

METALWORKING AND RECYCLING IN LATE BRONZE AGE CYPRUS — THE EVIDENCE FROM KITON

Summary. Excavations at the sacred precinct of the Late Bronze Age city of Kition uncovered the remains of metalworking workshops which were clearly associated with the temples. The results of the excavation as well as a number of specialist reports of the archaeometallurgical finds have already been published. Since their publication, however, archaeological research has progressed and new evidence has come to light regarding the Late Bronze Age in general and metalworking in particular. The object of this paper is to present the finds from these workshops and reconsider some of the issues that their discovery has raised. The results of the previous studies of the archaeometallurgical studies are critically assessed and the evidence reinterpreted based on what is available today. One of the issues addressed is that of metal recycling during the Late Bronze Age. This communication was presented at a research workshop organized by the Israel Science Foundation and the University of Haifa on 'Recycling, Hoarding and Trade in Bronze, 13th–11th centuries BCE' (Haifa 26–28 April, 1998). The first part of the paper was written by Karageorghis, the second part by Kassianidou.

INTRODUCTION

As early as 1965, Vincent Desborough, in his review of Catling's *Cypriot Bronzework in the Mycenaean World*, expressed his opposition to the tendency to minimize the importance of Cypriote bronzework during the period prior to ca. 1200 BC and to over-emphasize the role of the Mycenaean Greeks in its development (Desborough 1965). This problem need not be discussed here in any detail, but the writer would like to suggest an explanation of the situation which led Catling and others to reach such conclusions. It is true that far more is known about Cypriote

bronzework of the early 12th century BC than about that of the 14th and 13th centuries BC. It is also true that the 12th century BC yielded some of the finest examples of Cypriote bronzework of the Late Bronze Age, namely the rod tripods and the wheeled four-sided stands.

The fact that far more bronzes are known from the 12th century BC than from previous periods in Cyprus requires an explanation. Cyprus was rich in copper and exported large quantities of the metal during the 14th century BC, as the Ulu Burun shipwreck has demonstrated. The Cypriots did not wait for half a millennium to be taught by others

how to produce tools, weapons, vases and other artifacts, although admittedly the Mycenaean Greeks did introduce some metallurgical innovations during the 12th and 11th centuries BC.

One explanation for the comparative lack of bronzes dating to the 14th and 13th centuries, and there may be more than one, is the fact that copper and bronze had become so valuable by ca 1200 BC, probably as a result of the troubled conditions which prevailed in the Aegean and the Eastern Mediterranean, that the Cypriots started to recycle bronze on a large scale. This suggestion is supported by two phenomena. Firstly, that of 14th–13th century tombs being purposely looted by early 12th century Cypriots or foreign residents, not only for gold but also for bronze. Tombs 4 and 5 at Kition may serve as an example (Karageorghis 1974, 16–17). These tombs, lying below houses of the early 12th century BC, had been completely emptied of their contents by the new 12th century BC settlers. They were rich in Mycenaean pottery, ivory and other goods, and the famous faience rhyton belonged to one of them. But not one single bronze object was found. Unlooted tombs of the same period known from elsewhere are usually quite rich in bronze objects such as bowls, tools and weapons. The bronzes of Tombs 4 and 5 were apparently carefully collected and recycled.

This phenomenon of recycling may also explain the appearance of hoards in fairly large numbers ca. 1200 BC. Bronzes of earlier periods were collected from tombs and sanctuaries and from elsewhere. The Sinda hoard, the Mathiati hoard and the Enkomi hoard are but a few examples (Catling 1964, 278–298; Karageorghis 1973) (Fig. 1). Similar hoards also appear in the Aegean such as the Tsountas Acropolis hoard at Mycenae, the Poros Wall hoard at

Mycenae and the Anthedon hoard in Boeotia. Metal became more valuable than ever before. At Catling rightly observes: ‘The Cypriot market had not been forgotten, and ships continued to go eastward in search of metal ... the demand for metal was so high that whatever could be obtained was acceptable — the Cape Chelidonia ship shows that whole ingots, half ingots, ingot scraps, sound tools, broken tools, castings, and all kinds of foundry rubbish were all acceptable’ (Catling 1964, 298). It is, of course, unlikely that the raw material became scarce in Cyprus. It is to the Aegean and elsewhere that we should look for such a scarcity, and this may explain why Cypriote ships, like the Cape Gelidonya ship ‘carried so much rubbish with her main cargo of copper ingots’, as Catling rightly observed (Catling 1964, 298; cf. also Muhly 1982, 256; Muhly *et al.*, 1988).

The occurrence of a mould for oxhide ingots in the palace at Ras Ibn Hani in Syria may also be explained in this context. Copper was not produced there, so why should a mould for oxhide ingots be found in one of the most prominent courtyards of the palace? In a recent very comprehensive study of oxhide ingots, Lagarde and Lagarde (1997, 79–88) tried to assign religious connotations to them. The writer is rather reluctant to accept any religious significance for the oxhide ingot, but would certainly agree that they were symbols of power and prosperity; since religious and political authority was often in the hands of the same person or persons, by possessing ingots, not necessarily of raw copper, but of bronze, made of melted scraps of metal, these authorities could claim power. Power, therefore, from one end of the Mediterranean to the other, symbolized by the number of ingots of copper or bronze possessed, was the main target of religious and political rulers, particularly in the 12th century BC. To cite a modern parallel, the



Figure 1
Sites mentioned in the text.

US dollar might be proposed as today's symbol of power. The dollar has become the universally accepted banknote. The UN budget and other international organizations function in terms of the US dollar. The dollar is not a sacred symbol, but nobody can do without it, and it is perhaps not difficult to endow it with a 'sacred quality'. Last year, when in Moscow and Saint Petersburg, the author soon became conscious of the fact that in post-communist Russia one can observe three categories of people: those who were nostalgic for the previous regime, those who tried to bring back the old saints of tsarist Russia, but the most fanatical were those who believed in the power of the dollar (not the rouble).

