SOTIRA *KAMINOUDHIA*

AN EARLY BRONZE AGE SITE IN CYPRUS

Edited by

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APPENDIX 8.1

ARCHEOMETALLURGICAL STUDIES

by Claudio Giardino, Giovanni E. Gigante and Stefano Ridolfi

INTRODUCTION

Twenty seven metal items from Sotira *Kaminoudhia* were analyzed by Energy Dispersive X-Ray Fluorescence (EDXRF). One of the main advantages of this technique is that it is non-destructive and thus preserves the integrity of the artifacts. A portable EDXRF spectrometer was used to obtain in situ measurements on the objects, which are stored in the Cyprus Museum, Nicosia.

Because EDXRF only analyzes the surface of a metal object, in the case of copper-based artifacts it is necessary to remove a few square millimeters of patina from around the target area. The results in Table 8.1.1 have a precision of 10% for concentrations below 1%; 4% for concentrations between 1% and 4%; 2% for concentrations between 4% and 10%; less than 1% for concentrations higher than 10%. An element is quoted as tr (trace) when it is detected, but not quantified.

METHODOLOGY

EDXRF is a non-destructive multi-elemental analytical technique which consists of irradiating a sample with low energy X-rays and detecting the resulting X-ray fluorescence. The energies of the X-rays emitted are characteristic of the elements present in the sample (as "finger prints") and their intensities are proportional to the concentrations of the elements.

The depth to which the X-rays penetrate the sample varies from a few to several hundred microns, depending on the matrix studied and the element analyzed. This characteristic feature of EDXRF analysis has both advantages and disadvantages. In particular, it is necessary to evaluate whether a surface measurement obtained by EDXRF, as compared with the results from core boring, may be viewed as representative of the overall composition of the material. With reference to this issue it is worth noting the results of an experiment carried out by V.F. Hanson (Herglotz and Birks 1978) in which a non-arsenical bronze alloy was cast and then cut in very thin layers (0.15 mm). The analysis of each layer demonstrated that at different depths the concentrations of the various elements do not undergo important variations and that the composition remains constant throughout.

With optical positioning instruments and a microscope the target area can be accurately identified (Giardino et al. 1996:327). The possibility of analyzing the surface of the artifact in several places offers the ability to characterize the artifact through variations of its essential parameters linked to its composition. Figure 8.1.1 shows the results of a measurement performed with EDXRF on an alloy.

In addition to the non-destructive nature of analyses performed with EDXRF, the equipment is also easily transportable so that the analyses may be undertaken in situ. Carrying the instrument to the sample and not vice versa (if this second solution were possible) overcomes security and bureaucratic issues. The mobility of the analytical equipment (due to a non cryogenic detector, a miniaturised X-ray tube and a laptop computer) even allows us to go beyond the concept of analysis in situ. Such an instrument could be made available to an excavation project, thereby assisting the research of archaeologists and archaeometallurgists in the field.

MEASUREMENT SPECIFICS

The diagram of the measurement system is shown in fig. 8.1.2.
The technical characteristics of the tube used are:

•Tungsten anode
•Focus 0.6 mm
•Inherent filtering 3 mm Al
•Anode HV max 50kV
•Anode current max 1 mA
•Air cooled
•Dimensions 163(W) x 193(D) x 180(H) mm
•Weight 7 kg
•Laser pointer

The tube operates with a voltage of 40 kV and current of 0.35 mA. To maintain the stability of the tube when the environmental temperature is high it, along with the detector and computer, was cooled with portable fans. The whole system tended to rapidly overheat in the high summer temperatures in Cyprus.

The characteristics of the detector are as follow:
•Si-PIN of AMPTEK with a 300 micrometers Si-diod cooled with a Peltier cell.
•Resolution 250 eV at 5.9 keV.

The pointing system uses a laser diode, which along with the collimating system of the X-ray beam permits the study of surfaces 5 mm square.

The uncertainties shown on Table 8.1.1 have been calculated with error propagation on the net counts and on the estimated background (Poisson's statistic) as well as by a Monte Carlo method inside the iterative cycle, which is at the basis of the solution of a set of integral equations with common variables.

For silver and zinc the minimum concentrations detectable are 0.8% and 1% respectively. No sample reached these limits of detection.

The strong self-absorption of the radiation emitted in the sample is an intrinsic limit of the method; it produces non-linearity in the response of the measurement system. To avoid this, a physical model of the emission process of characteristic X-rays must be used.

With this technique the non-linear response of the system may be corrected. The "fundamental parameters" model was used, in which some parameters may be fixed using standard samples.

It is opportune to stress that in the method employed here the concentration of the matrix element (copper in this case) is calculated by difference. The presence of any elements detected but not quantified does not affect this calculation. In other words, copper is not measured directly, the sum of the elements concentration is normalized to 100% with the variation of the copper.

DISCUSSION

All the objects from Sotira *Kaminoudhia* were made of copper alloys, with the exception of two earrings made in gold. This same technique was used to analyze metallic traces on a crucible fragment found on the surface of the EC/MC settlement of *Pharkonia* in the Paramali Valley (Swiny 1981:68). The use of X-ray fluorescence, being non-destructive, permitted multiple measurements to be taken from several artifacts (fig. 8.1.5) in order to highlight any differences in the composition of the alloy connected to segregation phenomena, an aspect often mentioned in studies on arsenical alloys.

