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Author(s): K. Demakopoulou, E. Mangou, R. E. Jones, E. Photos-Jones

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MYCENAEAN BLACK INLAID METALWARE IN THE NATIONAL ARCHAEOLOGICAL MUSEUM, ATHENS: A TECHNICAL EXAMINATION

(PLATES 19–22)

Dedicated to the memory of Agnes Xenaki-Sakellariou

AMONG THE FINEST and best-known metal artefacts from the early Mycenaean period on mainland Greece (sixteenth–fourteenth centuries BC) are the bronze daggers and silver vessels with remarkable inlaid decoration, depicting marine (PLATE 19 *a*) and hunting scenes, or stylized floral designs (PLATE 19 *b*), and animal and human figures. The technique of decoration, which is known as painting in metal, is based on the arrangement of foils of different precious metals giving the finest aesthetic effect.¹ Artefacts with this decoration have been found mainly in the Argolid, and also in Messenia, Achaea, Laconia, Thera, and Cyprus. The currently prevailing opinion is that this technique reached the Aegean from Syria, and furthermore its examples, which appear at Mycenae during the time of the Shaft Graves, are the products of specialized craftsmen who probably came from Crete or even Syria.² The National Archaeological Museum, Athens, holds the largest collection of these objects, twenty-four in total.

The decoration on the Mycenaean daggers and silver vessels is executed by inlaying thin foils of silver, gold, or electrum (and possibly copper as well) against a black background, which itself is inlaid onto the bronze or silver (or silver alloy) body of the object. The black inlaid decoration has long been assumed to be niello, an alloy of copper, silver, or lead sulphides,³ although this claim has not usually been substantiated by any detailed scientific examination.⁴

Recently, analytical examinations have been carried out on the body and black inlaid decoration of three Mycenaean daggers:

- (a) From Kataraktis–Ayios Athanassios in the NW Peloponnese, now in Patras Museum (PMX 52).⁵ Analysis of the black inlaid decoration, by non-destructive X-ray fluorescence spectrometry (XRF), indicated an alloy of the following composition: copper 85–91%, tin 3–5%, gold 5–10%, silver 1%, lead 1%.

¹ See e.g. R. Laffineur, 'L'incrustation à l'époque mycénienne', *Ant. Cl.* 43 (1974), 5–37; A. Xenaki-Sakellariou and Ch. Hatziliou, *Peinture en métal à l'époque mycénienne* (Athens, 1989).

² See S. Hood, *The Arts in Prehistoric Greece* (London, 1978), 178–81, and more recently O. T. P. K. Dickinson, *The Aegean Bronze Age* (Cambridge, 1994), 99–100. See also Laffineur (n. 12 below), 269–76, for a thorough discussion of the origin of inlaid Mycenaean objects.

³ S. Marinatos, S. and M. Hirmer, *Crete and Mycenae* (London, 1960); Xenaki-Sakellariou and Hatziliou (n. 1). Niello is produced by heating copper, silver, and/or lead with sulphur in a crucible, resulting in the formation of the black sulphides of these metals. After cooling, it is crushed to a fine powder, reheated, and then poured as a

liquid, or spread, in a semi-paste-like state, onto the metal to be decorated, be it silver, gold, brass, or bronze. This technique was used extensively from the Roman period to the 19th cent. in many parts of the world. For a detailed account of niello, see S. La Niece, 'Niello: an historical and technical survey', *Ant. J.* 63.2 (1983), 279–98.

⁴ There are two exceptions: objects **7842** and **2489**, both discussed in detail here. Xenaki-Sakellariou and Hatziliou (n. 1), 34 n. 6. The reported presence of sulphur is now thought to have arisen from atmospheric weathering.

⁵ E. Photos, R. E. Jones, and Th. Papadopoulos, 'The black inlay decoration on a Mycenaean bronze dagger', *Archaeometry*, 36.2 (1994), 267–75.

- (b) From Thera, now in the Danish National Museum collections, Copenhagen (no. 3167).⁶ The black inlaid decoration composition, determined by atomic absorption spectrometry (AAS), was similar to that in the Patras dagger: copper with c.10% tin, c.5% gold, 1–2% silver and lead.
- (c) Now in a private collection.⁷ The black inlaid decoration, analysed by energy dispersive X-ray fluorescence, resembled the two above: copper 92%, tin 5%, gold 1.7%, silver 0.5%, arsenic 0.5%.

These analyses show that the black inlaid decoration consists of a bronze with variable quantities of gold and silver with some lead or arsenic. Elsewhere, there is a small figurine of Tutankhamun to consider, inlaid with gold and silver, now in the University Museum, Philadelphia, and dating to the 18th Dynasty (FUM. acc. E14295). It was found, upon analysis by proton-induced X-ray emission spectrometry (PIXE), to contain similar elements and in comparable quantities:⁸ copper 88.7%, tin 4.6%, gold 4.7%. In this case it is the whole object that is made up of this alloy, rather than bronze with areas consisting of black inlaid decoration.

The examples cited thus far suggest that, between the sixteenth and the fourteenth centuries BC in the Peloponnese, the Aegean (Thera), Cyprus, and Egypt, an alloy of bronze with gold and silver would either be inlaid in bronze or, in one case, was used *per se* in a figurine. The alloy has a characteristically black patina (rather than the usual green) and was itself inlaid with foils of precious metals.