Thus in Cyprus at the end of the Late Bronze Age the possession of oxhide ingots was connected with religion; to be more precise, the religious authorities, through

religion, tried to control the production and diffusion of copper which was the backbone of the national economy, a situation for which modern parallels can easily be found. The question of the association of metallurgy and religion in Cyprus, particularly at Kition, has been discussed on numerous occasions ever since the excavation of the temples and workshop complexes in Area II. Similar phenomena also appear elsewhere, both in the Late Bronze Age and in later periods. The writer has nothing to add to the arguments proposed in 1985 when volume V of *Excavations at Kition. The pre-Phoenician Levels* was published (Karageorghis and Demas 1985, 253–254).

Presumably the workshops that were established in the sacred precinct at Kition would have been actively involved in the recycling of metal, as well as other metallurgical activities. The exact nature of these

activities can only be ascertained by a study of the installations and finds that have been recovered in these workshops. The remaining part of this paper will deal specifically with these issues.

THE NORTHERN WORKSHOPS AT KITION

The earliest architectural remains from Area II come from Floor IV and date, according to Karageorghis and Demas (1985, 272), from 1300–1190 BC, in other words within the Late Cypriot IIC period. Unfortunately these remains are not very well preserved owing to extensive rebuilding in the subsequent phase of occupation (Karageorghis and Demas 1985, 24). Unlike the later periods, no buildings or installations clearly connected with metalworking were identified. However, finds related to metallurgical activities were recovered from the floors and features of this period.

Copper slag was found in small quantities in the fill used by the builders of Floor IIA to level the ground in Temenos A and Temple 1, and a crucible fragment (Inv. No. 3242: Karageorghis 1985, 99) was found in one of the pits in the area in which the Northern Workshops were established later. In the same fill was found material clearly associated with Floor IV which strongly suggests that the metallurgical debris also dates to this period (Karageorghis and Demas 1985, 37). Although the slag and the crucible were both found in a secondary context, the fact is that they are present, and their presence indicates some metallurgical activity in the vicinity of the sacred precinct from the outset, even if no actual workshops dating to this period have been excavated. Besides the slag and the crucible fragment some pieces of scrap bronze were also found on Floor IV. The scrap metal comes from Temple 2 and its associated rooms (Inv. No. 2578: Karage-

orghis 1985, 88; Inv. No. 2412: Karageorghis 1985, 89; Inv. No. 2419: Karageorghis 1985, 90; Inv. No. 2506: Karageorghis 1985, 90).

In the following period of occupation, Floor IIIA which corresponds to Late Cypriot IIIA and dates to the 12th century BC (Karageorghis and Demas 1985, 272), the sacred precinct was completely rebuilt on a grand scale (Karageorghis and Demas 1985, 38). Among the new structures are two sets of workshops built in the vicinity of Temple 1. The Western Workshops, probably connected with the treatment and weaving of wool, and the Northern Workshops, located between the north wall of Temple 1 and the city wall, which were clearly connected with metalworking.

The Northern Workshops basically consist of a series of rooms in which pyrotechnological installations, pits and working platforms were found. They had direct access to the Western Workshops, to Temenos A and most importantly to Temple 1, the largest and presumably most important temple of all in the sacred precinct.

The plan of the workshops of the Late Cypriot IIIA phase is illustrated in Fig. 2. In Room 12 were found, among other features which are not related to metalworking activities, two benches, a number of pits, a well and finally a large furnace (Karageorghis and Demas 1985, 81–82). Furnace J, with a diameter of 0.95m and a preserved height of 0.26m, had a clay lining and a mudbrick border of which only traces survived. In it were found bone ash as well as a smaller pit.

Immediately south of this furnace was a low, square platform, south of which were two small pits lined with hard-fired mud and filled with green sand and slag. More pits were found scattered around the room, the use of which remains uncertain. Among the finds from this room were crucible fragments

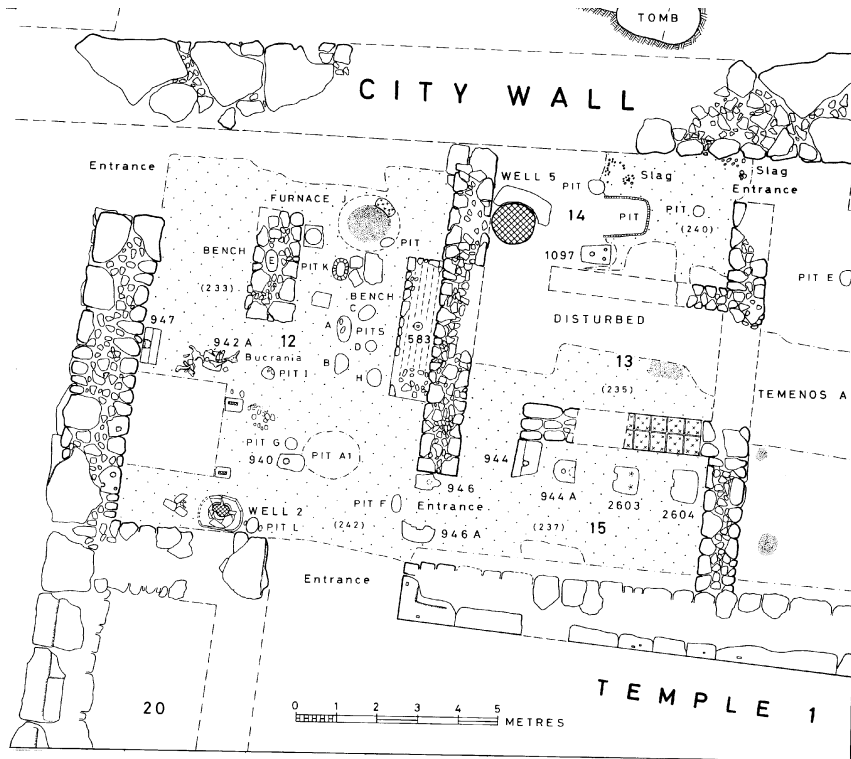


Figure 2
Kition: plan of the Northern Workshops — Floor IIIA

with evidence of burning on the interior surface (Inv. No. 939: Karageorghis 1985, 121; Stech *et al.*, 1985, 394), as well as copper slag (Karageorghis and Demas 1985, 83).

