

THE DEVELOPMENT OF COPPER METALLURGY IN LATE BRONZE AGE CYPRUS

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For many years we were in a difficult position regarding the assumed existence of a copper smelting industry in Late Bronze Age Cyprus. Basically, all scholars wanted to believe in its existence although there was little to support this belief. What evidence there was tended to be circumstantial in nature and all of the artifactual evidence came from the site of Enkomi. This in itself was not surprising as all of our evidence for Late Bronze Age Cyprus came from Enkomi. You have all heard of one-period sites; the Late Bronze Age in Cyprus was a one-site period. Thus good arguments could be brought against all the evidence in favour of Bronze Age copper production on Cyprus and there was a lingering suspicion, most clearly enunciated by Oliver Davies over fifty years ago, that the history of copper smelting in Cyprus went back no earlier than Roman times (Davies 1932).

There was the very name of Cyprus itself, thought to derive from *cuprum*, the Greek and Latin word for copper. Cyprus was, as its name indicated, the "Copper Isle" (as well as the island of Aphrodite, and this is why Mediaeval Alchemy used the sign for 'woman' as a symbol for 'copper'). But, in reality, *χαλός* is the Greek word for copper and *aes* is the Latin one; neither word has anything to do with Cyprus. Imperial Latin did develop a phrase *aes cyprium* which, by ellipsis became *cyprium* and then *cuprum*, but this development only served to support a late Roman knowledge and use of Cypriot copper (Muhly 1976, 174). Furthermore in the Bronze Age the name of the island was Alashiya, although Mycenaean Greek does

production of perfumed oil (Shelmerdine 1985). Individuals named *ku-pi-ri-jo* (and it is most unlikely that we are dealing with one and the same individual in all known attestations of the name) were involved in the production of scented olive oil (Melena 1983), either as unguent-boilers or, more likely, at least at Knossos, as "a palace official responsible for administering this sector of the royal economy" (Killen 1979, 178; also Killen 1985, 296, n. 91).

What this evidence means is that the island of Cyprus was known already to Mycenaean Greeks by that name, at least from the time of the Knossos tablets (whenever that might be, probably not much removed in time from those found at Pylos). Moreover, individuals designated as being from Cyprus seem to have held important positions in the administration of the palace economy. It is impossible to assess the importance of a LBA alum trade between Cyprus and Greece, but it cannot have been a trade of any great economic significance.

What is remarkable is that the individuals named *ku-pi-ri-jo* are never in any way connected with copper and the copper trade. It is, of course, true that the Linear B archives, like those from Hittite Anatolia, do not deal with foreign trade or with economic matters in general. Yet it is possible to link individuals named *ku-pi-ri-jo* with the apparently insignificant alum trade. But there is not the slightest hint of any connection between *ku-pi-ri-jo* and *ka-ko*, *χαλός*. The Linear B texts certainly provide no evidence in support of a LBA copper industry on Cyprus or of a LBA trade in Cypriot copper.

There were the copper mines themselves, and the vast slag heaps associated with them. All the known Cypriot copper mines are exhausted today and every vein of copper discovered by modern prospectors had

already been worked by ancient miners. But all the remains found in these ancient shafts seemed to be no earlier than Roman times. The slag heaps contained hundreds of thousands of tonnes of copper smelting slag, but again there was no way of dating them. They could easily be seen as documenting smelting activity going back no earlier than the time of Pliny the Elder and the physician Galen, who visited Cyprus in AD 166 and provided us with a description of his visit to the mines in search of copper salts for his pharmacopoeia (Walsh 1929).

There were the famous copper oxide ingots, especially the example that made its way to the British Museum as part of the Foundry Hoard discovered at Enkomi almost one hundred years ago. While other such ingots, and fragments of same, were subsequently found at other sites in Cyprus, none came from a controlled excavation or even a secure context. Nor were there very good reasons for associating such ingots with Cyprus, rather than with Minoan Crete or even with Sardinia, although such an ingot was shown on the famous open-worked stand said to come from Kourion. As for the Foundry Hoard, it was considered so important that it was finally all put on display just two years ago. It was only upon seeing this exhibit, in the new Cyprus Gallery, that I realized that the Foundry Hoard contained several oxtide ingot fragments in addition to the famous intact example (GR 1897.4-1.1535). I counted at least five such fragments GR1897.4-1.1520.12.13,14,15 & 36). I would argue that the significance of this hoard has yet to be properly appreciated.