Instances of bronze or silver objects with similar decoration from elsewhere in the Mediterranean during the second millennium BC are not common; they are conspicuous by their apparent absence in Minoan Crete. On Cyprus there is the famous Enkomi silver cup in the Cyprus Museum, Nicosia,⁹ and a bronze Egyptian or Egyptianizing figurine from the same site, now in the Louvre, dating to 1200–1050 BC.¹⁰ In Egypt a bronze dagger from the tomb of Amenhotep of the 18th Dynasty has been described as probably a form of niello.¹¹ Parallels for the Mycenaean daggers from the Levant include the well-known blade (harp) of Ypchemouabi and other items from Byblos, and specimens from Sichem and in Munich,¹² yet there appear to be no direct counterparts at Ras Shamra (Ugarit), apart from an axe decorated with wild boar and lion's heads, and a falcon.¹³ The Louvre has in its collections the bronze harp in the form of a serpent, with inlaid decoration, from Byblos.¹⁴ It is primarily on account of these objects, which on the one hand are Levantine and on the other predate the Mycenaean

⁶ S. Dietz, pers. comm. Illustrated in E. Vermeule, *Greece in the Bronze Age* (Chicago, 1972), pl. 13 c, and in Xenaki-Sakellariou and Hatziliou (n. 1), pl. 9. 1.

⁷ J. Ogden, 'Aesthetic and technical considerations regarding the colour and texture of ancient goldwork', in S. La Niece and P. T. Craddock (eds), *Metal Plating and Patination: Cultural, Technical and Historical Development* (Oxford, 1994), 39–49, in particular 41–2.

⁸ B. Fischman and S. J. Fleming, 'A bronze figure of Tutankhamun: technical studies', *Archaeometry*, 22.1 (1980), 81–6.

⁹ C. F. A. Schaeffer, *Enkomi Alasia: nouvelles missions en Chypre 1946–50* (Paris, 1952), 379–80. See also Xenaki-Sakellariou and Hatziliou (n. 1), 30, pl. 10. 3.

¹⁰ C. F. A. Schaeffer, *Enkomi-Alasia*, i (Paris, 1952), pl. 9.

¹¹ A. Lucas (revised by J. R. Harris), *Ancient Egyptian*

Materials and Industries (London, 1962), 250–1; Xenaki-Sakellariou and Hatziliou (n. 1), pl. 9. 3.

¹² Xenaki-Sakellariou and Hatziliou (n. 1), 20–1, pl. 15; R. Laffineur, 'Material and craftsmanship in the Mycenaean shaft graves', *Minos*, n.s. 25–26 (1990–1), 245–95, in particular 269.

¹³ C. F. A. Schaeffer, *Syria*, 19 (1938), pl. 34 and *Syria*, 10 (1929), pl. 52 respectively.

¹⁴ We are indebted to Dr Annie Caubet, Département des Antiquités Orientales, Musée du Louvre, for bringing to our attention the two objects in the Louvre's collections and for suggesting the possibility of analyses being carried out on these objects. For the Byblos harp see P. Montet, *Byblos et Égypte* (Paris, 1929), pl. 98. 648; 99. 653; 100. 653, and Xenaki-Sakellariou and Hatziliou (n. 1), pl. 15. 1–2.

examples, that the idea of *ex oriente lux* developed; yet none of the former has been analysed to confirm the presence of niello, as in their description,¹⁵ or of an alloy possibly resembling the one described above.

In the light of this introduction, it is clear that a detailed examination of the black inlaid surfaces of the Mycenaean daggers and vessels in the prehistoric collection of the National Archaeological Museum, Athens is overdue. In response to this need, the present study has been designed to provide a detailed scientific investigation by non-destructive means of a select number of these objects. The museum houses the largest extant collection of such metalware, including examples of black inlaid decoration on both bronze and silver. Among the aims of the study was to establish whether the composition of this decoration on the two metal types was similar. One crucial issue, the introduction of this technique into mainland Greece during the Shaft Grave period by Cretan or Syrian craftsmen working in the Peloponnese, has not been directly addressed in the study for two reasons: the absence at this time of Cretan parallels, and the lack of comparable analytical data for the Syrian objects. However this issue is eventually resolved, the point is that, as the results below make plain, the production of a wide range of different alloys designed to achieve specific aesthetic effects and prepared to high technical standards was consistently achieved in the Peloponnese over a period of two centuries. This seems not to have been matched anywhere else in the Mediterranean world at that time.

CATALOGUE

The objects selected for analysis and described below comprise some sixty per cent of the museum's corpus of such bronzes and silver vessels. For convenience the objects are classified into three groups.

(i) *Bronze daggers*

NM 395. Mycenae, Grave Circle A, shaft grave IV. Three running lions on both sides (FIG. 1).¹⁶

NM 744. Mycenae, Grave Circle A, shaft grave V. Intertwining spirals on both sides (FIG. 1).

NM 764. Mycenae, Grave Circle A, shaft grave V. Lilies on both sides. Dagger is broken at nearly half length (FIG. 2).

NM 6416. Prosymna, chamber tomb III. Three birds in flight (side A) and traces of one bird in flight (side B) (FIG. 2).

NM 8446. Prosymna, chamber tomb XIV. Single dolphin on both sides (FIG. 2).

NM 8339. Routsi (Pylos), tholos tomb 2. Nautilus in marine landscape on both sides (FIG. 1 and PLATE 19 a).

(ii) *Silver vessels*

NM 390. Kylix, from Mycenae, Grave Circle A, shaft grave IV. Floral decoration (FIG. 3 and PLATE 19 b).

NM 2489. One-handled cup, from Mycenae, chamber tomb 24. Fifteen heads of bearded men (warriors?) around the exterior (FIG. 3).

NM 7336. Hemispherical, one-handled cup, from Dendra, tholos tomb. Bulls' heads around the exterior (FIG. 3).

(iii) *Cup handles and other fragments*

NM 2874. Bronze handle, from Mycenae, acropolis. Four stylized nautilus (FIG. 4).

NM 7639. Silver handle, from Mycenae, prehistoric cemetery. From Vapheio-type cup decorated with two rosettes and bands of gold and silver (FIG. 4).

NM 7640. Bronze wing, decorated with 'adder mark' on one side, from Mycenae, 'house of lead' (FIG. 4).