East of Room 12 is a row of three rooms, Rooms 13, 14 and 15. In Floor IIIA of Room 15 there was a well and some pits, one of which was filled with burnt soil and some pieces of slag. A small pile of slag comprising 45 pieces was also found on the floor in the northern part of the room (Karageorghis and Demas 1985, 84). Finally, pieces of bronze scrap were found in Room 13 (Karageorghis 1985, 121), Room 14 (Inv. No. 980: Karageorghis 1985, 107) and in Room 16A (Inv. No. 2638: Karageorghis 1985, 107). Finds related to metalworking,

such as crucibles (Inv. No. 3242: Karageorghis 1985, 99; Inv. No. 3328: Karageorghis 1985, 105; Karageorghis 1985, 125) and slag (Karageorghis 1985, 119) were also recovered from some of the other open areas of the sacred precinct. A significant concentration of crucible fragments and slag seems to have been found in Courtyard C between Floor III and Floor IIIA, below Floor III (Karageorghis 129–131).

In the period that followed, the Northern Workshops were remodelled (Fig. 3). Some of the old installations remained in use while others were constructed. As in the previous period of occupation a number of pits were found in Room 12, and most of them were lined with hard-fired clay and filled with ash

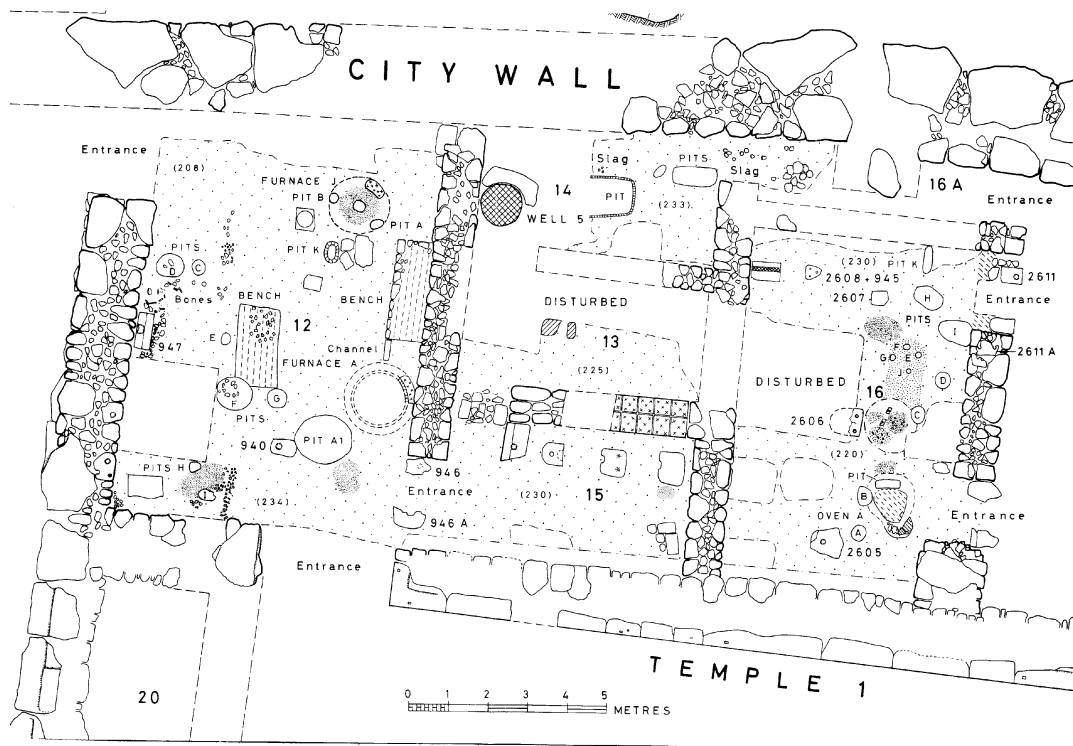


Figure 3
Kition: plan of the Northern Workshops — Floor III

and/or charcoal and bones (Karageorghis and Demas 1985, 115). Ashes and evidence of burning were found in the whole room. The presence of a fragmentary crucible with traces of tin bronze (Inv. No. 5468: Karageorghis 1985, 144), a fragmentary 'shovel' (Inv. No. 5467: Karageorghis 1985, 144) and slag recovered from various spots on the floor bear witness to metallurgical activity (Karageorghis and Demas 1985, 117). Also recovered on floor II of Room 12 were droplets of blister copper (Zwicker 1985, 404). Scrap metal (Inv. Nos. 937, 981 and 982: Karageorghis 1985, 144) and copper slag were found in the three adjacent rooms (Karageorghis and Demas 1985, 117).

The only structural changes of this period are seen in what was previously area 16. This

open area was transformed into a room which could be accessed through a corridor formed along the north wall of the workshops and the city wall or through Temenos A. The most important finds from this room were the remains of two furnaces (Karageorghis and Demas 1985, 118). One of them had a diameter of 1.20m with a stomion protruding toward the south. Near its centre was a 'slab' of red hard-fired clay. As charcoal and ash were found below the fired slab, it was suggested that this may, in fact, have represented a raised floor, separate from a firing chamber which would have been reached through the stomion.