In this connection, the results from M12, the dagger-ingot (or billet), are significant because the measurements taken on the lower side (A), on the tang (C) and near the tip of the blade (B), gave practically identical values (As 3.2%, As 3.5% and As 3.8%). This is an indication that the metallurgist had good control of the composition of the arsenical alloy. Furthermore, the piece has a relatively high weight (114 g)—therefore a high metal mass—and even the thickness (1.7 cm) and length (16 cm) are comparatively substantial.

Among artifacts made from copper alloys, three groups stand out: 1) those made of nearly pure copper in which other metals are present only as traces, certainly unintentional; 2) those made with arsenical copper; 3) those made of tin bronze.

COPPER-BASED ARTIFACTS

Eight of the metal objects from *Kaminoudhia* (M5, 8, 11, 18, 27A, 27B, 28, 29) are copper, with only small amounts of other elements (see Table 8.1.1). It could be argued they were made of native copper, which does exist in Cyprus, but it is rare. Native copper is extremely pure, impurities occurring only in the parts per million level (Gale 1991:50) which is beyond the detection limits of X-ray fluorescence. In any case most copper-based artifacts from *Kaminoudhia* contain small percentages of arsenic or iron much higher than those recorded in native copper. These data suggest that the objects analyzed were not made from Cypriot native copper and were more likely to have been forged from smelted copper ore.

ARSENICAL-COPPER ALLOYS

Arsenical alloys are the first true form of copper alloying, extensively widespread in the Near East and in Europe. The addition of arsenic to the alloy lowers the melting point of copper; it also acts as a deoxidant and improves both the castability and the mechanical properties of the metal. This considerably increases the ultimate strength of copper and makes it easier to work, whether cold or hot, and finally, it makes it less brittle. Cold hammering considerably hardens Cu-As alloys by comparison with pure copper, and imparts properties quite similar to tin bronzes (Charles 1967:21–24; Tylecote 1976:7–8; Northover 1989:111–15; Giardino 1998:182–83). Arsenic also modifies the color of copper, making it lighter; in sufficiently high concentrations it bestows a silver color to the surface (Eaton and McKerrell 1976:175–76) and tends to concentrate on the surface of objects (surface enrichment). Experimental studies have shown how enrichment can involve surface layers of up to 0.5 mm thickness; this surface concentration occurs during casting in the early stages of solidification (cf. McKerrell and Tylecote 1972; Mohen 1990:99–101). This behavior of arsenic must be kept in mind when comparing the quantitative data obtained by EDXRF with that taken from other types of analysis, even if patina removal before measurement is considered as a corrective precaution.

One of the main issues connected with the study of prehistoric artifacts containing arsenic is to determine whether the alloy was voluntary or the result of the chance use of copper ores rich in arsenic.

A point of controversy is the determination of the minimum value of intentionally added arsenic in a Cu-As alloy (cf. Craddock 1995:287–89). Branigan suggests that in the Early and Middle Bronze Age Aegean the presence of more than 1–2% of arsenic in an artifact is indicative of a deliberately produced alloy (Branigan 1974:71–73); Craddock (1986:153–54) suggests a deliberate alloying level of about 1% of arsenic in the Cypriot Bronze Age. With specific reference to Cyprus, some authors have theorized that the arsenic came from the direct smelting of the arsenical copper-ore (de Jesus et al. 1982:27; cf. also Muhly 1985:278–79); yet according to others it is connected with deliberate alloying with arsenic minerals such as realgar (As4S4) or orpiment (As2S3) (Craddock 1986:154).

The amount of arsenic in Cypriot copper sulfide ores is generally very low. At around 0.02%, it is insufficient to change the mechanical properties of smelted artifacts. The only known areas where the ore contains sufficient values of arsenic (up to 7.6%) are at Laxia tou Mavrou near Dhierona and around Pevkos in the Limassol Forest. There the sulphide and arsenide mineralizations contain arsenic associated with other metals such as iron, nickel and copper (Swiny 1982:71; Thalhammer et al. 1986). Experiments have shown that copper arsenic alloys could have been produced using the arsenical ore available in Cyprus, with an addition of CaO flux. Arsenic could be transferred from the ore to the liquid copper when operating in a reducing atmosphere under a layer of charcoal at 1250°C (Zwicker 1982:64–67).

The data from the analysis has been used to produce a chart (fig. 8.1.3) showing the content of arsenic in the finds from *Kaminoudhia* which have been arranged in categories. The first one, which is quite large, consists of pieces with contents of As less than 1%. The second category, separated from the first by a caesura, exhibits values of between 1.7% and 4%. The third category consists of a single piece with 7% of As. The chart emphasizes how the first caesura actually coincides with the unintentional alloys, while the other samples exhibit a deliberate addition of arsenic.