NM 7842. Heads of bearded men, from Nestor's palace, Pylos. Fragments of a silver cup similar to **NM 2489** decorated with same heads (FIG. 4).

NM 7843. Fragments of black band inlaid with silver leaves, from the same vessel as **NM 7842**.

¹⁵ Laffineur (n. 12), 270, 'on which (blades) both metal inlays and niello are used'.

¹⁶ We thank Ms Lorraine McEwan for the drawings in FIGS. 1-4.

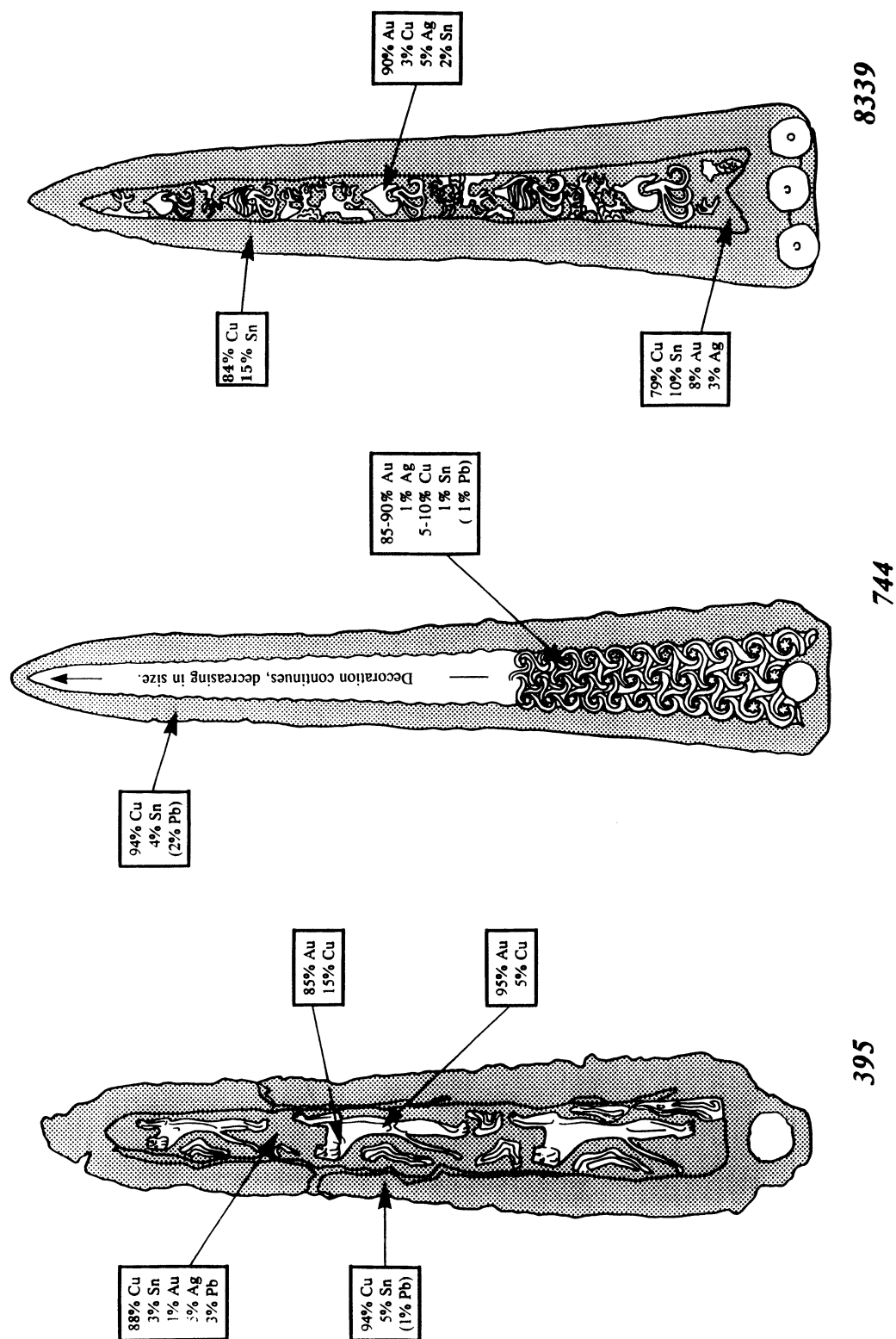


FIG. 1. Daggers NM 395, 744, and 8339, showing compositions of the different components.