The excavation of Room 16 did not reveal any finds clearly related to metallurgy, not even slag, although slag was noted between Floors IIIA and III. A small concentration of

slag was found in Room 16A, the passageway leading from Room 16 to the other rooms of the Northern Workshops (Karageorghis and Demas 1985, 119).

Finds related to metallurgy, mainly scrap metal (Inv. No. 2534: Karageorghis 1985, 136; Inv. No. 2588: Karageorghis 1985, 137; Inv. No. 4290: Karageorghis 1985, 139; Inv. No. 4212: Karageorghis 1985, 141; Inv. No. 4222: Karageorghis 1985, 141; Inv. No. 2433: Karageorghis 1985, 142; Inv. No. 3004A: Karageorghis 1985, 150; Inv. Nos. 3006 and 4811: Karageorghis 1985, 157), slag (Karageorghis 1985, 143) and refractories (Inv. No. 5089: Karageorghis 1985, 159; Karageorghis 1985, 164), were also found in other parts of the sacred precinct. Among these is ceramic material which has been identified as furnace lining (Inv. No. 3766: Karageorghis 1985: 156). The fragments are body sherds whose interior surface is heavily slagged (Stech *et al.*, 1985, 396). They seem to have come from a single straight-sided vessel like the one from Enkomi. Similar furnace lining has been found at the primary smelting site of Politiko Phorades, currently being excavated, which dates to the 16th century BC (Kassianidou 1999; Donnelly, *et al.*, 1999). What is interesting is the fact that this was found between Floors II and III in Room 58 of Temple 5 and not in the area of the Northern Workshops. Also found in Temple 5 was a piece of slag containing tin (Zwicker 1985, 408). Tin-rich slag also occurred in Temple 2 (Zwicker 1985, 408).

Important changes in the temples, the temene and even the Western Workshops took place in the period that followed, which according to the ceramic evidence corresponds to the Late Cypriot IIIB period, i.e. the 11th century BC (Karageorghis and Demas 1985, 122). The Northern Workshops, however, remained essentially as they were

in the previous levels while the number of industrial installations seems to have been reduced (Fig. 4).

Room 12 remained in use, although most of the installations were abandoned (Karageorghis and Demas 1985, 135). The floor was blackened by fire. A series of thin superimposed soil strata full of ash, charcoal and bone shows that the floor was renewed regularly. The benches of the previous periods were covered over and a new one was built. Furnace J was no longer in operation as it was covered by this floor while Furnace A was transformed into an oval pit with an inner lining of hard-fired red clay. In the pit were found a thin layer of slag, as well as a crucible and a tuyère (Karageorghis and Demas 1985, 135). On the floor in the immediate vicinity of the furnace was found a large piece of slag measuring $0.28 \times 0.18\text{m}$.

The three rooms to the east continued to be in use and, in fact, in Room 15 there was clear evidence of metalworking. From Floor II came a piece of bellows, fragments of a crucible and slag (Karageorghis 1985, 177; Karageorghis and Demas 1985, 137). Large pieces of slag (Inv. Nos. 85, 94 and 96A: Karageorghis 1985, 174) were found in Room 14. Although slag was also found in Room 16 there was no evidence to suggest that it was produced there (Karageorghis and Demas 1985, 138). Once again scrap metal (Inv. No. 4160: Karageorghis 1985, 168; Inv. Nos. 4188 and 4181: Karageorghis 1985, 169) and refractories (Karageorghis 1985, 171–172) were found in other areas of the sacred precinct.

Floor II is the last period of occupation in which there is clear evidence of metalworking. It seems that an earthquake brought an end to the structures of this level. Although the temples and temene remained in use, the industrial areas seem to have been neglected