At least eight of the *Kaminoudhia* artifacts (M9, 10, 12, 16, 17, 20, 25, 30) analyzed have sufficient arsenic to make them deliberate alloys (2.5–7%). In these pieces other elements are normally absent (such as antimony, bismuth or nickel), elements which are generally present in arsenic-rich ore (cf. Craddock 1995:287). The highest values of arsenic have been found in tools used for cutting, carving or sewing (axe [M19+26], awls [M10, 25], needle [M30], chisels [M9, 17]) and in ornamental objects (earrings M16, 20). For the ornaments the silvery effect was clearly sought after by the ancient metallurgist. It should be pointed out that the piece with the highest content of arsenic (7%) is M16, an earring.

Mention should be made that the analysis confirmed that fragments M26 and M19 belong to the same object, a flat axe broken in antiquity. Both pieces show a similar chemical composition. While this axe contained substantial arsenic (1.7%), the amount was below the 2.5% considered to be the minimum threshold to indicate an intentional alloy.

M24 was only qualitatively analyzed; it revealed the presence of copper and arsenic.

TIN-COPPER ALLOYS

The presence of tin in some of the samples examined has aroused considerable interest. This element has been found in four earrings: M13, M14, M21 and M22, all of which were excavated in Tomb 6, which dates to the Philia Phase. The amount of tin is so high (between 5% and 13%) that it cannot be regarded as an accidental alloy.

The presence of tin bronzes at *Kaminoudhia* is significant because these objects provide the first evidence for tin-copper alloys in Cyprus during the Philia Phase. These results strengthen the connection between the Philia Phase and the appearance of technological, economical and social developments and innovations (Webb and Frankel 1999:4).

In the Aegean, tin bronzes appear in Crete and in the Cyclades in the Early Bronze 2 (Early Minoan II and Early Cycladic II), in the second half of the third millennium B.C.E. (Branigan 1974:106–9). Yet in Anatolia the bronze alloy appears much earlier, at the end of the fourth millennium B.C.E., in the southeast at Tell Judeideh in the Amuq.[24] A concentration of bronzes occurs in the Troad during the Early Bronze Age, at Troy and Thermi (de Jesus 1980:150). The earliest, sporadic evidence from Troy and Thermi is dated to the late fourth millennium B.C.E.,[25] but in the Troad tin bronze becomes more common later, in the first half of the third millennium.[26]

On the basis of the few analyses previously undertaken on Philia Phase metal objects, it appeared that most consisted of unalloyed copper and arsenic-copper alloys (Balthazar 1990:97–106). The Sotira earrings now prove that tin bronze was also in use, although it was apparently reserved for prestige objects. Chronological data seem to emphasize the importance of Cyprus in transmitting this new technology by sea from the Anatolian coast across to the Aegean.

The *Kaminoudhia* tin bronzes all belong to the same type of spiral earring with a narrow circular loop broadening to an expanded end, consisting of a strip of metal with one end pointed and the other flattened, a type of artifact peculiar to the Philia Phase (Swiny 1997: fig. 2a:9; Webb and Frankel 1999:31). It is significant that the use of bronze was reserved for delicate ornaments, where the mechanical properties of the alloy found no use. As in the case of similar samples in arsenical copper, the artisan's aim was to make jewellery with a particular chromatic effect, in this case a brilliant tone of yellow similar to gold. Since a pair of gold earrings (M6 and M7) were found on the site, this metal was well known and appreciated by the *Kaminoudhia* community.

Unfortunately all the *Kaminoudhia* bronze artifacts were extremely corroded, so much so that no trace of non-mineralized metal was preserved. The quantitative result of the analysis is therefore purely indicative, since it concerns values measured on patinas, even though the more superficial alteration products had been previously removed. In order to check whether and to what degree the percentage of tin was linked to the core of the artifact, a microstratigraphic analysis was undertaken on the completely mineralized earring M13 by progressively removing the layers of alteration from an area about 5 mm in diameter. At the point examined, the earring had a thickness of little more than 1 mm.

First the outer layer was analyzed, then the deeper ones, proceeding through four layers of patina of various thickness, characterized by different colors, from green to red-brown. Pure metal was never reached, having been completely destroyed during the corrosion process. The percentage of tin remained constant from the surface to the innermost layer, thus proving that the high percentages of tin registered were actually linked to the composition of the object and were not the result of post-depositional surface enrichment.

No known tin deposits exist on Cyprus, nor is any tin present in Cypriot copper ore (Muhly 1985:277), so the tin—or bronze—used for making earrings must have been imported. As previously mentioned, the earrings are of a typical Cypriot type, therefore must have been made on the island. It is impossible to establish how this tin reached Cyprus, whether as a stanniferous mineral to be alloyed with copper or as bronze in the form of ingots or scrap metal that was then remelted as required.

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[24] Tell Judeideh, level G: a pin (7.79% Sn), an awl (10% Sn) and slag (5% Sn) (Yener et al. 1996:379). The presence of three bronze artifacts from the late Chalcolithic period at Mersin is doubtful; they may be incorrectly attributed to this stratum (see Muhly 1976:89; de Jesus 1980:132–33).

[25] At Troy I a bangle appears with 10% Sn; at Thermi I a pin with 13.1% Sn (Branigan 1974:147).