Proper attention to the importance of metallurgical remains and to the significance of the copper industry for the economic and political life of Late Bronze Age Cyprus came only with the publication of Dikaios' excavations at Enkomi (Enkomi). With the appearance of these volumes the study of

Chadwick further argued that the occurrences of *ku-pi-ri-jo* attested to the presence of Cypriot traders at Pylos as well as Knossos and that the tablets indicated that these traders dealt with alum (Linear B *tu-ru-pi-ri-ja*, Greek *στυπτηρία*), a product known in Classical times to have been shipped from Cyprus to Greece (Chadwick 1964, 22-23). His arguments for textual evidence documenting connections between Greece and Cyprus have been accepted by later scholars (Godart 1983, 132) as has the connection with alum and a trade in alum (Baumbach 1987, 51).

The Knossos tablets mentioning *ku-pi-ri-jo* were written by Scribe 135 and refer to *ko-ri-ja-do-no*, coriander (Melena 1974) and *ku-pa-ro*, cyperus (Wylock 1970, 129-130; Melena 1974a) as spices used in the

Late Bronze Age Cyprus came of age. Building upon the foundations established by Gjerstad and Sjöqvist, Dikaiois presented in meticulous detail the results of ten long seasons of excavation at Enkomi (1948-1958), wherein, for the first time in Cypriot archaeology or, for that matter, in Mediterranean archaeology, proper attention was paid to such mundane categories of material as crucibles, tuyeres, moulds and slags.

We take such things so much for granted today that we tend to forget just how radical was the approach taken by Dikaiois a short twenty years ago. Having spent some six months going through some six hundred wooden trays of Enkomi material in the Cyprus Museum, during 1987 and 1988, thanks to the interest and support of Dr. Vassos Karageorghis, then Director of the Department of Antiquities, I can testify to the care with which Dikaiois catalogued and studied his material and his attention to detail. He recognized as a tuer (or blow-pipe) what European archaeologists were still calling a votive phallus, and had an uncanny ability to appreciate the meaning and significance of his material. He made mistakes, of course, notably in identifying his pair of pot bellows as stone moulds for casting bun-shaped ingots (Enkomi 1969: 43, 241; 1971: Pl. 127: 48 & 48a). But Claude Schaeffer identified his pot bellows from Ras Shamra as a receptacle for making cheese (Schaeffer 1949: 204, Fig. 84:15), so Dikaiois did not do so badly.

With the publication of *Excavations at Enkomi* the fortunes of the Cypriot Late Bronze Age seemed to change. Beginning with the work of Karageorghis, who actually had started work at Kiton back in 1959, the year after Dikaiois finished at Enkomi, we have had a whole series of important Late Bronze Age excavations in Cyprus, all of them devoting proper attention to the

presentation and interpretation of metallurgical remains. It is still true, however, that prior to 1300 BC virtually all our evidence still comes from the site of Enkomi. Nevertheless the changes that have taken place are truly revolutionary. Whereas prior to about ten years ago we had not a single fragment of a copper oxide ingot from Cyprus found in a secure archaeological context, we now have excavated examples to which secure dates can be assigned from the following sites: Enkomi, Kalavassos-Ayios Dhimitrios, Maroni-Vournes, Maa-Palaeokastro and Pyla-Kokkinokremos but, strangely enough, none from Kiton or from Hala Sultan Tekke.

Slag heaps that once were sources of road-building materials, hence the expression "metalled road," are now preserved as archaeological monuments, thanks to Dr. Karageorghis, and technical studies have been carried out on copper smelting slags from a number of Cypriot LBA sites, notably by Steinberg and Koucky (1974; 1982) and by Bachmann (1982). Studies of the LBA copper smelting furnaces excavated by Karageorghis at Kiton have been carried out by Tylecote (1971; 1985), Zwicker (1985) and the team of Stech, Maddin & Muhly (1985). More importantly, the copper oxide ingots themselves, not just the ones from Cyprus but also those from Crete, Greece, Sardinia and the two LBA shipwrecks excavated by George Bass off the southern coast of Turkey, have been studied using various techniques of elemental analysis as well as by lead isotope analysis (cf. Muhly, Maddin & Stech 1988; Gale 1989; Gale & Stos-Gale 1989). What have we learned and what have we yet to learn?

We still lack any good evidence for Late Bronze Age copper mining activity on Cyprus. Thanks to the archival research of Robert Merrillees (1984) the evidence for MC I copper mining at Ambelikou-Aletri has

been rediscovered and promptly published. This puts the first evidence for the mining of copper on the island just prior to the first references, in the texts from Mari, to copper from Alashiya (Bordreuil *et al.* 1984: 407-408, n. 10; Limet 1986, nos. 483, 691, 718 & 719), another piece of evidence in favour of the identification of Alashiya as Cyprus. The mining timbers excavated by Joan du Plat Taylor at Apliki-Karamallou, and now preserved in the Deutsches Bergbau Museum in Bochum, could be of LBA date, but the excavator thought them to be Roman chiefly because she could not imagine such sophisticated shaft supports being erected in a LBA mine (Taylor 1952). If Cyprus was producing any quantity of copper during the LBA, as we now think was the case, then copper mining must have been quite a common activity across the island and the evidence recovered at Apliki should be interpreted within such a context.