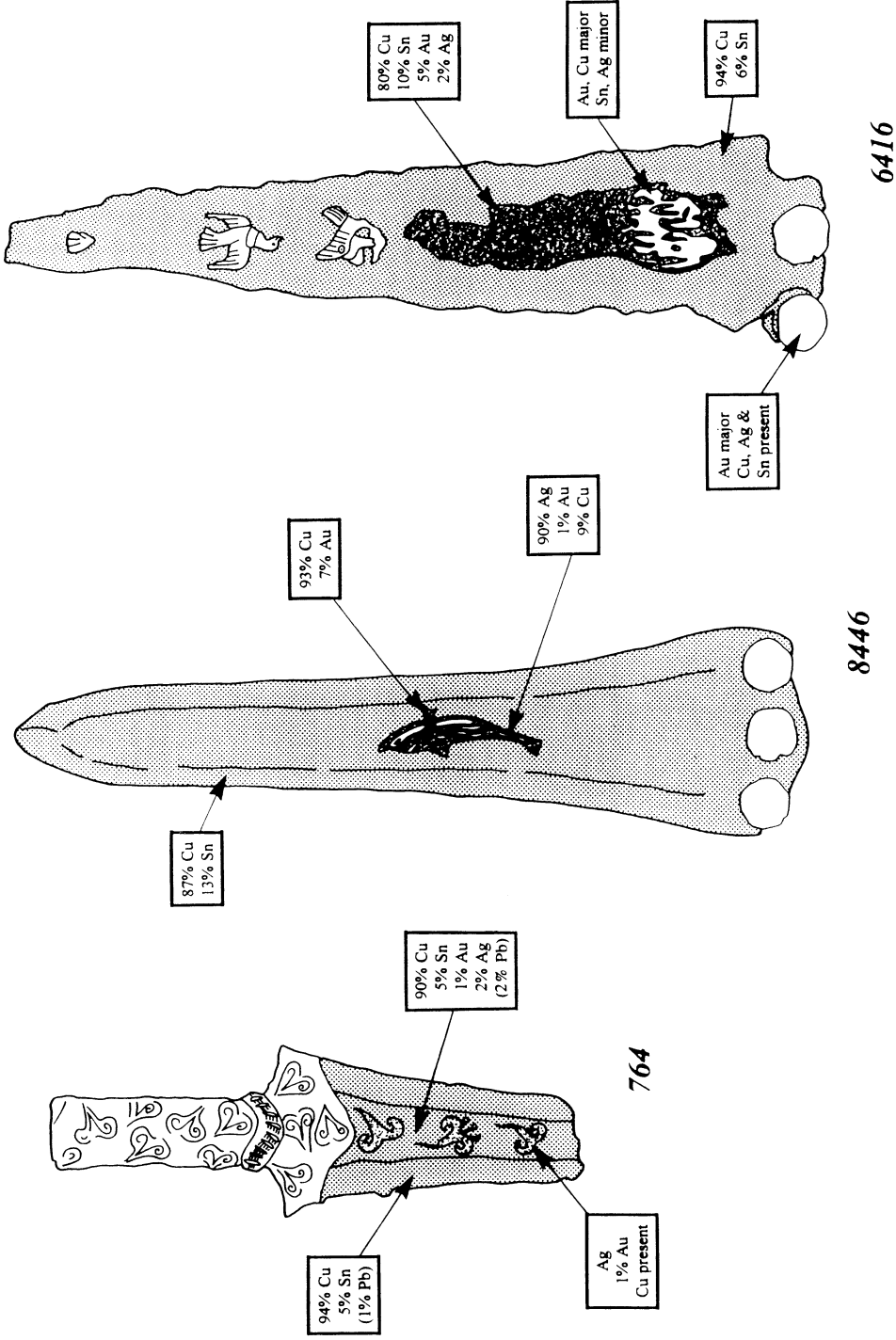


FIG. 2. Daggers NM 764, 8446, and 6416, showing compositions of the different components.

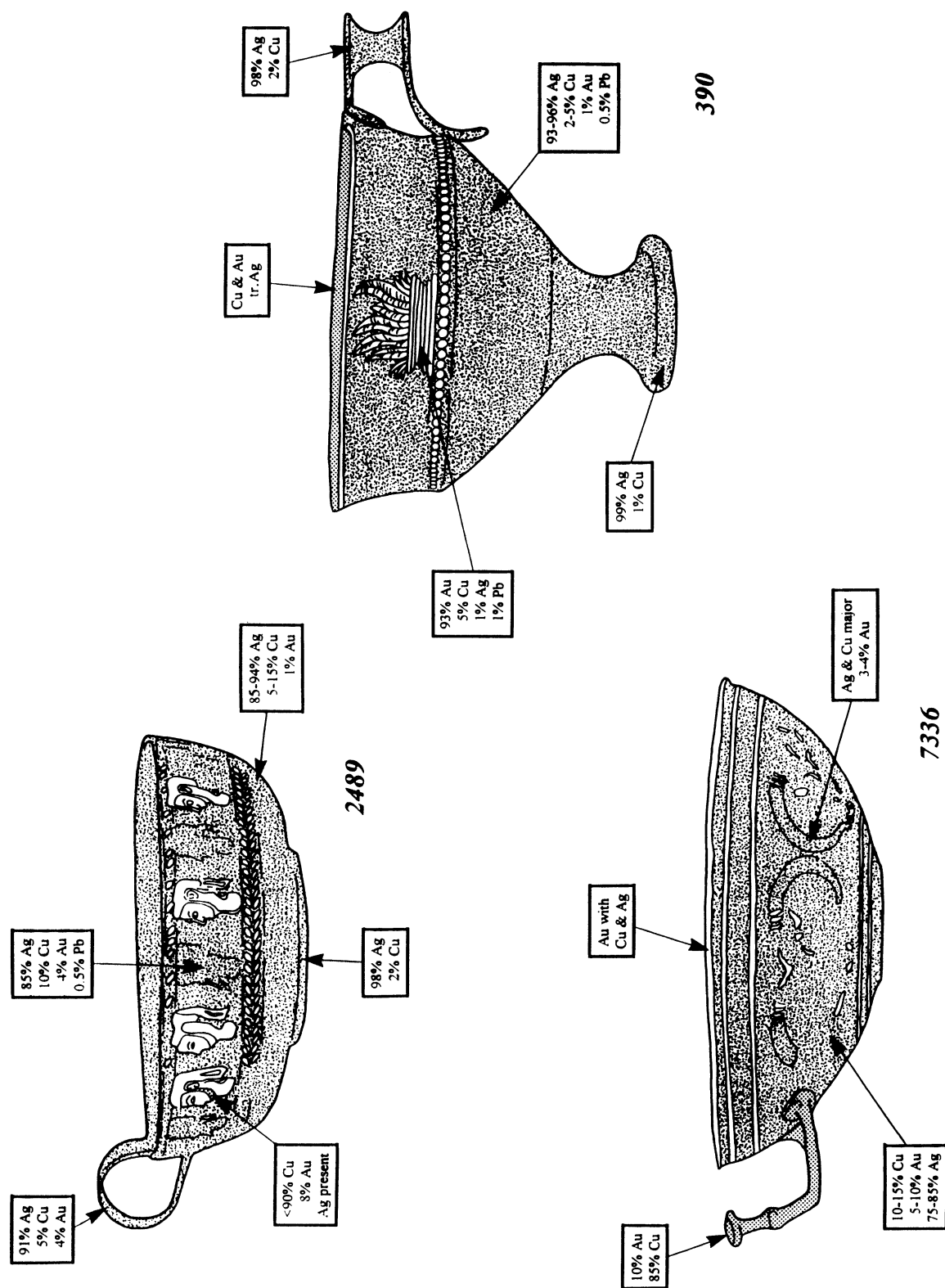


FIG. 3. Silver vessels NM 390, 2489, and 7736, showing compositions of the different components.