[26] A dagger from Troy II has 10.62% Sn. Seven bronzes from Troy II g (6 chisels and 1 flat axe) have tin levels of between 2.89% and 8.49% (Branigan 1974:147). On the chronology of the first tin alloys in the Near East, cf. also Pernicka 1990:52.

Tin is certainly one of the less widespread metals on the crust of the earth and there are no geologically verified deposits in the eastern Mediterranean area (Maddin et al. 1977:35). Aside from the deposits in central and western Europe (British Isles, France, Germany, Bohemia, Italy and the Iberian Peninsula), deposits of cassiterite (SnO_2) have been reported in Egypt, in the Eastern Desert, even though ancient exploitation of them is quite unlikely (Wertime 1978:5; Muhly 1978:45–46; Penhallurick 1986:7–13). In the Taurus region, in central Anatolia, and in Kestel and Göltepe, tin deposits have preserved traces of worked outcrops (Earl and Özbal 1996). Other deposits are in Iran, near Tabriz and in the region of Lake Sistan, as well as in central-south and eastern Afghanistan (Muhly 1973:260–61; Cleuziou and Bertoud 1982:14–20; Pigott 1986:21–23).

Three of the *Kaminoudhia* pieces fail to exhibit the presence of elements other than tin; in one of the pieces, earring M21, 10.2% tin is associated with 1.7% arsenic. Even though the measurement was taken on the patina since the piece was deeply corroded, the substantial presence of arsenic suggests that the tin may have come from melting bronze with arsenical copper scrap metal, a practice that some scholars suggest was in use in the MC period (Balthazar 1990:73).

Earring M31, only qualitatively analyzed, revealed the presence of copper and tin.

SECONDARY ELEMENTS

Iron is a measurable element in nearly all the samples although in variable proportions, sometimes reaching around 2%. On average, however, iron ranged from around 0.5% to 0.6%. It is found as an impurity in unalloyed copper and in the arsenical and tin bronzes. In this respect the *Kaminoudhia* metals do not differ substantially from other previously analyzed Philia Phase and EC objects, for which a variable iron content was observed within a range of between 0.1% and 0.95% (Balthazar 1990:105). The iron content provides information on the smelting process and it is generally connected with the use of iron oxides as fluxes to remove the silica gangue from copper ore. At about 1200°C, iron and silica react to form liquid iron silicate slag. On Cyprus the most common copper mineral is chalcopyrite (Tylecote 1982:81; Constantinou 1982:13–17; Rapp 1982:35) and the preliminary roasting of sulphide ore in order to convert it to an oxide, in which the elimination of iron is difficult, could also explain the presence of iron (Tylecote 1982:97). In the reducing atmosphere of the furnace some iron from the ore and the flux is picked up by the molten copper to form copper-iron alloys (Craddock and Meeks 1987:191–92; Craddock 1995:137–39).

Data regarding the presence of relatively high percentages of iron in Philia Phase and EC artifacts could provide information on the choice of (sulphide) ores and slagging techniques adopted for copper production in Cyprus at this early period. The most recent research tends to move sulphide metallurgy back in time, which was previously thought to begin with the Late Bronze Age (Rapp 1982:35). Archaeometallurgical investigations carried out on the slag from the Pyrgos *Mavroraki* site demonstrates that the use of sulphides for the production of copper dates back at least to the Middle Bronze Age (Giardino 2000). In some areas of prehistoric Europe there is proof of sulphide treatment from cultures of the Early Bronze Age. This is the case of the eastern Alps area, a region rich in copper ore deposits, mainly of chalcopyrite as in Cyprus (Fasani 1988:172–79).

In only one sample, the chisel M17, were nickel and antimony found, both of them in high concentrations, around 2% and 1% respectively. These values were confirmed by repeating the measurement several times, even in the presence of the patina. These percentages make the piece under examination—made of an alloy low in arsenic—unique in the group of *Kaminoudhia* metals. Although M17 is typologically similar to other chisels of EC date (Stewart 1962: fig. 100:25) and most likely originated from the settlement, it was unstratified, having been found above Units 6, 18 and 33. This might explain why the mineral from which the copper was smelted differed in origin from that of all other pieces at the site. Nickel can occur in copper minerals in quantities much greater than 1% and its presence in finished objects may therefore be considered accidental (Branigan 1974:71).

Nickel was usually absent from the EC and MC analyses undertaken to date, although a few remarkable exceptions do show fairly high values.[27]

EVIDENCE FOR METALLURGICAL ACTIVITY IN THE EPISKOPI REGION

The 1997 Sotira Archaeological Project Survey discovered a crucible fragment on the surface of the EC/MC settlement of Paramali *Pharkonia* (Swiny 1981:68; Swiny and Mavromatis 2000:435). The original crucible had been cup-shaped and about 10 cm in diameter. The X-ray fluorescence analysis was undertaken on several points of the inner surface, three of them localized on a lump of slag material adhering to the wall of the crucible.

The results of the investigation clearly show the presence of copper with a high iron content. The presence of arsenic was not significant (0.3 %), so there is no evidence that arsenical copper had been melted in the crucible. The crucible had apparently been used to produce artifacts of almost pure copper with a small unintentional amount of arsenic. The analysis supports the attribution of the fragment to the same chronological and cultural environment as the other finds, bearing in mind the characteristic composition of most metal artifacts from *Kaminoudhia* (fig. 8.1.4).

