A Late Bronze Age hoard of bronzes rediscovered, probably from Palaepaphos in Cyprus

Vassos Karageorghis, with an appendix by Andreas Charalambous and Vasiliki Kassianidou

ABSTRACT: Two groups, each of six bronze tools, which are thought to be parts of a single Late Bronze Age hoard probably found in the area of Palaepaphos in Cyprus, were studied and their composition determined by pXRF. Three of the objects carry small cross-shaped marks. Despite their lack of archaeological context, they are considered significant finds. Seven of the objects are of a type known as 'ploughshares' but here the implied use is questioned and a possible function as mining tools is proposed.

Introduction

In December 2019 I completed the study of two registered private collections of Cypriote antiquities in Nicosia and had sent already the manuscript and illustrations to the publisher. One of the collections, the S.O.F.I.A. Foundation Collection, included six cast bronze tools in perfect condition, usually described as 'ploughshares', but perhaps better identified as mining tools. They came to me before conservation, with the soil still on their corroded surfaces. The owner of the collection Mr Renos Michaelides informed me that he had bought them from another private collector from Nicosia, Mr Takis Phylactou. In the notebook of Phylactou's collection it is mentioned that '… the bronze tools were found at Kouklia-*Palaepaphos*'. In the publication of the two private collections we concluded that it was very likely '… the six "ploughshares" were found together in a settlement, probably in a bronzesmith's workshop specializing in the production of such tools.' We compared them with other similar tools found in Cyprus and elsewhere, mainly in hoards dating to the Late Cypriote IIIA period, following their dating by Catling and Courtois (see below). It should be noted that one bronze ploughshare was found in a tomb of this Late Cypriote IIC period at Palaepaphos-*Eliomylia*. It is 117mm long and has rivet holes on either side of the socket slit (Karageorghis and Michaelides 1990, 80-81, 84, no 39). Another fairly small 'ploughshare' was found in a settlement context of the Late Cypriote III period at Erimi-*Pitharka*. For other find spots see Catling (1964, 80-82).

A few days after the material for the publication of the two private collections had been sent to the publisher, Mr Renos Michaelides brought me a box with five more bronze tools of a different type, and one 'ploughshare' (referred to here as the second lot) again in perfect condition, but treated drastically at an earlier stage by a non-professional technician, who removed their corrosion and patina altogether. According to Mr Michaelides the 'ploughshare' and tools of the second lot were found together with the six 'ploughshares' of the first lot, at Palaepaphos, but because of negligence on the part of members of his staff they were not brought to me earlier, in time to be included in the publication of the two private collections. That the two lots were found together is stylistically possible, but not absolutely certain. This is a weakness detected by Prof Vasiliki Kassianidou (2018a) in several 'hoards of bronzes' belonging to private collections. There is, however, one element, which may be of decisive importance for the problem of ascertaining the provenance of the two groups and indeed their potential manufacture by the same bronzesmith: on two of the 'ploughshares' and on the shovel (part of the second lot) there is a small sunken cross-shaped sign, of the same form and size (cf Figs 1, 6b and 8b). The one on the shovel is only faintly visible, because of the drastic treatment of its surface by the technician. Is the appearance of this sign on the three tools accidental or is it a 'signature' by their common manufacturer? One should also consider the results of the chemical analyses, which provide some indications for the use, in the majority of the artefacts, of a similar copper metal.

We decided that the tools of the second lot could not be published together with the six 'ploughshares' of the first lot, because this would mean renumbering all the entries in the catalogue, changing all cross-references in the text and redoing the layout of the book, which would raise the cost of the publication. We thus decided to publish both lots together in this article, as a hoard, in collaboration with colleagues specializing in the study of Late Cypriote bronzework, profiting also from new technologies in such research. This would do justice to the two groups, the importance of which we considered as by no means negligible.