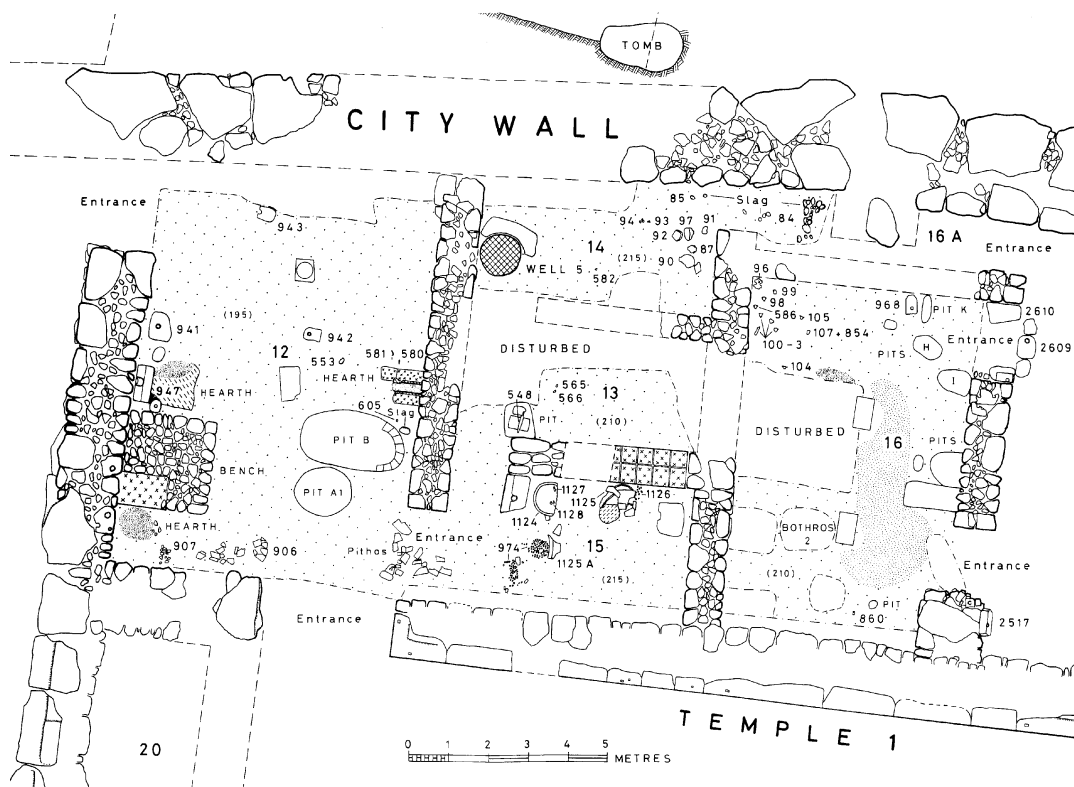


Figure 4
Kition: plan of the Northern Workshops — Floor II

while metalworking was no longer practised (Karageorghis and Demas 1985, 141).

A REVIEW OF THE EVIDENCE

These then are the excavated remains from the metallurgical workshops of Kition whose discovery is extremely important for a better understanding of Late Bronze Age technology. As is often the case, however, rather than providing a solution to all outstanding problems their discovery has, in fact, raised many more issues and queries. Some of the most crucial technological questions to be asked are the following: what were the pyrotechnological processes that were taking

place in the Northern Workshops — primary smelting, secondary smelting, refining of black copper and/or casting and recycling of bronze? Why are there so many deposits of burned bones and bone ash in the industrial quarters? Was the bone ash used in the metallurgical processes and in what way? And finally, does the presence of scrap metal imply that recycling was part of the temple's policy?

Some of these questions have already been addressed by Tylecote (1982, 1985), Zwicker (1985) and Stech *et al.* (1985). The purpose of this paper is to examine and re-evaluate the conclusions of these scholars using the published analytical results together with the

detailed excavation report. The conclusions of the present study may have to be modified in the face of new analyses, which the writer believes are essential in the understanding of such an important site as Kition.

Smelting, refining and/or casting?

The question whether primary and/or secondary smelting was taking place in the Northern Workshops may be considered first. The idea that copper was produced in these workshops stems mainly from the discovery of slag. The fact is, however, that slag is not produced only in smelting operations (Bachmann 1982, 2). Chemical and microscopic analyses can differentiate between a smelting, a refining and a melting slag.

In Room 14 were found samples of what has been called furnace conglomerate, a type of find well known from the Late Bronze Age in Cyprus. These unfortunately have not been analysed, although it is generally assumed that they were a product of a roasting operation (Stech *et al.*, 1985, 395). Samples of slag from Kition, Area II (the sacred precinct), analysed by Tylecote, have been identified as smelting slags (Tylecote 1982, 89). The problem is that he does not state where in Area II these samples came from. In the Stech *et al.* (1985) publication where they do specify the findspot of each sample, all analysed samples that they have identified as smelting slags came from secondary contexts, i.e. features outside the Northern Workshops (Stech *et al.*, 1985, 396). Thus they may have originated from other workshops, not necessarily located in the excavated area of the sacred precinct. The only analysed sample from the Northern Workshop area has been identified as a slag deriving from a refining process (Stech *et al.*, 1985, 394). Obviously one sample is not necessarily representative of the whole.

Nevertheless, even if this sample is dismissed as not being representative, there are further problems with the identification of these workshops as copper smelting workshops. Firstly, the amount of slag that has been found scattered in a number of the rooms of the Northern Workshops and some of the pits and rooms of the other buildings is relatively small. In the current excavation of a primary smelting workshop dating to the 16th century BC two tons of slag have been recovered from an area of less than 50m² (Knapp *et al.*, 1998). Stech *et al.* (1985, 397) have suggested that the Northern Workshops may have been regularly cleaned since they were in constant use. This does not seem to be the case at Enkomi where a large amount of slag was found in the copper workshops (Dikaïos 1969, 46). The amount of slag found in Kition does not support the idea of an active smelting workshop.

This statement can be further supported by the absence of smelting installations in the rooms of the Northern Workshops. The clay lining of Furnace J was not slagged, as would have been expected of a smelting furnace. Furthermore, based on what is known of Bronze Age technology, mainly through the work of the IAMS group on material from Timna, a smelting furnace operated with bellows should have an optimal diameter of around 40 cm (Bamberger and Wincierz 1990, 156). Furnace J is just too large to be a smelting furnace, as are most of the furnaces in the industrial areas of Kition.

The only feature within the Northern Workshops which could possibly have been related to a smelting installation is a small pit that was dug in the centre of what was identified as a stone bench in Floor IIIA (Karageorghis and Demas 1985, 82). This central bench rose only a few centimetres above the floor. The pit, which measured 0.50 × 0.30m and had a preserved depth of

only 5 cm, unlike any of the other excavated pits and indeed any of the other furnaces, had a fired clay lining to which 'bits of a greenish substance' were adhering (Karageorghis and Demas 1985, 82). Although slagging is not specifically mentioned, based on the above published description the so-called pit seems to be the best candidate so far for a metallurgical installation. As no remains of a clay or mudbrick superstructure were found in relation to the bench, this may in fact have been a stone platform or working surface on which a furnace was built. The pit may have been the furnace base or even the pit in which slag had been tapped from a free-standing furnace that was set on this platform.

There is, however, an additional problem and that is the fact that no fragments of furnace lining have been found in association with these installation and only a few fragments of tuyères, which may, in fact, be associated with other processes such as refining and/or melting. The only identified furnace lining came from Room 58 of Temple 5.

Thus, archaeometallurgical finds related to smelting activities have been found in the sacred precinct. This points to the presence of a smelting workshop somewhere in the vicinity, but based on the available evidence these smelting activities do not seem to have been taking place within the confines of the Northern Workshops.