Although no evidence for metallurgical activity has so far been found at *Kaminoudhia*, the presence of crucibles at Paramali *Pharkonia* and Episkopi *Phaneromeni* (Swiny 1986:67, 87) argues in favor of at least some metal work being carried out at the site. In view of this fact, it is worth mentioning the issues concerning the identification of the dagger-ingot M12. It appears to be a casting produced inside a one-piece mold. The upper surface clearly shows blisters and other casting irregularities, while the lateral and lower sides are nearly smooth.

The considerable thickness of both the blade and the tang (7–12 mm) argues against its interpretation as an unforged dagger preform. Daggers of this period are usually between 2 and 2.5 mm thick, so an inordinate amount of metal would have had to have been removed from the preform in order to produce a dagger of typical Philia or EC proportions. In view of the above we suggest that M12 is an arsenical copper ingot (3.5% of As) weighing 114 g.

Ingots of various metals, with tapered shapes and of sizes similar to the Cypriot piece, are found in the Aegean area in middle third millennium B.C.E. contexts.[28] Ingots shaped as weapons, tools or ornaments are fairly frequent in Aegean prehistory and on the European continent in this early period.[29]

GOLD

The analyses performed on the two gold earrings (M6 and M7, described as "electrum" in Ch. 8) from Tomb 6 at *Kaminoudhia* showed that they were made from an alloy of gold, silver (15–20%) and copper (1–3%). In this case it is not easy to establish if the alloying was deliberate or not: native gold can contain quite high values of silver, much higher than those found in the two earrings (Giardino

[27] For example the knife CMRR 18/3 from a tomb at Ephtagonia *Pervolia* had 1% Ni (Swiny 1986:95); the nail M17 from Episkopi *Phaneromeni* 0.62% Ni (Craddock 1986:156); the pin 16 from Tomb 91 at Bellapais *Vounous*, 1% Ni (Desch 1950:371).

[28] Cf. Poliochni, copper alloy, EB 2; Troy II g, silver; Mochlos, copper alloy, EM-MM (Branigan 1974:198).

[29] For example there are two ingots from Mochlos which again show the type of coeval triangular daggers (Branigan 1974: pl. 25:3297A and 3298).

1998:151). Even copper may be combined with gold, though in much lesser amounts. Percentages of Cu above 2% are in fact considered a deliberate addition (cf. Hartmann 1970:9; Stos-Ferner and Gale 1979:306; Pingel 1995:389). It is not possible to determine if the two pieces from *Kaminoudhia* suggest the deliberate addition of copper, perhaps to counterbalance the paler hue imparted to the gold by the silver, because of the relatively wide range in the quantitative evaluation of this element. The sheet of gold from Tomb 164B at Bellapais *Vounous* was a gold alloy with silver and copper as well as some lead (Plenderleith 1950:370).

CONCLUSIONS

The use of X-ray fluorescence permitted the analysis in a substantially non-destructive manner of most of the metal finds from Sotira *Kaminoudhia*. The results demonstrate how Cypriot metallurgy was quite advanced in the Philia Phase and Early Cypriot period.

Along with the arsenical alloys, which show a clear addition of arsenic to obtain an alloy with precise characteristics of hardness and color, tin alloys have also been found. In this latter instance, tin, which was certainly a highly prized and valued metal, appears to have been used for mainly aesthetic purposes, to obtain objects of prestige denoting a particular social rank of the people who possessed them. Gold had a similar function and was used, like tin-bronze, for the manufacture of earrings.

Finally, it must be mentioned how a range of evidence, such as the dagger-ingot and the crucible for melting copper-based metal, suggests the presence of local metallurgic activities, mainly aimed at the casting of artifacts. It is therefore possible to suggest that at least some of the *Kaminoudhia* objects were made directly *in loco*.

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Table 8.1.1. Quantative Energy Dispersive X-Ray Fluorescence analyses of metal objects from Sotira *Kaminoudhia* and a crucible from Paramali *Pharkonia*.