Cypriot Bronze Age tools

The publication in 1964 by H W Catling of his doctoral thesis laid the foundations for the study of the rich production of bronzework in Cyprus during the Late Bronze Age. The new horizons in Late Cypriot archaeology opened by extensive excavations at the Late Bronze Age site of Enkomi and other sites in Cyprus, Ugarit and the Aegean, mainly after the end of the Second World War, inflamed the 'enthusiasm' of the then young scholar (Catling) to '… excessive attribution of elements in the assemblages to the Aegean' (Catling 1986, 91). He admitted that '… of the very rich series of bronzes found in Cyprus from the latter years of the 13th century BC, not particularly in sanctuary deposits, melting hoards and tombs, a significant proportion has strong Aegean elements, whether in form, style or technique. That proportion, though, no longer seems as high as I once thought, while the Near Eastern and Egyptian elements are more pervasive than I allowed' (Catling 1986, 99). For criticism of Catling's pro-Aegean bias see the publications by Desborough (1965, 233-235), Åström (1972, 560-565) and Matthäus (1982, 185-202). The above criticisms, however, do not diminish the value of Catling's 1964 work, which still remains a standard reference book for the study of Late Cypriot bronzework.

In publishing the five new bronze tools of our 'hypothetical' hoard we followed the identification and the typology of objects proposed by Catling but considered Åström's comments regarding influences. With regard to chronology, it is difficult to make any safe pronouncements without any other independent evidence since our only criteria are stylistic. We therefore propose a tentative date for this hoard at the transition from Late Cypriote IIC to Late Cypriote IIIA, roughly *c*1200BC.

Archaeologists of the older generation, including myself, when publishing hoards of bronze objects found during proper excavations or kept in modern collections, usually follow the traditional method proposed by Catling in 1964, focusing '… on establishing a secure chronology through consideration of stylistic developments or technological change, within unilineal, culture-historical perspective' (Knapp 1988, 149). A major study of Cypriote bronze hoards published by Matthäus and Schumacher-Matthäus (1986), proposed that all metal deposits (*Hortfunde*) on Bronze Age Cyprus have a cultic character, either as 'foundation deposits', 'building sacrifices' or 'votive deposits', all associated with religious practices. This proposal was very severely criticized in two articles, one by Knapp (1988) and another by Knapp *et al* (1988). In both these articles it is proposed that the hoards of bronzes which included scrap metal '… did not mark the declining period of metal production and scarcity of metal supply and that these hoards were the first manifestation of a newly created bronze industry, one that underwent a temporary setback during the LCIIC/IIIA transitional period, *c*1200BC. Hoarding activity in the Aegean and in Cyprus must be directly related not only to the interregional economic collapse, but also to the growth of defensive sites and the abandonment of other sites that indicate intra-island strife' (Knapp *et al* 1988, 258). These theoretical approaches are now followed by scholars of the younger generation (*eg* Kassianidou 2018a, 211) and no doubt will dominate future discussions, hence our rather lengthy digression on this topic. In this paper we do not intend to discuss in detail the above mentioned theoretical approaches which we consider in many ways quite sound, but we would like to add that each case of hoarding metallic objects or indeed any valuable objects requires a careful consideration of the circumstances of discovery (place, time, context, prevailing socio-political and economic conditions). In this respect we may mention as a related phenomenon the hiding in a safe place of precious objects of gold or silver before temporary abandonment of a site in the face of an imminent danger, with the hope of returning to retrieve them. We observed this phenomenon at Pyla-*Kokkinokremos*, a site which was abandoned *c*1200 BC by its inhabitants who never returned to retrieve their hidden treasures (Karageorghis 2002, 83-84, figs 162-163), and also at Vouni palace in the Cypro-Classical period (*c*380 BC), where the royal treasure was hidden under the staircase and was discovered during excavations by the Swedish Cyprus Expedition (Gjerstad *et al* 1937, 288); in modern times we have seen numerous such phenomena connected with the 1974 invasion of the Turkish Army in the now occupied part of Cyprus.

Catalogue of objects

1 Shovel: well preserved, very heavy, roughly rectangular blade with rounded corners and downwards-sloping shoulders; long tubular socket with slit, no holes for rivets; wedge-shaped swelling between the inner part of the blade and the lower part of the socket; the blade is slightly concave; small sunken cross design at the inner part of the blade, below the socket, very faintly preserved (shown with an arrow in Figure 1). The tool was made probably in a one-piece mould, with the socket rolled with a hammer. See Catling (1964, 78-79), Åström (1972, 482) and Courtois (1984, 38–39, no 323) for comparanda. Shovels of this type are identified by Catling as agricultural tools; the thickness of their blade, however, may also suit their use in mining, for shovelling heavy minerals. Catling noted that such objects were not found in the Aegean, but fragments of them were among the tools on the Cape Gelidonya shipwreck sailing from Cyprus to the Aegean. Åström (1972, 561) mentions that such shovels have parallels in the Near East. The cross on the inside of the blade is of interest, as mentioned above. An early 12th-century BC date is suggested by Catling for this type of tool.