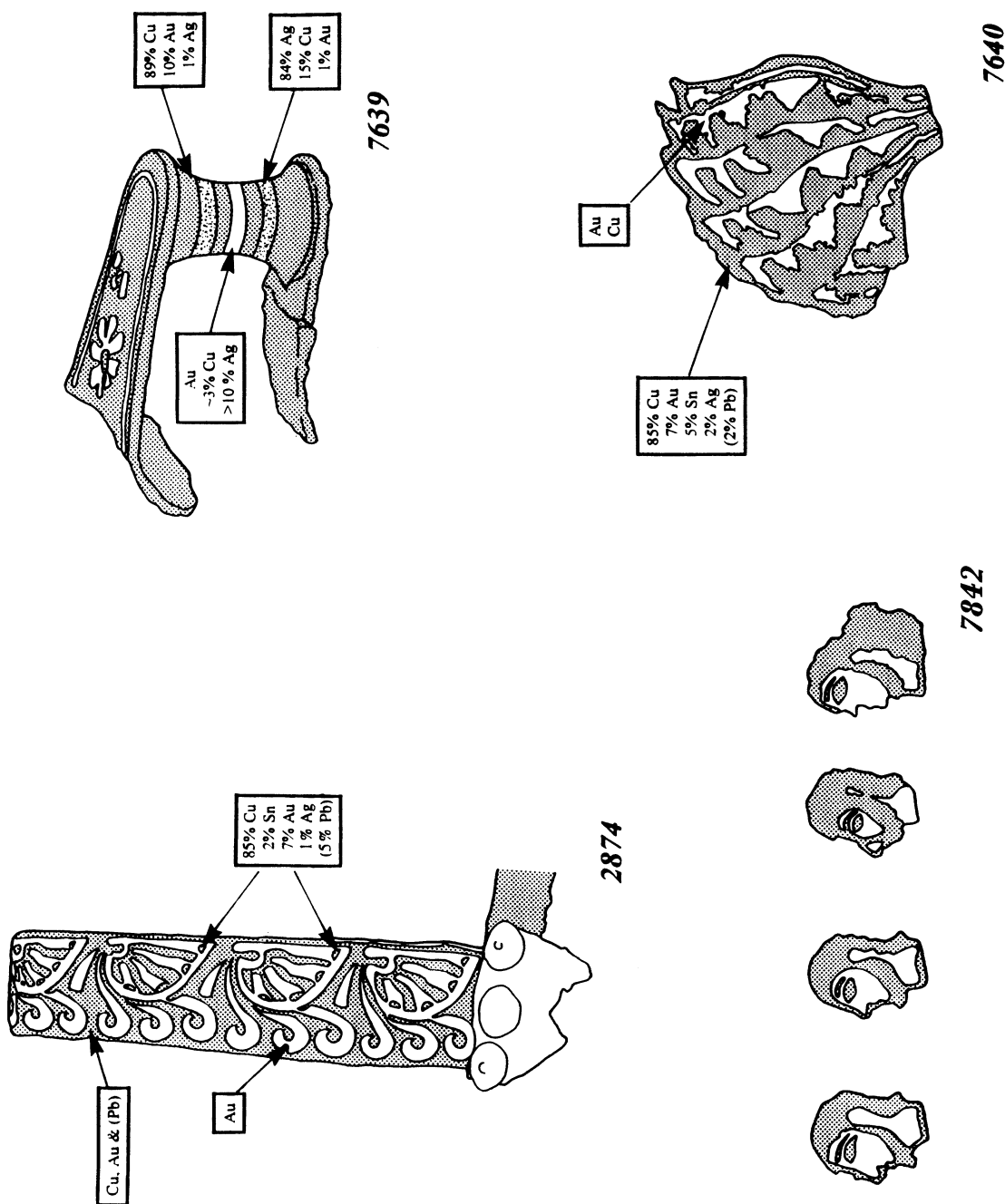


FIG. 4. Cup handles and other fragments NM 2874, 7842, 7639, and 7640, showing compositions of the different components.

TECHNIQUES AND METHODOLOGY

The technical examination and analyses were carried out in two short periods in 1991 and 1992 in the chemistry laboratory of the National Archaeological Museum. All the objects were initially examined under a binocular microscope for a preliminary assessment of the decorated areas and their physical condition and to select suitable locations for analysis. A few of the objects were subsequently radiographed in the laboratory to reveal possible details of their manufacture. In addition to the main data set of XRF analyses, two small fragments of a black inlay (**NM 7843**) decorated with gold leaf were examined by XRD and AAS for their mineralogical and elemental compositions respectively.¹⁷ This AAS composition served the additional purpose of acting as an independent check on the XRF data; the inlay was part of the silver cup (**NM 7842**) which was analysed by XRF.