	%							weight
	as	pb	sn	fe	sb	ni	cu	grams
sample name								
m5 (A)	-	-	-	tr	-	-	100.0	3
m8 (A)	-	-	-	tr	-	-	100.0	2
m9 (A)	4.0	-	-	tr	-	-	96.0	8
m10 (A)	2.7	-	-	tr	-	-	97.3	4
m11 (A)	-	-	-	tr	-	-	100.0	6
m12 (A)	3.2	-	-	0.3	-	-	96.5	114
m12 (B)	3.8	-	-	0.6	-	-	95.6	
m12 (C)	3.5	-	-	tr	-	-	96.5	
m13 (A)	0.9	0.3	4.8	0.3	-	-	93.7	1
m14 (A)	0.5	-	5.8	-	-	-	93.7	1
m15 (A)	0.6	-	-	0.2	-	-	99.2	1
m16 (A)	7.0	-	-	2.1	-	-	90.9	<1
m17 (A)	2.0	0.1	-	tr	0.9	2.1	94.9	10
m18 (A)	0.3	-	-	0.5	-	-	99.2	35
m18 (B)	0.3	-	-	0.5	-	-	99.2	
m19 + m26 (A)	1.7	-	-	0.4	-	-	97.9	20
m19 + m26 (B)	1.6	-	-	tr	-	-	98.4	
m20 (A)	2.8	-	-	tr	-	-	97.2	<1
m21 (A)	1.7	0.3	10.2	0.7	-	-	87.1	<1
m22 (A)	0.5	-	13.1	-	-	-	86.4	<1
m25 (A)	2.9	-	-	0.7	-	-	96.4	<1
m27 (A)	0.6	-	-	0.7	-	-	98.7	4
m27 (B) rivet	1.0	-	-	tr	-	-	99.0	
m28 (A)	0.4	-	-	0.6	-	-	99.0	1
m29 (A)	-	-	-	-	-	-	100.0	4
m30 (A)	2.9	-	-	1.4	-	-	95.7	<1
	cu	ag	au					
m6	1 - 3	15 - 20	77 - 84					
m7	1 - 3	15 - 20	77 - 84					
	as	pb	sn	fe	sb	ni	cu	
crucible (A)	0.3	-	-	2.8	-	-	96.9	

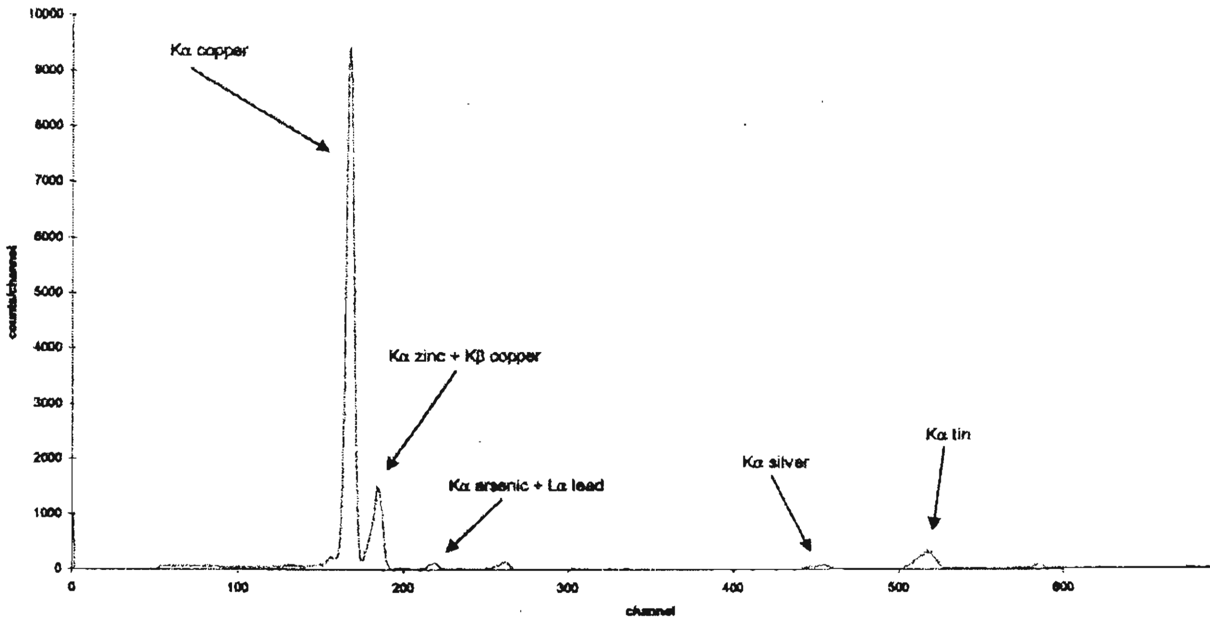

Fig. 8.1.1. Measurement performed by Energy Dispersive X-Ray Fluorescence on an alloy.