The mined ore must have been smelted at or near the site of the mines themselves, and that is certainly the explanation for the large quantities of primary smelting slag excavated at Apliki. In his recent doctoral thesis on Cyprus Volcanogenic Sulphide Deposits in Relation to their Environment of Formation, N. G. Adamides describes the West Apliki deposit as a "medium sized low-grade copper orebody" (Adamides 1984, 219) containing some 1,650,000 tons of ore with an average of 1.8% copper (Adamides 1984, 141, Table 4.2). The Mavrovouni mine, just to the north of Apliki and probably the richest copper deposit on Cyprus, contained 15,000,000 tons of 4.0% copper ore (Adamides 1984, 141, Table 4.2).

It is easy to appreciate the location of a site such as Apliki, in the heart of the Skouriotissa mining district, and to understand the existence of the tuyeres and the great blocks of primary smelting slag excavated at what must be interpreted as a

village built to house all those involved in mining the local sulphide ores and carrying out the roasting and smelting operations that reduced that ore to metallic copper. I am currently working on a full publication of the excavations at Apliki and, in that regard, have been assembling all the Apliki material stored in the Cyprus Museum and, formerly, in the Institute of Archaeology, University of London. This has resulted in a catalogue of twelve tuyeres from Apliki. All three types are represented: straight, bent or elbow, and D-shaped tuyeres. And the Apliki tuyeres are massive, as one would expect in primary smelting operations.

The question is, just how much metallic copper was produced at sites such as Apliki? This has become a major question as a consequence of our attempts to understand what was going on in the major urban centres on the island, especially at the numerous coastal settlements that came into existence in the years after 1300 BC (Negbi 1986). Each of these sites had some connection with copper production, involving the use of furnaces, pot bellows, tuyeres and the production of slag. But it makes little sense to think in terms of primary smelting operations, involving the shipment, over great distances, from the mines to the coast, of ore that was over 90% waste product. Nor was an urban setting the likely context for such noxious operations, especially in the case of temple workshops such as those at Kiton.

What we find at all of these urban centres is large chunks of a material that H.-G. Bachmann has designated furnace conglomerate (Bachmann 1982a). This material was first recognized by Tylecote at Kiton (Tylecote 1971, 53). I have now identified this distinctive material at Enkomi, Kalavassos-Ayios Dhimitrios, Maroni-Vournes and Myrtou-Pigadhes (all unpublished). The theory is that this furnace

conglomerate represents what was produced at mining-smelting sites such as Apliki-Karamallos, the conglomerate then being shipped to the coastal urban centres and there further refined to produce metallic copper.

I have already supported such an interpretation in print (Muhly 1989, 301-304), as has my colleague Tamara Stech (1982; 1985), but I must admit that I am not very happy with the idea. It presumes a very primitive smelting technology in use in 13th century Cyprus and it really does not explain the nature of the slag found at Apliki. Does Apliki somehow represent an entirely different stage in the complex of activities involved in LBA copper production, with the distinctive furnace conglomerate being produced at other, as yet unidentified inland sites? The lack of any furnace conglomerate from Apliki itself supports such an interpretation, but how then *does* Apliki relate to the metalworking activities underway at the coastal centres?

The evidence from Enkomi indicates that the industry at such centres underwent periods of expansion and decline during the course of the Late Bronze Age, but seems to have undergone very little technological development. My own study of over four hundred tuyere fragments from Enkomi indicates that, at least at that site, the type of tuyere in use remained unchanged during the entire duration of metal-working activities, from LC IA to the end of LC IIC (ca. 1600-1180 BC). Dikaiois regarded the copper industry at Enkomi as going back to the MC III period (his Level A), but I would regard this pre-LBA level at Enkomi as representing nothing more than some sherds of Bichrome ware and a few tuyeres buried under foundations of the Level IA building. The French excavations at Enkomi produced only Middle Cypriot sherds, with no associated architecture (Schaeffer 1952, 299), another example of the very ephemeral nature of any

pre-LCIA occupation at Enkomi.

This is not a trivial point, for it has recently been argued that, when the Hittite push into southeastern Anatolia and across the Taurus mountains, in the reigns of Hattusili I and his grandson Mursili I, deprived the Amorites to the south of access to the copper mines at Ergani Maden, these Amorites moved over to Cyprus and established there the mining and smelting of the local Cypriot ores (Baurain 1984, 39-40 and 60-61; Fortin 1989, 240). Such ideas represent nothing more than a revival of the old idea of a Hyksos invasion of Cyprus (Sjöqvist 1940, 198-199) and have no basis of support in the archaeological or the historical evidence from Cyprus.