Figure 1: The shovel, front and back. The arrow indicates the position of the sunken cross-shaped mark, cf Figure 13; length 343mm.

Figure 2: The double adze, top and side views; length 331mm.

2 Double adze: quite large, consisting of two cutting blades of equal length on either side of a round socket; the socket on the haft side is reinforced with a raised ring; sharp straight cutting edges; the cutting blades have the same width all along their length (Fig 2). The tool was made in a two-piece mould. See Catling (1964, 89-90) and Åström (1972, 480-481) for comparanda. Catling mentions that the majority of the double-adzes are small and light and that they could be more suitable for carpentry rather than for stone masonry. Our tool is the largest so far found in Cyprus. It could well have been used by stone carvers. Catling proposed an Aegean origin for the double adze, considering that no examples were known from the Near East. This type appeared in Minoan Crete, but with two strengthening rings, one on each side, during the Middle Minoan III to Late Minoan I period. According to Catling this type was adopted by the Greek mainland from Crete and from the mainland it reached Cyprus in the 12th century BC (Catling 1964, 90). Åström rejected its Aegean origin, as it is found in various forms from the Indus valley to central Europe; she proposed a Mesopotamian origin (Åström 1972, 561) while Courtois proposed a Late Cypriote II date for this tool (Courtois 1984, 39).

3-4 Double axe: there are two typologically identical specimens, one large (Fig 3) and the other small (Fig 4). They are heavy, functional tools, unlike the thin ceremonial double axes of Minoan Crete. They have both arms of equal length, with straight or slightly convex cutting edges and a round shaft-hole, like all other shalt-hole tools from Cyprus. The examples from Crete also have a round shaft-hole, but those from the rest of the Aegean have an oval shaft-hole. Surprisingly, however, examples from Megiddo and Cape Gelidonya have oval shaft-holes. Another double axe with an oval shaft-hole was found in the Jatt Hoard in Israel; it is similar, but not quite the same as the Cypriote type. For a discussion of the Jatt double axe see Artzy (2006, 62) and also for a general discussion about Cypriote hoards of metal objects and their relations with the Aegean and the Levant (Artzy 2006, 91–94). She more or less agrees with Knapp *et al*'s (1988) proposals and expresses her disagreement with Catling's 1964 ideas for a Late Cypriote IIIA date of all hoards of bronzes for which the Aegean colonists were supposed to be responsible. Unlike in Minoan Crete, where the double axe had a ceremonial function, in the rest of the Aegean and in the Levant it was simply functional, though in Cyprus the sign of the double axe also had a religious meaning, *eg* in locally-made Cypriote vase-painting (cf Karageorghis 2002, 95, fig 186). The oval shaft-hole may have developed outside Crete for greater efficiency. Catling (1964, 88-89) had no doubts about the import from the Aegean of the double axe in the 12th century BC. Buchholtz (1959, 21) suggested a Mesopotamian origin, while Åström (1972, 561) agreed with Catling about a Cretan origin. In Cyprus it continued being used as a hunting weapon down to the Cypro-Archaic I period (cf Karageorghis and Des Gagniers 1974, vase IV. 3).

Figure 3: The large double axe; length 304mm.

Figure 4: The small double axe; length 95mm.

5 Socketed chisel: it has a long narrow shaft, rectangular in section, with slightly wider cutting edge, a long tubular socket with slit but no rivet hole, narrowing towards the shaft (Fig 5). See Catling (1964, 98) who proposed a Near Eastern origin for this type of tool, and also Courtois (1984, 24-25, no 210).

Figure 5: The socketed chisel, both sides; length 218mm.