X-ray fluorescence (XRF) was selected as the only appropriate technique of analysis in this study since it met the absolute requirement of providing a non-destructive analysis of the objects. It provided a semi-quantitative determination of elemental composition of the surface material (to a depth up to 100 microns), elements heavier than potassium being detectable. The instrument was an updated form of the portable 'isoprobe' system,¹⁸ employing an intrinsic germanium detector and a Silena ADC, amplifier, MCA, and display unit, and using two excitation sources: X-rays produced from a Mo target (20 kV, 1 or 2 mA) and gamma rays (for silver and tin excitation) from an Americium 241 source. The counting times were 4–6 minutes; the spectra were recorded on digital tape.

Semi-quantitative determinations of those elements detected at concentrations greater than 0.5% were made with reference to a variety of standards: tin bronze, leaded bronze, gold–silver and a series of five specially prepared alloys of gold, silver and copper, whose concentrations had been determined by AAS. The standards covered the element concentration ranges: Au 0–5%, Ag 0–80%, Pb 0–6%, Sn 0–12% and Cu 20–94%. With the exception of copper, which was usually estimated by difference, the element contents were determined with reference to calibration curves prepared from the standards. Estimations of lead and arsenic at low concentrations (<5%) in the presence of gold proved problematic¹⁹ such that no attempt could realistically be made to distinguish between the two metals. In the TABLES the contents are quoted as *lead*.

The different components of the objects were usually submitted to multiple analysis (the number being indicated in TABLES 1–6), and where possible several locations of each component were analysed. Estimates of each element concentration that lay within 1–2% of each other were averaged. Some difficulties were encountered, the principal difficulty being the secure alignment of the excitation source, especially the gamma rays which were less well collimated than the X-rays, with the small area selected for analysis. The mounting of some of the smaller objects in perspex also presented difficulty. Account had to be taken of (a) the surface non-homogeneities of the objects, (b) in the case of the bronzes, the state of preservation of their matrix, (c) the differential penetration of the X- and gamma rays, and (d) the presence of surface coatings of a resin on some of the objects.

¹⁷ We wish to thank the British School at Athens for permission to use the Fitch Laboratory's XRF in 1992, and Dr V. Perdikatis, of the Institute for Geology and Mineral Exploration in Athens, for the XRD. EM was responsible for the radiography and AAS, REJ for the XRF, and EPJ for examination with optical microscope and compilation of the data.

¹⁸ E. T. Hall, F. Schweizer, and P. A. Toller, 'X-ray analysis of museum objects: a new instrument', *Archaeometry*, 15 (1973), 53–78.

¹⁹ Due to the proximity of the Pb, As and Au, K, and L peaks lying in the 10–12 KeV region of the XRF spectrum.

TABLE 1. Compositions (expressed as element percentages) of the bronze daggers (body)
(In brackets is the number of spot analyses)

<i>Group I</i>	Cu	Sn	Pb
395 (2)	94	5	1
744 (2)	94	4	2
764 (2)	94	5	1
6416 (4)	94	6	—
8339	84	15	<1
8446 (5)	89	11	—

TABLE 2. Composition (expressed as element percentages) of black inlay in bronze daggers
(In brackets is the number of spot analyses; see text for Pb determination)

<i>Group I</i>	Cu	Sn	Au	Ag	(Pb)
395	88	3	1	5	3
764 (2)	90	5	1	2	2
6416 (3)	83	10	5	2	—
8339 (2)	79	10	8	3	—
8446	93	—	7	—	—

TABLE 3. Composition (expressed as element percentages) of gold and silver inlays in bronze daggers
(In brackets is the number of spot analyses; see text for Pb determination; pr present)

<i>Group I</i>	Au	Ag	Cu	Sn	(Pb)
395 Lion's mane	85	—	15	—	—
— reddish gold					
395 Lion's body	95	—	5	—	—
— yellow gold					
744 (2) Gold insert tray	85–90	1	5–10	1	1
764 Ag lily	1	pr	pr (but present through the foil)		
764 gold handle	pr	—	pr (in same amount as in lily)		
6416 reddish gold area on black panel	Cu, Au major; Ag, Sn minor				
6416 gold areas (4)	Au, Cu, Sn present				
6416 gold stud	Au, Cu, Ag, Sn present				
8339 gold nautilus	90	5	3	2	—
8446 silver on dolphin	1	90	9	—	—

ANALYTICAL RESULTS

The individual analyses are set out in TABLES 1–6, and FIGS. 1–4 show the locations of the analyses and also summarize the data.

(i) *Bronze daggers*

NM 395. *Body*: low tin bronze.

94% Cu, 5% Sn, 1% Pb (TABLE 1).

Black inlay: low tin bronze, like the body, with small quantities of silver, gold and lead.

88% Cu, 3% Sn, 1% Au, 5% Ag (3% Pb) (TABLE 2).

Gold foil: includes the lion's mane rendered in reddish gold (85% Au, 15% Cu), and the lion's body rendered in yellow gold (95% Au and 5% Cu) (TABLE 3).

TABLE 4. Compositions (expressed as element percentages) of the silver vessels (body)
(In brackets is the number of spot analyses; see text for Pb determination)

<i>Group II</i>	Ag	Cu	Au	(Pb)
390 body (4)	93–96	2–5	1	<1
390 base	99	1	–	–
390 handle	98	2	–	–
2489 body (4)	85–94	5–15	1	–
2489 base	98	2	–	–
2489 handle	91	5	4	–
2489 area where head 5 has dropped off	85	10	4	<1
7736 (3)	75–85	10–15	5–10	–

TABLE 5. Composition (expressed as element percentages) of black inlay on silver vessels and bronze fragments
(In brackets is the number of spot analyses; see text for Pb determination; tr trace; pr present)

<i>Group II</i>	Cu	Sn	Au	Ag	(Pb)
390 black below rim of vessel	Cu and Au; tr Ag				
2489 black inlay on hair (2)	<90	–	8	pr	–
2489 gold foil outlining men's heads	Au (qualitative)				
7736 dark patinated area (2)	Cu & Ag major, 3–4% Au				
<i>Group III</i>					
2874 black on back of handle	85	2	7	1	5
2874 black on handle	Cu, Au (Pb/As) (qualitative)				
7639 (4) black band	89	–	10	1	–
7640 black area	84	5	7	2	2
7842 black above heads 4 & 7	Cu only				
7842 black to side of head 1 & above head 10	Cu, Ag (Au minor)				

7843 Black band AAS analysis: 53.32% Cu, 8.73% Au, 2.83% Ag, 2.42% Sn, 0.27% Fe, 0.03% Ni, 0.02% Zn, 0.22% As, 0.03% Sb; Pb and Co were not detected.