The use of bone ash in the Northern Workshops

The second issue that needs to be addressed is the presence and use of bone ash, large amounts of which have been found in all of the rooms of the Northern Workshops and in some of the installations of the Western Workshops. Stech *et al.* (1985, 399) suggested that bone ash may have been

used as a flux in the smelting furnace, in order to lower the melting point of the slag, although they admit that this would, in fact, have made the slag more viscous. They suggest that this would have been an advantage as the copper would have had more time to separate. In fact, a slag of low viscosity is preferred so that the copper can run through the slag without the risk of being trapped (Bachmann 1982, 9) and, therefore, bone ash would not have been a good flux.

Furthermore, had bone ash been added as a flux in a smelting furnace, it would not have been found in such great quantities within features which have been identified as furnaces, because it would have reacted with the gangue to form a slag (Tylecote *et al.*, 1977, 307). The slag produced would be enriched by the constituents of bone ash, namely calcium and phosphorus. Thus, no ash at all is to be expected in a smelting furnace, while high levels of calcium and phosphorus would be expected in the resulting slags. The fact that the furnaces from the Northern Workshops contain ash is, therefore, another argument against their identification as smelting installations. Furthermore, chemical analysis of the slags from Kition has not detected any phosphorus (Stech *et al.*, 1985, 399). The fact that there is so much ash in the area of the Northern Workshops, often within large furnaces, must be explained in a different way.

The bones had clearly been burned at a high enough temperature to reduce them to ashes. This could have been done intentionally, either to dispose of the bones or to produce bone ash, which is useful for a variety of processes. On the other hand the bones may have been used as fuel for some processes which required high temperatures. These processes may well have been the melting and casting of copper alloys. Although in antiquity crucibles were heated

from above (Tylecote 1987, 189), their outer surface also had to be heated and, therefore, they would be set in a hearth where normally wood or charcoal would have been used as fuel. According to Tylecote (1982, 82), however, small dry bones also make an excellent fire. The bone ash, therefore, may, in fact, have been the result of such a process in which bones, instead of or with charcoal, were used as a fuel.

In an area where there are five temples, bones from sacrificed animals would have been abundant and readily available. By using them as fuel the inhabitants of Kition not only solved the problem of bringing wood into the city, presumably from some distance, but also the problem of disposing of the remains of the sacrificial victims. The ashes produced could then have been used in other processes, some of which may have been related to metalworking.

Metallurgical treatises of the 16th century, such as those of Agricola (Hoover and Hoover 1950, 230) and Biringuccio (Smith and Teach Gnudi 1990, 137) describe the use of bone ash for the production of cupellation dishes, the specialized crucibles used in the separation of silver from lead. Such cupellation dishes are also used in the refining and separation of precious from base metals. For example, in the case of a gilded bronze, the bronze could be melted with lead which would act as a collector and would remove all of the gold from the alloy (Smith and Teach Gnudi 1990, 156; Hawthorne and Smith 1979, 146). The lead would then be oxidized in a cupellation dish made of bone ash leaving behind the precious metal. There is no evidence for such processes from the workshops at Kition, but it is not unlikely that some of the temple bronzes would have been recycled and perhaps those that were gilded would have been treated in this way.

It is apparent, according to Zwicker's

analyses, that bone ash was used in the production of the crucibles. Phosphorus, at levels over 2%, was detected in the ceramic matrix of nine analysed samples of crucible fragments from Room 12 and other areas of the sacred precinct (Zwicker 1985, 415). These samples were also found to contain traces of tin bronze. Clearly they had been used in the melting and casting of bronze. Biringuccio describes the method of preparing crucibles in the following passage (Smith and Teach Gnudi 1990, 391):

It is first necessary to have the clay of a good nature, that is, resistant to the force of the fire by its own natural virtue, either when it is lean or when its viscousness is mixed with much talc, and whether it is yellow or white. This should be well freed from small stones and beaten well with an iron, and then thoroughly mixed by hand. With this should be mixed an eighth part of finely ground and sifted iron scale, and some young ram's-horn ashes. These things should be well mixed together by hand and by heating them. If this clay should not be strong enough by itself, it is mixed with another lean clay, with crushed peperino, flintstone, or some other stone that in your judgment seems to be arid and resistant.

Bone ash can also be used in the production of moulds for casting, as we are told by both Biringuccio (Smith and Teach Gnudi 1990, 229) and Cellini (Ashbee 1967, 112).

Fragments of crucibles have been found at Kition but no moulds. A possible explanation for this may be supplied by Theophilus (Hawthorne and Smith 1979, 142) and Agricola (Hoover and Hoover 1950, 230) who suggest that ground up ceramic (*chamotte*) should be added to the clay of crucibles to render it more refractory. Any used crucibles and moulds may have been

crushed and re-used as mixing material for the production of even more refractory clay. Thus not only could the metal have been recycled but also the actual reaction vessels.

When this paper was first presented to the workshop on '*Recycling, Hoarding and Trade in Bronze, 13th–11th centuries BCE*', Shlomo Eisenberg suggested another possible use of bone ash in metalworking. Bone ash ($3\text{CaO.P}_2\text{O}_5$) consists basically of calcium and phosphorus, as shown in the chemical formula (Tylecote 1982, 81). In modern metallurgy phosphorus is a well known de-oxidizer. According to Avner (1974, 672), a de-oxidizer is a substance that can be added to molten metal to remove either free or combined oxygen. In modern casting processes phosphorus is always present as a de-oxidizer and tin bronzes are generally referred to as phosphorus bronzes. The usual range of phosphorus content is between 0.001 and 0.5 percent (Avner 1974, 472–473). According to Percy (1861, 279):

By adding a little phosphorus to melted copper in a crucible the metal may be cast into a perfectly sound ingot and marked contraction occurs during solidification. Phosphorus increases the fusibility and hardness of copper and when present in a large quantity renders it brittle at the ordinary temperature. The metal appears to be perfectly homogeneous.