6-11 'Ploughshares': Six almost identical to one another. They have been described and commented on by Karageorghis (2020, cat no 14a-f). They consist of a socket without any rivet holes and a long blade with sides slightly widening towards the end of the blade which is straight with rounded corners (Figs 6-11). No 6 and 8 are marked with crosses, similar to that on the shovel and there is a deeply impressed small circle on the side of the socket of No 10. Together the six tools weigh 10.470kg.

12 'Ploughshare': similar to Nos 6-11; from second lot (Fig 12).

Figures 6-11: 'Ploughshares' Cat Nos 6-11. .

Figure 12: 'Ploughshare' Cat No 12; length 283mm.

Table 1: Dimensions of catalogued objects.

Cat No	Artefact	Length (mm)	Width (mm)	Weight (g)	Figure No
1	Shovel	343	max 197	1554	1, 13
2	Double adze	331	60	1865	2
3	Double axe	304	52	2797	3
4	Double axe	95	33	913.4	4
5	Socketed chisel	218	16	361.4	5
6	'Ploughshare'	297	63*	1722	6, 13
7	'Ploughshare'	291	60*	1465	7
8	'Ploughshare'	311	63*	1832	8, 13
9	'Ploughshare'	305	63*	1798	9
10	'Ploughshare'	322	63*	1818	10, 14
11	'Ploughshare'	305	60*	1835	11
12	'Ploughshare'	283	59*	1545	12

Note: * = diameter of socket

About 'ploughshares'

This type has been studied by Catling (1964, 80, type b) and Courtois (1984, 18-19, no 134). They both date it to the 12th century BC. There are several variants: (a) the blade of the share tapers to a point, (b) the sides of the blade are either parallel or widen slightly below the socket. As Catling points out, in most cases the blade ends are convex, but No 7 here has a damaged blade. There are two examples, Nos 6 and 8, which have a clearly-shaped small cross on the inside surface, near the socket (Fig 13). Is this an insignificant sign or a sign of the Cypro-Minoan script, as on a ploughshare from Enkomi in the Gunnis hoard (Catling 1964, 80, (a) 1, fig 7.5, pl. 4.a)? There is also a deeply impressed small circle on the side of the socket of No 10 (Fig 14).

Apart from the actual tools we also have bronze moulds (Catling 1964, 272–273) and bronze T-shaped unworked castings of 'ploughshares' (Catling 1964, 276–277). Two such T-shaped castings were found at Kition as part of a foundation deposit. Their Cypriot manufacture has never been doubted; their origin, however, seems to be the Near East. Their occurrence in the Aegean may be due to exports from Cyprus. Forty such tools were found in the Cape Gelidonya wreck, no doubt meant for the Aegean market from Cyprus (Catling 1964, 81).

Catling was the first to doubt their use as ploughshares. He rightly suggested that some of them, mounted on a

Figure 13: Close up views of the three sunken cross-shaped marks on Cat Nos 1, 6 and 8 (L to R); each image width c75mm.

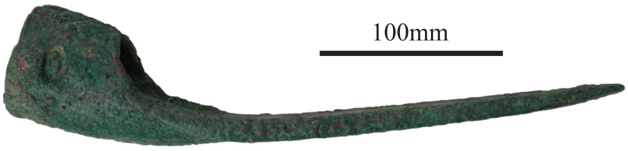

Figure 14: Cat No 10 showing the sunken circular mark on the side of the socket.

knee-joint haft, could have been used manually as mattocks (Catling 1964, 80). In fact there are some which were too small to be used otherwise (the smallest is 106mm long). We expressed our agreement with Catling when commenting on the unworked castings from Kition (Karageorghis 1985, 133–134), on a complete tool from Palaepaphos-*Eliomylia* (Karageorghis and Michaelides 1990, 84) and later on another bronze tool from Enkomi (Karageorghis 2011, 39.6, 114, 23.6). Hadjisavvas (2017, 66) identified an example from a Late Cypriote II C-III A settlement context at Alassa as a hoe.

It is unfortunate that the vast majority of these bronze tools were not found during properly conducted excavations. Even those which belonged to 'hoards', as Catling and others believed, are now proved to have initially been the property of individual collectors (Kassianidou 2018a, 223 and figs 1, 3, 6).

