote, R. F. (1971) Observations on Cypriot copper smelting. *Report of the Department of Antiquities Cyprus*, 53–58.
- Tylecote, R. F. (1982) The Late Bronze Age: copper and bronze metallurgy at Enkomi and Kition. In J. D. Muhly, R. Maddin and V. Karageorghis (eds) *Early Metallurgy in Cyprus, 4000–500 BC*, 81–103. Nicosia, Pierides Foundation.
- Tylecote, R. F. (1985) Copper working at Kition. In V. Karageorghis and M. Demas, *Excavations at Kition V*, part 1. *The Pre-Phoenician Levels. Areas I and II*, 430. Nicosia, Department of Antiquities.
- Webb, J. M. and Frankel, D. (1999) Characterising the Philia facies. Material culture, chronology and the origin of the Bronze Age in Cyprus. *American Journal of Archaeology* 103, 3–43.
- Webb, J., Frankel, D., Stos, Z. A. and Gale, N. (2006) Early Bronze Age metals trade in the eastern Mediterranean. New compositional and lead isotope evidence from Cyprus. *Oxford Journal of Archaeology* 25, 261–288.
- Zwicker, U. (1988) Investigations of material from Maa-Palaeokastro and copper ores from the surrounding area. In V. Karageorghis and M. Demas, *Excavations at Maa-Palaeokastro 1979–1986*, 427–448. Nicosia, Department of Antiquities.