The casting of copper oxhide ingots would be one procedure where phosphorus would have been especially beneficial, considering the fact that almost 30 kgs of pure metal were cast in an open mould, either made of stone or, as has recently been suggested, of sand. Under these conditions the chances of introducing oxygen into the molten metal are very high and the craftsmen would have had to deal with this problem in some way. Metallographic analysis of some oxhide

ingots from the Ulu Burun shipwreck showed that the eutectic of $\text{Cu/Cu}_2\text{O}$ is absent in many of the ingots (Maddin 1989, 99). This could be indirect evidence for the use of a de-oxidizer.

The chemical analyses of bronze objects and oxhide ingots should be checked in order to ascertain whether in the Late Bronze Age phosphorus, in the form of bone ash, was added to metallic copper or tin bronze as a de-oxidizer. If bone ash was used, phosphorus should be present in the chemical composition of the artifact. Unfortunately, phosphorus is not one of the elements which would be searched for in a routine chemical analysis and, therefore, it is never listed in the analytical results. For example, tables of chemical analyses of LBA bronzes compiled by Stos-Gale and Gale (1994, 215–216) give only the percentages of the following elements: Cu, Sn, Pb, Zn, As, Ni, Fe. These are also the only elements given in Balthazar's extremely detailed book on Cypriot metallic artifacts dating to the Early and Middle Bronze Ages (Balthazar 1990, 70–78). The published analyses of copper oxhide ingots by Muhly *et al.* (1988, 286) included some of the trace elements but not phosphorus and the same is true of the preliminary analysis of some of the Ulu Burun oxhide ingots published by Maddin (1989, 100).

It would be worthwhile to re-analyse some of these objects and to include phosphorus as one of the elements to be examined. This would be particularly important in any future analytical work on copper oxhide ingots.

The bone ash from Kition seems, therefore, to have been produced while using bones as a fuel. The bones probably came from the animals which would have been sacrificed in the temple. Once produced bone ash could be used in other processes such as the production of cupels, crucibles, moulds and as a de-oxidizer of the molten metal. According to

Smith (forthcoming) in the Western Workshops of the sacred precinct, bone ash may have been the product of the use of bone for the washing and bleaching of textiles. First the bones would have been boiled to extract grease, which would have been combined with potash producing a form of 'soap', and after drying out, the bones could have been burnt to form charcoal, a substance that could have been used as a decolorizing agent.

A new interpretation of the evidence

Returning to the installations excavated in the Northern Workshops the activities may be reconstructed in the following way. As has already been pointed out, Furnace J is too large to have been a smelting furnace. It could, however, have been a furnace for heating the crucibles containing the metal to be cast or to be refined. The platform built south of Furnace J could have been the place where the person operating the bellows once stood. The moulds could have been set in one of the smaller pits that were dug near Furnace J and which were full of sandy soil. There is not much time to lose between the melting of the metal and the casting, so the hearth would be set as close as possible to the casting pit, so that the molten metal could be poured before it had time to cool down and solidify.

The well that was present in Room 12 would have provided water which was necessary both for the metalworkers' own use, as well as for the manufacture of the crucibles and the moulds. The furnace that was found in Room 16 of Floor III sounds very much like a kiln. Could this have been the kiln where the refractories were fired?

What these workshops were producing remains unknown as there are no moulds at all from Kition. This is a problem, but it may be explained by the recycling of the moulds as has been suggested for the crucibles. The

products of these workshops may have been copper ingots that were cast in sand rather than in stone moulds, but also bronze votive offerings and figurines.

Recycling

Judging from the number of pieces of bronze scrap found in the sacred precinct it seems that the workshops would also have been involved in the recycling of metal.

Indirect evidence for the practice of recycling in temples may be the virtual absence of metal objects in the sacred deposits of the later periods, which are defined by the Greek word *bothros* or the Latin word *favissa*. In Antiquity, mainly it seems after the Archaic period, when the number of votive offerings had increased to a point where there was no more space in the temple or around the altar or after the destruction of a temple, votive offerings were collected and buried in a *bothros* (Karageorghis 1982, 107). Such *bothroi* have been found in various sanctuaries in Cyprus, for example in the temple of Apollo Hylates at Kourion (Buitron 1984), at the temple of Athena and Heracles at Kakopetria (Karageorghis 1977), at the sanctuary of Heracles-Melkarth Kazaphani (Karageorghis 1978) and at the sanctuary which was found outside Salamis, near the Monastery of St Varnavas (Yon 1974). A number of such *bothroi*, dating to the later periods of occupation, have also been found in the sacred precinct of Kition (Karageorghis and Demas 1985, 245). In all these cases the *bothroi* contain large quantities of terracotta or limestone figurines and only a handful, if any, of metal objects, such as arrowheads or in the case of Kakopetria, fittings of shields (Karageorghis 1977, 196; Yon 1974, 103). Assuredly these were not the only votive offerings that had been made of metal.

Of course one may argue that one does not find metal objects in *bothroi*, but in hoards. As pointed out by Knapp *et al.* (1988, 236–7) although some of these hoards may be of a utilitarian nature, and they identify three types of utilitarian hoards: the personal hoard consisting of the immediate possessions of an individual, the merchant's hoard and the founder's hoard, there are hoards with a non-utilitarian nature. They identify different varieties of non-utilitarian hoards such as votive deposits and foundation deposits (Knapp *et al.* 1988, 237). However, these hoards do not seem to be the result of a similar activity as the one which is represented in the formation of a *bothros*. In other words these hoards do not consist of a collection of votive objects which had been given to the temple and which, at a later time when their number had increased, had been collected and buried in a pit as was the case with the terracotta and stone figurines.