The 40 examples found in the Cape Gelidonya wreck suggest that such tools were exported from Cyprus to the West and there must have been workshops specializing in their production. Were they really agricultural tools or were they used by miners for the extraction of mineral from the copper mines, in which case they could also be used widely in many parts of the island? Scholars specializing in bronzework have not been able to give us a satisfactory answer ever since Catling raised the problem in 1964! In 1984 we proposed that they might be used for digging in the mines (Karageorghis 1984, 900, III. 1, 903, figs 25–26). It is interesting to note that two 'ploughshare' tools were part of the Acropolis Hoard in Athens, which dates slightly earlier than the Cypriote 'ploughshares' (Steinmann 2015, 465, 485, fig 3 bottom row).

When I was a small boy in my village, my father used to plough the fields with a wooden plough that had an iron ploughshare. The same existed not only in Cyprus, but in all neighbouring countries. Now one can see examples in ethnographical museums – of the type which was described by Hesiod in the 8th century BC. The iron ploughshare had a long socket with a slit and a short point. It was fixed at the end of the horizontal part of the plough, with the slit downwards. There were no rivets for fixing the ploughshare to the wood as its long socket held it firmly together with the wood. Figure 15 shows the iron ploughshare on a small wooden plough, probably used for ploughing in vineyards, in the ethnographical collection of Andreas Georgiades. It is 230mm long with the maximum diameter of the ovoid socket measuring 92mm.

The six bronze tools which we described above and which are usually described as 'ploughshares', could hardly be used as such. Their short socket which had a diameter of about 60mm could hardly hold on the wooden part of a plough, which should have a thickness of at least 70mm. Moreover, the ploughshare should have a short, pointed tip to function as such.

Figure 15: Wooden plough with a pointed iron ploughshare 230mm long.

In order to ascertain that a bronze tool of the type known as a 'ploughshare' could be used in mining, we sought the opinion of Dr George Constantinou, former director of the Geological Survey Department of the Republic of Cyprus, who has long been studying the geology of the island (Constantinou 1972). Though sulphidic copper mineral is hard, according to him it appears in a 'sugary' form which can be dug out even with the fingers. Therefore, our bronze tools, with a convex edge and a short wooden shaft could be perfectly used in the narrow space of a mine gallery. We admit it is strange that such tools have not yet been found in a mine. Here are Constantinou's comments:

> 'A common characteristic of the thirty Cyprus cupriferous sulphide deposits which were exploited in antiquity is the conglomeratic structure of their massive ore. It consists of a solid sulphide block embedded in a matrix of sandy, friable sulphide ore. The conglomeratic structure made mining of the ore very easy, even with primitive tools, and this was an important factor for the extensive exploitation of the deposits in the second millennium BC. The ore was unstable for underground mining and the miners had to use timber supports in most of the underground galleries and shafts.'

We agree with Andreas Charalambous and Vasiliki Kassianidou (see below) that 'the presence of multiple examples of the same type of tool, the 'ploughshare', may be interpreted as evidence for the hoard to have been a founder's hoard with finished products of a workshop specializing in the production of agricultural tools. It is natural, however, that '… this hoard does not include any other types of objects which would enable us to identify it as a founder's hoard, such as the scrap metal, raw metal (fragments of ingots), and moulds'; most of these are not objects which interest a collector or perhaps even a looter.

Appendix: pXRF chemical analysis of a Late Bronze Age hoard

Andreas Charalambous and Vasiliki Kassianidou

This appendix presents the results of the non-destructive pXRF chemical analysis of 12 copper-base artefacts from the private collection of Mr Renos Michaelides. All the artefacts are tools: seven "ploughshares" or mining tools (see discussion above by Vassos Karageorghis), two double axes, a shovel, a double adze and a socketed chisel (see Table 2). The tools are well preserved but were conserved using different techniques. Six of the 'ploughshares' were conserved by a professional conservator who kept the patina without exposing any surface areas of metal, while the rest of the tools were treated drastically by a different technician who removed their corrosion and patina altogether, exposing many areas of metal. The main aim of the present analytical study is the determination of the chemical composition of the tools, in order to examine the possibility of them being manufactured by the same bronzesmith's workshop, since it is believed that they were found together. Since they are the product of clandestine excavations there is no information regarding their archaeological context and therefore, we can only assume that they were found together as part of a hoard.