We cannot, in fact, say anything at present about the origins of the copper smelting industry of LBA Cyprus. We simply have nothing in the way of comparative evidence upon which to base such an assessment. Recently a young German scholar, Claus Reinholdt, completed for the University of Salzburg a doctoral dissertation dealing with the evidence for metal-working in Bronze Age and Early Iron Age Greece, Cyprus and Troy (Reinholdt 1987).² Reinholdt gives an excellent presentation of the evidence for 'Schmelzöfen und Werkstätten', providing a catalogue that includes 13 sites from the Greek mainland, 5 from the islands and 6 from Crete (Reinholdt 1987, 144-157), but the evidence really does not amount to anything of any substance. His catalogue includes, as he himself recognizes, some quite dubious entries, including the pottery kiln at Zakro and the puzzling installation on the Kolonna Hill of Aegina that must be connected with some pyrotechnological operation but cannot have anything to do with the smelting of copper ore. As for the site of Steno, near Tripolis, I can only say that the published accounts (all based upon evidence derived from the Greek press, cf.

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pure fantasy.

I have yet to see a convincing copper smelting furnace from the eastern Mediterranean Bronze Age. Such installations might have been uncovered by Theodoros at Raphina, but no proper records of the excavation seem to have been kept and the site was subsequently totally destroyed. Most of the other such installations in the literature cannot be taken seriously. I, for one, doubt very much that anyone ever smelted copper inside such a building as House A at Ayia Irini on the island of Keos (Cummer & Schofield 1984, 38, 140, 149-150; Georgiou 1986, 23; Reinholdt 1987, 153-154). Reinholdt has done an excellent job of combing the existing literature in search of smelting furnaces; it is not his fault that the published identifications of technological installations leave so much to be desired.²

Our best evidence for LBA copper smelting furnaces in the eastern Mediterranean comes from Kiton and, together with Maddin and Stech, I have already published an interpretation of the smelting operations being carried out at that site (Stech, Maddin & Muhly 1985). It is very unfortunate that no technical examination was ever made of the smelting installations excavated by Dikaiois at Enkomi as existing political conditions on the island now make it impossible even to visit the site. The descriptions given by Dikaiois give the impression of simple so-called bowl or crucible furnaces not unlike those excavated by Rothenberg at Site 30 in Timna (for technical study see Bamberger et al. 1986). Timna still provides us with our best

artificial evidence for the nature of LBA copper smelting technology. That evidence seems to indicate that the ability to achieve real separation between metal and slag, resulting in an actual lump or ingot of metal and a tapped slag, developed only towards

the end of the 13th century BC and is best documented in Layers II and I at Site 2 of Timna (Bamberger et al. 1986, 3 and Table 2; Muhly 1989, 304-305). A similar process seems to have been in use, at about the same time, in the Mitterberg, southern Austria (Moesta & Schlick 1989).

The excavations of Alison South at the site of Kalavassos-Ayios Dhimitrios provide a good example of the difficulties encountered in trying to understand 13th century copper production on Cyprus. We have massive blocks of furnace conglomerate from Ayios Dhimitrios, as well as hundreds of lumps of black, ropy slag and even many fragments of furnace lining much like the famous example excavated by Dikaiois at Enkomi (ENK 1640) and identified by him as a crucible (Enkomi 1969, 58; 1971, 455, 644 & Pl. 159/20), but not a single smelting furnace has yet been identified at Ayios Dhimitrios. Furnace conglomerate was found everywhere; I have identified numerous examples from Buildings I, II, III, VIII and IX. From the so-called West Area, excavated by Cypriot soldiers in rescue operations at a time when the new Limassol road threatened the imminent destruction of the entire area, come massive blocks of furnace conglomerate identical to those excavated by Karageorghis at Kiton. There are also numerous fragments of scrap bronze from Ayios Dhimitrios, especially from Building III. Yet it is clear that we have yet to locate the actual industrial area of the settlement at Kalavassos-Ayios Dhimitrios, a settlement whose existence must surely be understood within the context of the copper mines just to the north.

Why were large quantities of furnace conglomerate stored in the various buildings at the site? Why was so much slag found in the rooms of House A at Apliki-Karamallos? Why were so many crucibles found in the rooms, most likely in the basements of the rooms of House A at Ayia Irini on Keos?

From the so-called 'Reception Room' of Building IX at Ayios Dhimitrios, with clay benches along the walls of the room, comes a large lump of solid furnace conglomerate with much sulphurous yellow incrustation. What was it doing there?