This may be rather simply explained if one considers the nature of the materials involved. Metal has one advantage over ceramic and stone and this is the fact that it can be recycled. The scarcity of metal artifacts from these *bothroi* and the absence of hoards consisting entirely of objects which may be identified as votive objects may be used as an argument to support the idea that in the later periods some of the bronze votive offerings rather than being removed and deposited in a ritual deposit, may have been recycled.

By extrapolation one may assume that a similar policy existed in the Late Bronze Age. Although some scholars may object to such an extrapolation, it is not altogether unsubstantiated, as there is written evidence dating to the Late Bronze Age, namely the Jn Series of Linear B tablets from Pylos, which suggests that at least in the Mycenaean world recycling of metal in general, but also

recycling of the temple bronzes, was practised. According to Smith (1992–1993, 182–183, 194 and 198), although in most cases the listed allotments to smiths refer to fractions of whole copper ox-hide ingots, some of the metal distributed would have been in the form of scrap bronze. The suggestion that among the scrap bronze given to the smiths were also included metallic objects that once belonged to a temple or shrine is based on the text of tablet Jn 829 which refers to the collection of 'temple bronze as points for spears and javelins' (Ventris and Chadwick 1956, 357–358; Chadwick 1976, 141). Chadwick (1976, 141) suggested that this text indicates that there was a shortage of metal at the time and that the administration of the palace of Pylos, in preparation to face a time of crisis, demanded the collection of temple bronzes. According to Chadwick (1976, 142):

Thus the shrines may be presumed to have quantities of bronze objects, often worn and useless; in an emergency the authorities might well demand that these, despite their dedication, be turned in for scrap.

Muhly (1992, 18) has not only contested Chadwick's suggestion that there was a shortage of metal in Pylos but also the translation of the text. He suggests that the words *ka-ko na-wi-jo*, in fact, should be interpreted as ship copper, in other words copper ingots coming to Pylos from the sea. As Chadwick (1976, 141) pointed out, however, the districts involved are inland districts, and therefore, would not have been associated with the trading ships which brought copper to the kingdom of Pylos. Smith (1992–1993, 205–206) supports Chadwick's interpretation of temple bronze although she is not sure whether this collection of bronze was a regular activity or whether it was indeed a reaction to a time of crisis.

The same, of course, is also true for Kition.

In other words, although we may suggest that recycling of the temple bronzes was practised, there is no way of knowing whether this was done routinely or only in times of trouble. In Cyprus, a parallel for such an activity may be found in modern day churches. Candles and wax *ex votos* are kept for a certain amount of time and then the person in charge of the church collects them and returns them to the wax workshop.

The suggestion that recycling was practised in Antiquity, and specifically in the Late Bronze Age is also supported by the archaeological evidence. Recycling is commonly identified by the presence of scrap metal. The presence of scrap metal among the components of a metal hoard is commonly used to identify the presence of a smith and hoards that consist of material that once belonged to a smith. According to Knapp *et al.* (1988, 237):

Founders' hoards should be represented by materials collected together for their *value as metal*, not for the intrinsic value of the original objects. They may be characterised particularly by broken objects or scrap metal, by castings and slag, and by ingot fragments, all items lacking special significance and all being reduced to their lowest common, metal denominator.

A number of founder's hoards have been identified in Cyprus the most important of which are the Foundry Hoard from Enkomi (Catling 1964, 278–81), the Mathiati hoard and the Pyla bronze hoard (Karageorghis and Demas 1984, 63).

Scrap metal has also been found, as at Kition, during the excavations of metal-working workshops of other Late Bronze Age sites. At Enkomi for example, where the excavations of both the Department of Antiquities of Cyprus and the French mission uncovered the remains of several workshops,

over four kilos of scrap metal were found (Courtois 1982, 166).

Evidence for recycling was also found in Building IX of Kalavassos — Ayios Dhimitrios. In Room 45 were located many pieces of bronze, some of which are clearly scrap metal, along with a piece of a crucible and slag, while in the adjacent Room 44 were found many more crucible fragments and metallic lumps (South 1982, 65). According to South (1982, 65) Room 44 may have been a workshop area where bronze objects were repaired or recast, in other words recycled.

Based on all the archaeological and textual evidence from sites contemporary with Kition, it is clear that recycling was practised in the Late Bronze Age. We cannot know how widely and in what way, but there is obviously a need to take this activity into consideration, especially when trying to identify the provenance of a metallic object. A number of papers have already been published on the problems that recycling would create for provenance studies and mainly for lead isotope analysis, but it is beyond the scope of this paper to enter into this discussion (see for reference: Budd *et al.* 1995; Gale and Stos Gale 1995; Gale 1997). It is, however, the writer's belief that, contrary to the suggestion by Budd *et al.* (1995, 23) although recycling was widely practised this did not involve the oxhide ingots which have been shown to be the final products of a series of roasting, smelting and various refining processes.

CONCLUSIONS

In conclusion, based on the available evidence, smelting does not seem to have been one of the main activities in these workshops. However, the presence of smelting slags and furnace conglomerate cannot be dismissed. Various interpretations of the finds are possible. They might represent a very short period of smelting activity which was soon abandoned once people realized that the temple area was less than ideal for the smelting of roasted ore or matte. Alternatively they may be indicative of other workshops in the vicinity of the Temple, perhaps even outside the walled area of the city. Such an arrangement would have been much more appropriate than having smelters in a presumably crowded religious centre.

What the evidence does clearly indicate is that the Northern Workshops of the sacred precinct of Kition were mainly involved in copper refining and bronze casting. Recycling of bronze may also have been an integral part of these activities.

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