Method of analysis

Given that these copper-based cast artefacts were conserved using different procedures, the pXRF surface chemical analysis could not provide comparable analytical results. In order to provide more secure results for the entire group of the objects, the six "ploughshares" without any exposed metallic surface were treated by a professional conservator who removed a small area (approximately 15x10mm) of the patina and the surface encrustation layers (Fig 16), exposing the original surface of the metal. The chemical analysis was conducted only on the exposed, original metallic surface of the objects.

The handheld X-Ray Fluorescence spectrometer (Innov-X Delta, now Olympus) used in the study is equipped with a 4W, 50kV tantalum anode X-ray tube and a high-performance silicon drift detector (SDD) with a resolution of 155eV (Mo-Kα). The diameter of the collimated X-ray beam was 3mm and the measurement time for each spot analysis was 70 seconds. The analytical mode of the instrument employed for the analyses was 'Alloy Plus'. For this mode, Beam 1 (40kV) analyses the elements Ti, V, Cr, Mn, Fe, Co, Ni,

Figure 16: Corrosion layers were removed to exposure of the original metallic surface of a 'ploughshare'; cleaned area 10x15mm.

Cu, Zn, As, Hf, Ta, W, Re, Pt, Au, Pb, Bi, Zr, Nb, Mo, Pd, Ag, Sn and Sb, whereas Beam 2 (10 kV) was used for the determination of Mg, Al, Si, P and S. Beam 2 was principally used for the determination of sulphur (S), an element that was expected to be present in the analysed alloys, since Cypriot copper ores are mainly sulphides (Constantinou 1982, 15; 2012, 5). The detection limits of this instrument for elements usually present in copper-based artefacts are 0.1wt% for Sn, Pb, Fe, Ni, Sb and 0.2wt% for As, Zn and S. Certified reference material (CRM) BCR-691 (set of five copper alloys, European Commission-Joint Research Centre, Institute for Reference Materials and Measurements, Belgium) was used for testing the accuracy and the consistency of the measurements of the applied analytical mode.

The reported value for the chemical composition of each analysed object is the mean value of at least three measurements (for the six 'ploughshares' with the fresh exposed metallic surface), while in the case of the second group with the totally removed patina where more extensive metallic surfaces were exposed, more than five measurements were taken.

Results and discussion

The results of the chemical analysis of the studied artefacts are presented in Table 2, while Figure 17 illustrates the tin (Sn) content of the artefacts. The 12 artefacts have a tin concentration ranging between 3.8 and 16.6wt% and can therefore be classified as bronzes. With the exceptions of 'ploughshare' No 9 that has the lowest tin content (3.8wt%) and the double adze and socketed chisel that have the highest content of tin (16.4 and 16.6wt% respectively), the rest of the tools have tin contents in the range 6.5-11.3wt%. Copper alloy with a

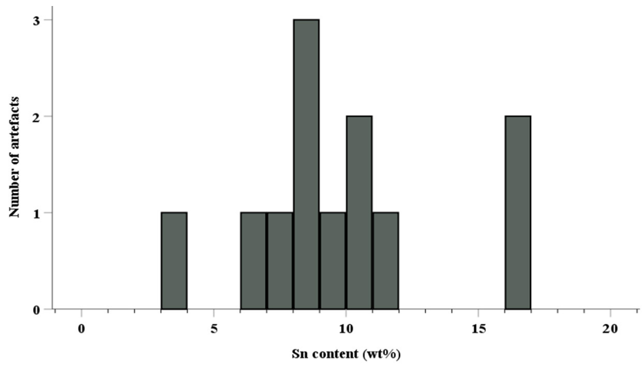

Figure 17: Histogram showing the tin content of the analysed copper-base artefacts.

tin content between 5 and 12wt%, considered a typical tin-bronze, has excellent casting qualities and hardens considerably when hammered (Lechtman 1996; Wang and Ottaway 2004). The optimal tin concentration that balances hardness against brittleness is considered to be about 10wt% (Catling and Jones 1977, 65).