One of the basic assumptions of non-traditional archaeology, whatever you want to call it, is that the function of a room or a building or an entire complex, can be determined through a detailed study of the contents found therein. One extrapolates from material culture to complex society. On the basis of the metallurgical evidence known to me I would say that there is no correlation whatsoever between what the archaeologist finds in a room and what might have been the original function of that room. What has been interpreted as constituting the contents of a room actually represents, in many cases, the goods or debris stored or put away in a basement beneath the actual floor of the room.

This situation relates directly to the proper identification of all the so-called metallurgical workshops in the archaeological literature. In the ancient Near East the lack of metallurgical workshops has created such a desperate situation that a hoard of copper/bronze objects from a room in the Earlier Northern Palace at Tell Asmar in the Diyala (never meant to be seen because it had been hidden away in a wall of the room and the wall was afterwards plastered over) has been presented as evidence for the existence of a metallurgical workshop in the palace (Delougaz 1967, 198). The hoard, dating to the middle of the third millennium (or ED III) is a remarkable assemblage of material, soon to be published at last, over 50 years after its discovery (Müller-Karpe, forthcoming), but it cannot in any way be used to support the existence of a metallurgical workshop at the site (cf. Margueron 1979, 9-14).

The same applies, I would argue, to the collection of moulds found in the palace of Mallia (Chapouthier & Demargne 1942, 56-66). Attempts have been made to connect these moulds with what has been interpreted as the remains of a metallurgical furnace, said to be similar to that found at Zakro, located nearby (Effetierre 1980, 387), but the whole reconstruction simply cannot be accepted (cf. Pelon 1987, 271). Whether or not some sort of metallurgical activity was going on in this area northwest of the palace during the Middle Minoan III period remains to be seen, pending analysis of the slag found there (Pelon 1987), but nothing published to date supports the existence of metal workshops located in or near the palaces of Minoan Crete.

The same holds true for those of Mycenaean Greece. Although workshops must have been a vital part of the palace economy (Chadwick 1987; Kilian 1988), and it has even been argued that Linear B *o-pa* designates a workshop (Palmer 1977, 55-58; compare Consani 1977; Melena 1983a) no convincing evidence has yet been found to support the identification of metal workshops at any Mycenaean palace. It could be argued that no such evidence should be expected from the palace at Knossos, where the Linear B tablets record a wool industry but scarcely even mention copper or bronze (Hooker 1987, 313), but what about Pylos with its workforce of some 400 smiths (Lejeune 1961), of whom only some 200 seem to have been active in the last days of the palace when they received a consignment of 1046 kg of copper? (Baumbach 1983, 30-32).

Valiant attempts have been made to identify such workshops, especially in the northeastern part of the palace, in rooms 97-100 (Teggey 1984), but it is most unlikely that any metalworking was carried out in any of these rooms. What has been uncovered in these rooms, as in other so-called workshop

artifacts. Can we do better than Dikaïos?

In the Proceedings of the Heidelberg Symposium on "Old World Archaeometallurgy" Noël Gale summarizes the contents of a paper I gave at the Athens Colloquium on Aegean Prehistory, held in September of 1987 (Gale 1989, 262). I do not object to what he does say but rather to what he does not say, for he has succeeded in leaving out the central point of the whole paper. On the basis of analytical and computer work, carried out by my colleague Robert Maddin, I concluded that Cypriot copper was not traded west, to the Aegean and beyond, before the mid 13th century BC. In her paper in the same session at the Athens Colloquium, Zofia Stos-Gale reported on recent lead isotope work on copper oxide ingots from 13th century Mycenae. I was delighted to learn that the copper oxide ingot fragments from the Poros Wall Hoard were thought to be of Cypriot copper (9 out of 11 fragments), and that the intact ingot found by Tsountas was of the same provenance (see now Gale & Stos-Gale 1989, 254 & Pl. LXV; Gale 1989, 254-255 & Fig. 29.16). It struck me at the time that we were in wonderful agreement on one of the basic aspects of the LBA metals trade in the eastern Mediterranean.

There were points of disagreement. The ingot fragments from Ayia Irini (Keos), of LM IB date, are said to be of Cypriot copper. I had argued that the Kommos fragments were the earliest oxide ingots from the Aegean made of Cypriot copper (and see now Muhly, Maddin & Stech 1988, 291-292). We had not included the Keos fragments in our own calculations because our original analytical work on one of the samples proved to be unsatisfactory and the sample itself had been turned over to the Gales to study. We also provided the Gales with samples of the ingots from Gournia, identified as fragments of copper oxide ingots by Philip Betancourt

areas, is equipment and goods of various sorts stored in the room and often, as I have already pointed out, in the basements of those rooms. None of the copper oxide ingots known from Minoan or Mycenaean Greece has been found in association with a metallurgical workshop. Those from Ayia Triadha and Zakro seem to come from actual storerooms or even treasuries (Verlinden 1988, 187-188).