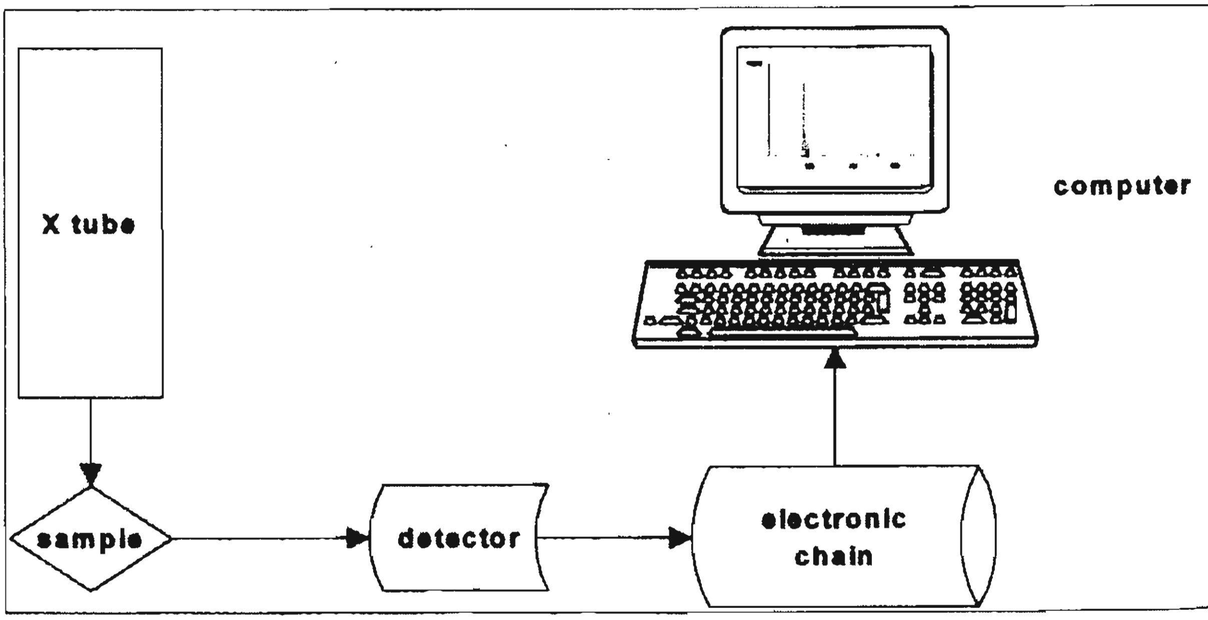

Fig. 8.1.2. Diagram of the equipment used for Energy Dispersive X-Ray Fluorescence Analyses.

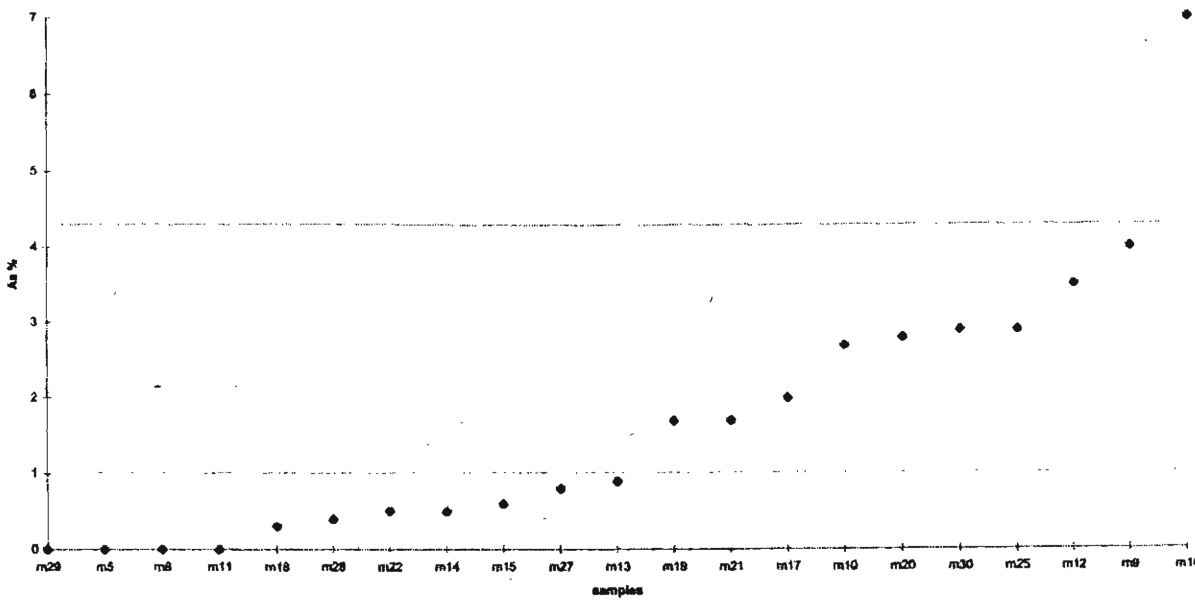

Fig. 8.1.3. Arsenic content of the objects from Sotira *Kaminoudhia*. Objects with less than 1% arsenic are considered as unintentional alloys.