According to Wang and Ottaway (2004), a tin concentration of 17wt% is the upper limit for successful manufacturing of bronze artefacts. Of much interest are the two high-tin tools, the double adze and the socketed chisel where the tin concentration is just below this limit, indicating either the random use of that quantity of tin or, most probably, a very good knowledge of alloying practices from the metalsmith/s who had manufactured these tools.

Lead (Pb) was detected in all artefacts but in most of the cases at trace levels. Only in four objects was the detected concentration higher than 0.1wt%. These objects are the double axe, the socketed chisel and two

Table 2: The chemical composition of the copper alloy tools (wt% ± std; analysis by pXRF).

Cat No	Artefact	Cu	Sn	Pb	Fe	Ni
1	Shovel	91.0 ± 0.5	8.7 ± 0.3	trace (bdl)	0.3 ± 0.03	trace (bdl)
2	Double adze	83.3 ± 0.7	16.4 ± 0.5	trace (bdl)	0.2 ± 0.02	trace (bdl)
3	Double axe	88.2 ± 0.6	11.3 ± 0.4	trace (bdl)	0.4 ± 0.03	trace (bdl)
4	Double axe	88.0 ± 0.6	10.9 ± 0.4	0.6 ± 0.05	0.4 ± 0.04	trace (bdl)
5	Socketed chisel	82.8 ± 0.6	16.6 ± 0.4	0.1 ± 0.01	0.4 ± 0.04	trace (bdl)
6	'Ploughshare'	89.5 ± 0.5	9.8 ± 0.3	trace (bdl)	0.5 ± 0.04	trace (bdl)
7	'Ploughshare'	90.8 ± 0.5	8.9 ± 0.3	trace (bdl)	0.2 ± 0.02	trace (bdl)
8	'Ploughshare'	93.0 ± 0.4	6.5 ± 0.3	0.2 ± 0.02	0.25 ± 0.02	trace (bdl)
9	'Ploughshare'	95.7 ± 0.4	3.8 ± 0.2	trace (bdl)	0.4 ± 0.03	trace (bdl)
10	'Ploughshare'	90.5 ± 0.5	8.6 ± 0.3	trace (bdl)	0.75 ± 0.05	trace (bdl)
11	'Ploughshare'	91.8 ± 0.5	7.6 ± 0.3	trace (bdl)	0.5 ± 0.05	trace (bdl)
12	'Ploughshare'	88.3 ± 0.7	10.0 ± 0.4	1.3 ± 0.1	0.35 ± 0.02	trace (bdl)

Notes: bdl = below detection limit. Arsenic (As), sulphur (S), zinc (Zn) and antimony (Sb) were not detected.

'ploughshares' (Table 2). The maximum concentration, 1.3wt%, was detected in 'ploughshare' No 12, the only one that had its corrosion and patina layers totally removed. Lead was commonly added to bronze in antiquity in order to improve the fluidity and castability of the molten alloy (Klein and Hauptmann 1999, 1080), but these improvements were achieved using higher concentrations of lead (2-3wt%) (Philip 1991, 99; Giumlia-Mair 1992, 109) than the concentrations detected in the analysed artefacts. As lead, like tin, is not present in Cypriot copper ores (Constantinou 1982, 15), or occurs in concentrations well below 0.5wt%, and the tin ores exploited in the Bronze Age contain only a few parts per million of lead (Stos-Gale 2016, 384), the occurrence of this element in the four objects (0.1-1.3wt% Pb) can be possibly explained as the result of melting together copper with scrap metal which contained much higher concentrations of lead (Muhly 1985, 80).

Iron (Fe) was detected in all artefacts, in concentrations from 0.2 to 0.75wt% (Table 2). The presence of iron can be interpreted either as a result of the smelting of chalcopyrite (Tylecote 1982, 81; Constantinou 1982, 15) or from the intentional or accidental use of iron minerals as a fluxing agent during smelting (Balthazar 1990, 75; Craddock and Meeks 1987, 191-192; Craddock 2001, 154; Ingo *et al* 2006, 516-517; Ashkenazi *et al* 2012, 532). Other secondary elements, such as arsenic (As), zinc (Zn), antimony (Sb) and sulphur (S), commonly present in Bronze Age copper-base artefacts (Balthazar 1990, 76-78; Charalambous *et al* 2014, 213; Giumlia-Mair 1992, 113; Hauptmann 2007, 202-204; Swiny 1982, 70-73; Van Brempt and Kassianidou 2017, 483), were not detected in the analysed artefacts, while nickel (Ni), another element commonly found in copper-base artefacts (Pernicka *et al* 1990, 273; Swiny 1982, 70), was non-securely detected (due to the detection limits of the technique used) in very small concentrations (trace levels).