Scholars dealing with religion and the identification of cult places or shrines face the same problem. E. French concludes that the so-called shrine at Mycenae is more properly described as a religious store. She goes on to argue, in reference to basement areas and the Shrine at Mycenae, that:

"It could be that both these areas dispensed materials which were then worked in the open area to the North and possibly on other parts of the site as well. The artisan would return both the finished object and the scrap material to store when he finished" (French 1981, 45).

Such, I would argue, is what was going on in all the so-called Bronze Age copper and bronze workshops.

I close with a few remarks on what happened to all the copper produced in LBA Cyprus. The desperate state of affairs that used to exist regarding the LBA copper trade can be appreciated by reading Dikaïos' discussion of what happened during his Level IIA at Enkomi, roughly the 14th century BC. He concluded that the scarcity of copper or bronze objects from that level was to be explained by

"a possible, wholesale export of copper to Egypt, presumably as tribute, as can be inferred from the Amarna letters, leaving small quantities for the islanders"

(Enkomi 1971, 509). It is to be hoped that only a limited number of readers have given this explanation serious consideration. Now, however, we have the benefit of a series of detailed analyses of Cypriot ores, ingots and

(Betancourt *et al.* 1978). The ingot fragments from Gourmia are difficult to categorize. We concluded that they should be included in the Cretan group, not the Cypriot one. The Gales agree that they are not of Cypriot copper, but would also not associate them with Crete, with the ingots from Ayia Triadha and Tyllissos (Gale 1989, 253, Fig. 29:14; Gale & Stos-Gale 1989, Pl. LXXV). Cyprus does seem to be the source of the copper prills found with the Ras Ibn Hani ingot mould in Syria, according to the lead isotope work by the Gales. Our work on the intact ingot from Hisholy Carmel and the ingot fragments from Kefar Zamir, both from the sea off the coast of Israel, south of Haifa, also indicates a Cypriot source for the copper of these Palestinian ingots. Cyprus had been exporting copper to the Levant in the 18th century BC and seems to have continued doing so in the years on either side of 1200 BC.

Again our conclusions seem much in agreement with those reached by the Gales. I feel that we have made real progress but that we still have a long way to go. Current work on the two most exciting finds of oxide ingots made in recent years, those from the Kas or Ulu Burun shipwreck and those from Sardinia, illustrate dramatically the scholarly differences that still exist. The Gales believe that both groups of ingots are of Cypriot origin. That is, regardless of place of manufacture, they are all made of Cypriot copper (see paper in this volume). This is quite a shift from their position in 1988 when they claimed that "there is virtually no direct evidence that Cypriot copper ever came into Minoan or Mycenaean hands. Neither is there, indeed, any direct proof that Cypriot copper ever left Cyprus in the Bronze Age in any quantity" (Stos-Gale 1988, 265). The Ulu Burun ship alone has been estimated at containing a cargo of six tons of copper.

Regarding the Ulu Burun ingots this is a most

unexpected conclusion. Our work on these ingots (reported in Maddin 1989) indicated that they had an elemental composition significantly different from that found in the ingots from Cyprus (Mathiati and Skouriotissa), from Crete (Ayia Triadha) or in those from the Cape Gelidonya shipwreck (Muhly, Maddin & Stech 1988). This is especially true in the case of arsenic content. The 16 oxide ingots from Ulu Burun averaged 0.08% arsenic (Maddin 1989, 100, Table 11.1), whereas the seven Gelidonya ingots averaged 0.57% arsenic (Muhly, Maddin & Stech 1988, 286, Table 2), the eight Cypriot analyses mentioned above averaged 0.45% arsenic (Gale & Stos-Gale 1986, 93, Table 3) and the nine Minoan ingots from Ayia Triadha averaged 0.12% arsenic (Gale & Stos-Gale 1986, 93, Table 4). In terms of trace element arsenic the Ulu Burun oxide ingots are very different from those from Cyprus or the Cape Gelidonya shipwreck whereas the latter two groups of ingots have much in common (Muhly, Maddin & Stech 1988, 291-292). The Gales agree with us in assigning a Cypriot origin to the Gelidonya ingots, but they would also include the Ulu Burun ingots in that category

Elemental analysis together with Principal Component analysis cannot relate ingots to ores. It does indicate, however, that if the Ulu Burun ingots were made of Cypriot copper then the ore being smelted to produce this copper was different from that used for any of the copper ingots known from Cyprus itself. To the eight Cypriot ingots analyzed by the Gales can now be added four more analyses, three from Mathiati and one from Enkomi (Muhly, Maddin & Stech 1988, 286, Table 2). There are also ten additional oxide ingot samples collected by Maddin and Muhly in September of 1987, comprising five from Maroni-Vournes, three from Kalavassos-Ayios Dhimitrios and one each from Maa-Palaeokastro and Pyla-Kokkinokremos, the latter two samples

having already been published (Muhly & Maddin 1989). This gives a total of 22 Cypriot ingot analyses, averaging 0.34% arsenic. Such a concentration of arsenic is unmatched by anything yet analyzed from the Ulu Burun shipwreck.