NM 744. *Body:* low tin bronze with some lead.

94% Cu, 4% Sn, 2% Pb (TABLE 1).

There is no black inlay on this dagger visible under the gold panel. This *gold panel* on which the decoration is executed is primarily gold but with a substantial amount of copper and low silver, tin and lead. The high copper

content helps explain the reddish colour of this gold alloy.

c.85–90% Au, 5–10% Cu, 1% Ag, 1% Sn (1% Pb) (TABLE 3).

NM 764. *Body:* low tin bronze with low lead.

94% Cu, 5% Cu, 1% Pb (TABLE 1).

TABLE 6. Compositions (expressed as element percentages) of gold and silver areas on vessels and handles/fragments (In brackets is the number of spot analyses; see text for Pb determination; tr trace; pr present)

<i>Group II</i>	Au	Ag	Cu	Sn	(Pb)
390 gold palm	93	1	5		1
390 gold strip on vessel rim	Au and Cu (Ag tr)				
7336 gold rim	Au with Cu and Ag (qualitative)				
<i>Group III</i>					
2874 gold foil	Au (qualitative)				
7639 silver bands	1	84	15	—	—
7640 gold foil	Au, Cu (qualitative)				

Black inlay: low tin bronze like the body, with small quantities of gold and silver.

90% Cu, 5% Sn, 1% Au, 2% Ag, 2% Pb (TABLE 2).

Silver lily: primarily silver with small quantities of gold, and copper present (TABLE 3).

Gold handle: gold with small quantities of copper (TABLE 3).

NM 6416. *Body:* low tin bronze.

94% Cu, 6% Sn (TABLE 1).

Black inlay: high tin bronze with considerable amounts of silver and gold

83% Cu, 10% Sn, 5% Au, 2% Ag (TABLE 2).

Reddish gold area exposed on black inlay: copper and gold major, silver and tin minor (TABLE 3) (see discussion).

Gold foil on the stud is mainly gold (TABLE 3).

NM 8339. *Body:* high tin bronze with low lead.

84% Cu, 15% Sn, <1% Pb (TABLE 1).

(ii) *Silver vessels*

NM 390. *Body:* silver with small quantities of copper and gold.

93–96% Ag, 2–5% Cu, 1% Au, <1% Pb (TABLE 4).

Base and handle: silver with small quantities of copper.

98–99% Ag and 1–2% Cu (TABLE 4).

The marked difference in surface colouring between (a) the body and (b) the base and handle is reflected in terms of composition, as well as the surface treatment the object may have undergone.

Black area: near the rim, under the gold strip.

Copper–gold alloy (qualitative analysis) (TABLE 5).

Gold inlay: palm motif is primarily gold with small amounts of copper, silver and lead.

93% Au, 5% Cu, 1% Ag (1% Pb) (TABLE 6).

Gold strip: below rim of vessel.

Gold and copper (qualitative analysis) (TABLE 6).

NM 2489. *Body:* silver–copper–gold alloy with low lead.

85–94% Ag, 5–15% Cu, 1% Au (TABLE 4).

Base: silver with small quantities of copper.

98% Ag, 2% Cu (TABLE 4).

Black inlay: a high tin bronze, like the body, but with substantial amounts of gold and silver.

79% Cu, 10% Sn, 8% Au, 3% Ag (TABLE 2).

Gold foil of the nautilus: primarily gold but with small amount of copper, silver and tin.

90% Au, 3% Cu, 5% Ag, 2% Sn (TABLE 3).

NM 8446. *Body:* high tin bronze.

89% Cu, 11% Sn (TABLE 1).

Black inlay: a copper–gold alloy, no tin.

93% Cu, 7% Au (TABLE 2).

The composition of this inlay is different from that of the others.

Silver foil on the dolphin's back is mainly silver but with copper and some gold.

90% Ag, 9% Cu, 1% Au (TABLE 3).

The base was made from a distinctly different metal from that of the body and handle.

Handle: silver–copper–gold alloy.

c. 91% Ag, 5% Cu, 4% Au (TABLE 4).

This suggests that the body and handle were probably made of two different batches of metal, but the intention was probably to make the same alloy.

Black inlay on the beard and hair of man's head 3 (see FIG. 3) is a copper–gold alloy.

<90% Cu, 8% Au, Ag present (TABLE 5).

Black area where head 5 has dropped off (see FIG. 3).

85% Ag, 10% Cu, 4% Au (<1% Pb) (TABLE 4).

Gold foil outlining the men's heads.

Gold (qualitative analysis) (TABLE 5).

NM 7336. *Body:* silver with some copper and gold.

75–85% Ag, 10–15% Cu, 5–10% Au (TABLE 4).

Dark patinated area (bull's horn).

Silver and copper with 3–4% Au (TABLE 5).

See TABLES 5 and 6 for compositions of the handle and gold rim of vessel rim respectively (see FIG. 3).

(iii) *Handles and fragments*

NM 2874. *Green areas* signifying bronze: not analysed.

Black area: copper with small quantities of tin and silver and larger quantities of gold and lead.

85% Cu, 2% Sn, 1% Ag, 7% Au (5% Pb) (TABLE 6).

NM 7639. *Body:* not analysed.

Shaft: silver bands.