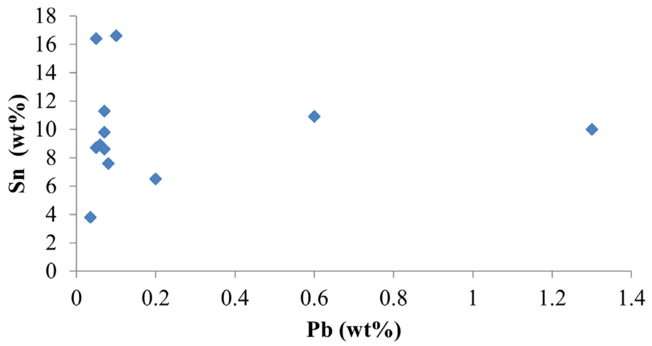

Figure 18: Plot of tin versus lead values in the assemblage (analyses by pXRF).

Figure 18 presents the correlation between the tin (Sn) and lead (Pb) values in the analysed assemblage. The relatively low concentration of Pb, below 0.2wt% in the majority of the tools, may provide some indication of the possible use of a specific, lead-free, copper metal for the manufacture of the bronze alloys. The low concentration of lead also indicates that the selected areas of analysis were relatively free of corrosion products and no enrichment of lead was observed or detected on the original metal that could have affected the data quality, at both the qualitative level of alloy identification and specific numerical values (Martinón-Torres *et al* 2014, 545, 547).

Conclusions

The chemical analysis of this set of copper-base artefacts from a private collection has come across some difficulties. The exposure of surface metallic areas makes the chemical analysis easier and can provide more reliable analytical results, but in this case the fact that the tools were treated using different conservation techniques made the analysis and the comparison of the results more complicated. Furthermore, the lack of any information regarding the discovery of the studied tools and their archaeological context makes it very difficult to attempt to identify their possible manufacture from the same bronzesmith's workshop. The presence of multiple examples of the same type of tool, the 'ploughshare' may be interpreted as evidence for the hoard to have been a founder's hoard with finished products of a workshop specializing in the production of agricultural tools. But the hoard does not include any of the other types of objects which would enable us to identify it as a founder's hoard such as scrap metal, raw metal (fragments of ingots), and moulds (Knapp *et al* 1988, 238). Such hoards are well known from Cyprus, the best examples being the Mathiatis hoard (Catling 1964, Kassianidou 2018a; 2018b), the Enkomi Foundry hoard (Catling 1964, 278-281) and the Pyla Founder's hoard (Karageorghis and Demas 1984, 63). The results of the chemical analyses provide some indications for the use, in the majority of the artefacts, of a similar copper metal, relatively pure and probably refined, with very low concentrations of lead and iron, traces of nickel and no detectable arsenic, sulphur and zinc, before the addition of tin and the creation of the bronze alloy. Moreover, the higher concentration of lead in two artefacts (0.6 and 1.3 wt% Pb, respectively) provides indications for the possible use of recycled metal for their manufacture, since the detected lead concentrations are very low and their addition would have not improved the properties of the bronze alloy. But the ploughshares are not identical and neither is their chemical composition which shows that they were not produced at the same time by the same batch of metal.

This is a fine set of tools that are well made with the best possible alloy. It is really unfortunate that all information regarding their archaeological context is lost as they would have made a significant contribution to our understanding of Cypriot metalwork and society.

Acknowledgements

I am very grateful to George Constantinou for his contribution, and to Andreas Charalambous and Vasiliki Kassianidou who undertook the pXRF analyses of the bronzes. Figures 1-14 were photographed by Angelina Demosthenous and Figure 15 by Andreas Georgiades.

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