Any theory proposing a Cypriot origin for the copper oxide ingots from the Ulu Burun shipwreck will have to explain why the elemental composition of those ingots is significantly different from that in any such ingots found in Cyprus itself. A possible Cypriot origin for the now numerous oxide ingots and fragments of same from Sardinia presents an even more surprising and controversial hypothesis. The metallurgical connections between 13th and 12th century Cyprus and Sardinia have been discussed on numerous occasions (most recently in Lo Schiavo, Macnamara & Vagnetti 1985; Vagnetti & Lo Schiavo 1989). The evidence is most impressive, but is it realistic to think in terms of Cypriot copper being imported by a central Mediterranean island with its own rich deposits of copper ore?

The presence of heavy smithing tools in Sardinian bronze hoards parallels the situation in Cyprus, indicating that both islands were copper-producing regions whereas Minoan Crete and Mycenaean Greece, without such tools in any of the surviving hoards, were copper-importing regions (Knapp, Muhly & Muhly 1988, 256-257). Why then would a local Sardinian metal industry be making use of imported Cypriot copper? Chronological considerations also present serious difficulties. Oxide ingots in Sardinia were in use down to the end of the tenth century BC (Lo Schiavo 1989, 36; Stech 1989, 39) whereas Cyprus provides no evidence for the use of such ingots after the early 12th century BC. Did Cyprus continue to export such ingots to Sardinia long after they had gone out of use back home in Cyprus itself or did they

somehow continue to produce oxide ingots in Sardinia out of Cypriot copper for some 200 years after the termination of such production in Cyprus? Both possibilities seem equally improbable.

Nevertheless the Gales have shown that the Sardinian ingots fall within the Cypriot isotopic field and they have therefore argued that the oxide ingots from Sardinia were made of Cypriot copper (cf. this volume; also Gale & Stos-Gale 1987, 1988). If the Ulu Burun and Cape Gelidonya ships were carrying cargoes of Cypriot copper ingots, as the Gales believe they were, then it could be argued that these two chance finds represent the only surviving evidence for the numerous ships that must have sailed west with cargoes of Cypriot copper. What seems to be an Italian sword in the cargo of the Ulu Burun ship could then be seen as one piece of evidence attesting to that ship's western Mediterranean operations (Vagnetti & Lo Schiavo 1989, 222-224).

What about the pithos sherds from the Nuraghe Antigori in Sardinia? The Cypriot origin of these sherds points to the southern part of the island as their place of manufacture, to Kalavassos-Ayios Dhimitrios and Maroni-Vournes, both sites with known metallurgical associations (Vagnetti & Lo Schiavo 1989, 221). The site of Kommos, on the south shore of Crete, has also produced such a Cypriot pithos and Kommos has produced not only fragments of oxide ingots that seems to be made of Cypriot copper but also sherds of Italian wares (Watrous 1989) that chemical analysis has now shown to come from the Nuraghe Antigori in Sardinia (Jones, this volume). Kommos, then, seems to be an ideal candidate for a way-station on an East-West trade route, connecting Cyprus and Sardinia, as also seems to have been the case during the period of Phoenician westward expansion

in the early Iron Age (Shaw 1989).

But can such a trade have involved Cypriot copper ingots being shipped west to Sardinia? Here it is important to remember the cautionary remarks of the Gales regarding the nature of lead isotope research. The situation is described very clearly by Noël Gale (1989a, 489):

"It is of course important to realise that, if the lead isotope analysis of a copper artefact results in an isotopic composition which falls within the isotopic field of a particular copper ore deposit, then strictly one can say only that the copper of the artefact is consistent with having come from that ore deposit".

Thus the fact that the Sardinian ingots fall within the Cypriot field means only that the copper produced from Cypriot ores. But what about other ore deposits?

The idea of a Cypriot origin for the Sardinian oxide ingots has been well received, indeed one might say almost uncritically so. In his closing remarks at the Oxford Conference Colin Renfrew admitted that he could see no reason for not accepting the idea, much as he obviously disliked doing so, and was even prepared to go so far as to suggest the possibility of a Cypriot colonization of Sardinia, a most surprising suggestion from a scholar who long has fought against explanations based upon colonization and migration (cf. Renfrew 1967). Although pleas for caution have been made (notably by Vagnetti & Lo Schiavo 1989, 232-233), it is surprising that no one has raised the possibility of ore sources in the central and western Mediterranean, sources perhaps with lead isotope profiles similar to those found in Cyprus. Lead isotope work on the ore deposits of the eastern and southern Alps indicates that they form a metallogenetic region far older than anything known from Cyprus (Köppel 1983). The lead-zinc deposits from the region of Sierra de