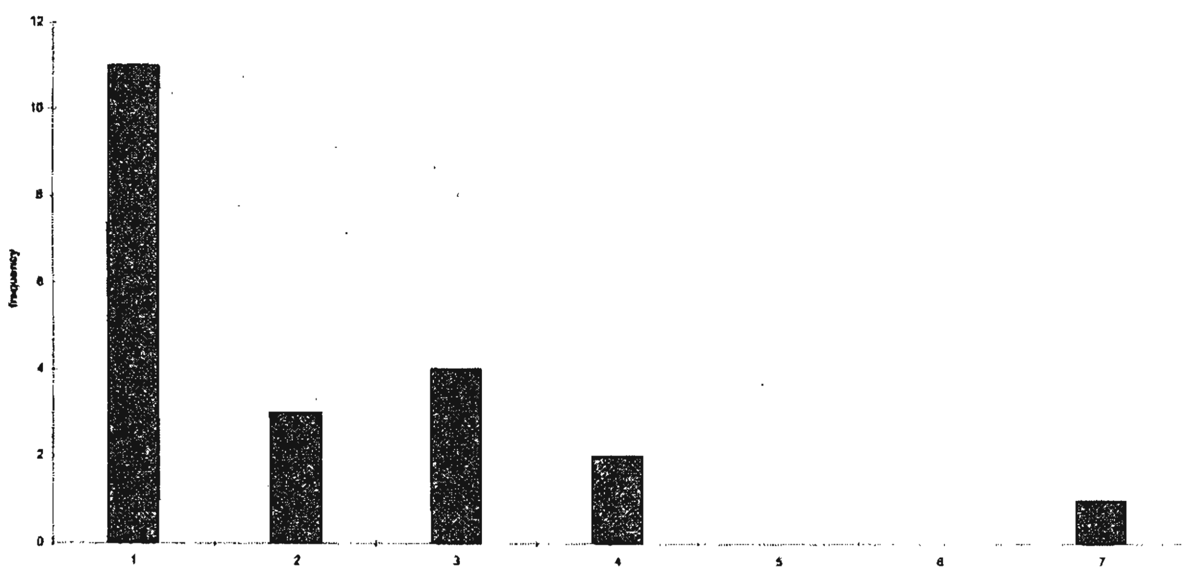

Fig. 8.1.4. Relative percentage of arsenic found in the metal objects from Sotira *Kaminoudhia*.

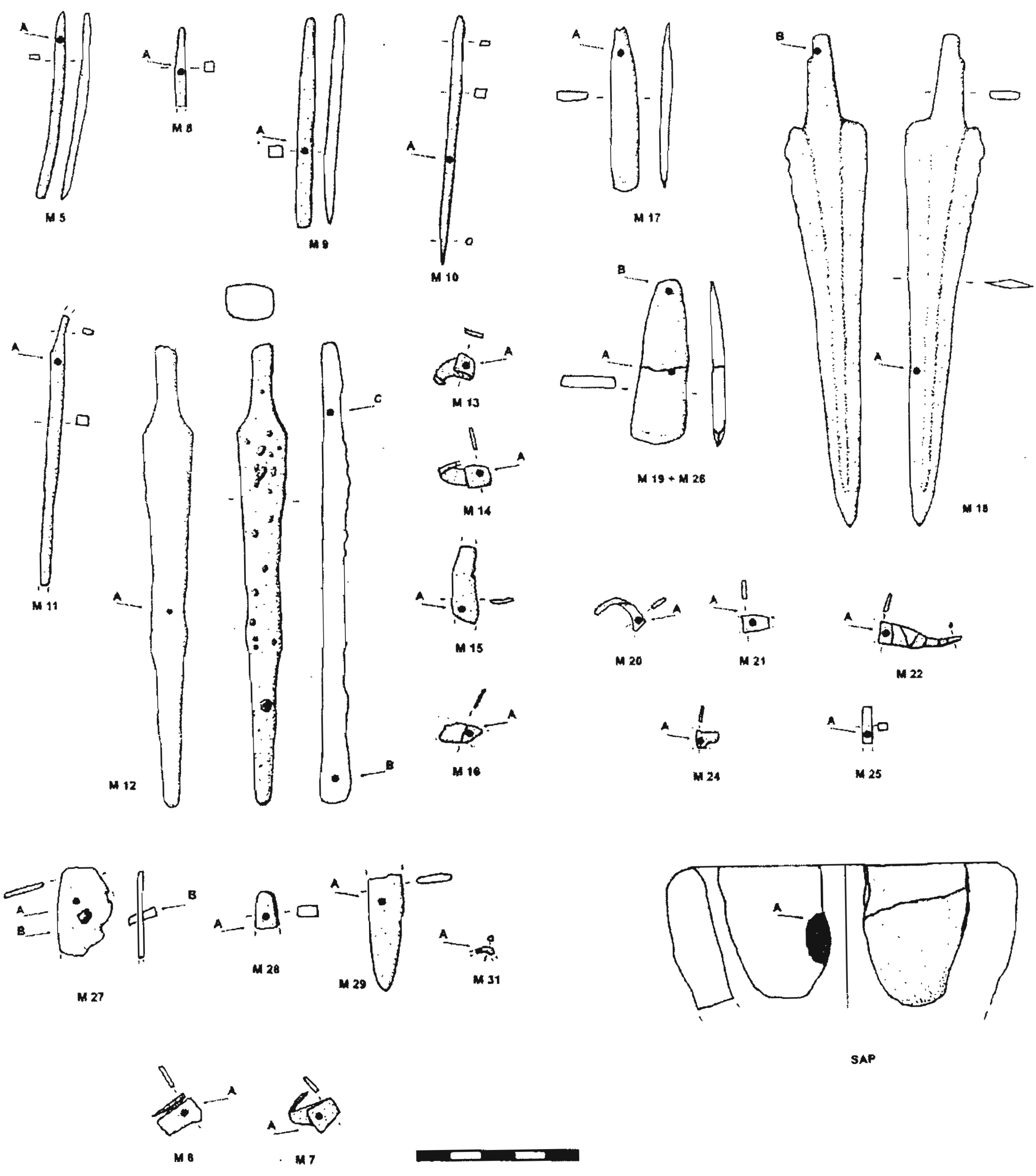

Fig. 8.1.5. Location of samples (A, B, C, etc.) taken from the metal objects from Sotira *Kaminoudhia* and the crucible (SAP) from Paramali *Pharkonia*.