Cartagena in Spain, on the other hand, have a geological age (ca. 30 million years) quite similar to that known from Cyprus (ca. 100 million years). These ores thus give a lead isotope profile quite similar to that known from Cyprus (Graessner & Friedrich 1970). That is, the ores from Sierra de Cartagena would fall in the Cypriot isotopic field. This has not been readily apparent because the geological study of these Spanish ores gave, as usual in such publications, ratios in terms of Pb206/Pb204, Pb207/Pb204 and Pb208/Pb204 (Graessner & Friedrich 1970, 368, Table 2). From these ratios, however, it is possible to calculate the Pb207/Pb206 and the Pb208/Pb206 ratios used in archaeometallurgy. (4) For Sierra de Cartagena they are (for the six samples analyzed in the table mentioned above):

Pb207/Pb206	Pb208/Pb206
0.8387	2.0856
0.8370	2.0767
0.8370	2.0764
0.8373	2.0794
0.8382	2.0792
0.8373	2.0765

A comparison with the Cypriot ratios published by the Gales (Gale & Stos-Gale 1986, Table 1; 86, Fig. 1) indicates that these figures place the Spanish lead-zinc deposits of Sierra de Cartagena within the Cypriot field.

This does not mean that the Sardinian ingots were made of Spanish copper. The point to be made here is that lead isotope analysis is most powerful in its ability to *exclude* ore deposits when they fall outside the lead isotope field in question. As Noël Gale (1989, 249) has put it:

"an enormous strength of lead isotope analysis is that it can with absolute certainty exclude particular ore deposits..."

When, however, two geographically distinct ore deposits fall in the same isotopic field

there is no way that lead isotope analysis can determine which one was the source of the metal in question.

There is much discussion these days regarding the use of lead isotope analysis in the study of archaeological materials. But it is not lead isotope analysis as a technique that should be called into question, but rather the application of the results of such analysis to the quondam reality that is the Late Bronze Age. We are all, each of us in his or her own way, attempting to say something about what we think happened over three thousand years ago. The very quality and complexity of our research efforts have caused us to lose perspective regarding the wonderful absurdity of our efforts. A dash of humility would do wonders for us all.

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FOOTNOTES

1. Merrillees (1986) realizes that the linguistic connection between Cyprus and copper is of recent derivation, probably going back no much earlier than the first century AD. He proposes, therefore, a connection between *kypros* and a Semitic word for 'henna' that is *kyr* in Ugaritic, *kopher* (or *koper*) in Hebrew. Merrillees believes that the Semitic peoples of the Levant applied this name to copper because of the reddish, henna-like color of that metal and, as the copper in question came from Cyprus, the use of the term *kypros* was extended to designate the source of the metal as well as the metal itself.

Although apparently unknown to Merrillees, this argument is similar to that proposed by M. Dahood to explain the use of *kā-pā-lum* or *kaparum* as a word for copper in a lexical text from Ebla, translating Sumerian URUDU. Dahood (1987, 7) believes that "In *kapar* one recognizes the etymology of the Latin *cuprum* and the origin of the toponym Cyprus." The Semitic root, according to Dahood, means "to be reddish-orange." Hence Cyprus, by etymology, would be "(the home of) the reddish-orange (metal)," and this connection between the color and the metal would go back to Ebla and texts from the mid-third millennium BC.

A new Hurrian-Hittite bilingual text, discovered at Boğazköy in 1983, provides *kabali* as the Hurrian word for 'copper', and linguistic arguments have been presented to connect this word with the name *Körpoç* and with words for 'copper' (Neu 1987, 181-182). C. Zaccagnini compares this Hurrian *kabali* with the Eblaite *kabulum* (his transcription of the Eblaite word) and regards both as words for copper that go back to a Sumerian KA.BAR (Zaccagnini 1988). It is doubtful that any of this tells us very much about the etymology of Greek *kypros* because we have no evidence to indicate that *kypros* was used in reference to copper before the first century AD.

2. I thank Dr. Reinholdt for providing me with a copy of his dissertation which, in a revised version, is to be published in the *Prähistorische Bronzefunde* series.

3. Harriet Blitzer, who is publishing the metallurgical remains from Minoan Kommos, has warned me of the danger of letting modern sensitivities unduly influence

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our interpretation of archaeological remains. I am very grateful for the opportunity of discussing these problems with her in Athens during January of 1990. Her unrivalled knowledge of the ethnographic evidence will, hopefully, soon be made generally available with the publication of her monumental work on *The Traditional Industries of Greece: their History, Technology, Raw Materials and Trade* (to be published by the Edinburgh University Press).

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