A silver–copper alloy with some gold.

84% Ag, 15% Cu, 1% Au (TABLE 6)

Shaft: gold band.

c.3% Cu, >10% Ag, remainder Au (TABLE 6).

Shaft: black bands.

89% Cu, 10% Au, 1% Ag (TABLE 5).

NM 7640. *Black areas:* low tin bronze with low silver but higher gold.

84% Cu, 5% Sn, 2% Ag, 7% Au (2% Pb) (TABLE 5).

Gold foil: gold and copper (qualitative).

NM 7842. *Black areas:* copper only for heads 4 & 7, and copper and silver with some gold to the side of head 1 and above head 10 (qualitative).

NM 7843. *Black band:* low tin bronze with silver and high gold contents (TABLE 5).

RADIOGRAPHY²⁰

The radiograph (PLATE 21) of **390** shows that the base and the handle of the silver vessel were made separately from the rest of the body. The base and handle are solid except for the handle shaft which is hollow. One end of the handle is fixed on to the exterior rim of the cup with three rivets, which are diamond shaped on the exterior of the cup and round on the interior.

Two bands are incised and inlaid with the bronze–gold–silver alloy: one band is just below the rim of the cup and carries an inlaid strip of gold foil, and the second is on the body of the cup which in itself carries small discs of gold foil. The discs are pierced in the middle by small rivets fixing them onto the body of the vessel. The floral decoration between the two bands is executed in gold foil and was engraved with a fine tool.

Vessel **2489** was raised from a single sheet of metal. A total of three rivets fix the handle of the cup onto the body; two of them fix the wider end of the handle onto the vessel just below the rim, while the third fixes the tapering end just above the band with leaf pattern. The body of the vessel was incised with two concentric circles, forming a thin band. This band is inlaid with the bronze–gold–silver alloy, which was itself incised and inlaid with gold foil in a leaf pattern.

The upper section of the vessel has also been incised, with heads of bearded men and was subsequently inlaid with a bronze–gold–silver alloy, in the same shape. Finally, this alloy was itself inlaid with gold foil, to outline the face and neck of the bearded mens' heads.

The base and handle are of different thickness and alloy composition from the body of the vessel.

Cup **7336** was raised from a single sheet of silver alloy (PLATE 22). Its interior is covered with a gold sheet. Near the bottom of the vessel the cup is incised with two narrow bands inlaid in gold foil, and there are three similar bands on and below the rim. Gold foil outlining some of the bulls' faces and horns is still evident. The handle was cast separately and fixed to the cup by three rivets with round heads. The free end of the handle is decorated with gold.

The radiograph of **7842** (PLATE 20 *b*) shows clearly the black inlaid decoration of the ten

²⁰ The X-ray instrument in the Chemistry Laboratory of the National Archaeological Museum is an Andrex, model 3001. Operating conditions for NM 390 were 130 kV, 4 mA, 4 min. exposure with Kodak film (X-omat MA, ready

backed without lead); for NM 2489: 130 kV, 2 min., 5 mA, D7Pb structurix Vacupac (SV); NM 7736: 140 kV, 2 min., 5.5 mA, D7Pb (SV); and NM 7842: 120 kV, 2 min., 2 mA, D4Pb(SV).

heads which, as the analyses suggest, is made primarily from copper. The white shadows shown on some heads (from left to right: heads 3, 4, 7, 9 and 10) suggest that some metal from the original vessel is still in place.

DISCUSSION

The results of our investigations point to a sophistication of techniques in the construction of Mycenaean decorated bronze and silver artefacts that is matched only by their aesthetic value. One characteristic of the craftsmanship involved is the range of alloy composition employed, each apparently suited to a particular decorative scheme followed by suitable surface treatment.

(i) *Bronze daggers*

The analyses of six bronze daggers focused on the composition of the body, the black inlaid panel and, the gold and silver inlaid decoration on the black panel (TABLES 1, 2 and 3). The bodies of two daggers (**8339** from Pylos and **8446** from Prosymna) consist of high tin bronze. Another dagger from Prosymna (**6416**) is, however, a low tin bronze, as are the other three daggers from Mycenae (**395**, **744**, and **764**). No attempt should be made at this stage to ascribe these variations in composition to the existence of different workshops: first in view of the daggers' chronological disparity (those from Mycenae date to around 1500 BC, the remainder to later in the fifteenth–fourteenth centuries BC), and second because the corpus of composition data for bronzes of varied typology from the Mycenaean mainland hints at a relatively low level of correlation between composition and either function or method of production.²¹

In examining the composition of the black inlaid panel in the bronze daggers (TABLE 2), two groups become immediately apparent. The first group, comprising five of the six daggers, has a black inlay which consists of a bronze with small quantities of gold and silver and, in one case, lead or arsenic (**395**). The second group consists of only one dagger (**8446** from Prosymna), whose black inlay firstly, consists of only copper and gold (TABLE 2) and secondly, is applied in a quite different decorative manner. Five of the six daggers include a panel wider at one end and tapering at the other, onto which the decoration is inlaid in gold and silver foil. By contrast, on the Prosymna dagger the panel has the shape of the final decoration, that is the dolphin itself. Furthermore, the craftsman seems to have attempted to imitate the daggers from the other 'workshops' by creating the illusion of a panel, that is raising the central section of the body of the dagger. The same effect occurs again on the Patras dagger (PMX 52) also bearing dolphin decoration.²² The composition of the Patras body is also a high tin bronze (10–12 % Sn, 1% Pb, remainder Cu) but the black inlay is a bronze with small amounts of gold and silver (3–5% Sn, 5–10% Au, 1% Ag, <1% Pb, remainder Cu). Thus from the point of view of composition, the Patras dagger bears closer similarities with the daggers of the first group rather than the dagger from Prosymna, despite the similarity in subject decoration.

²¹ On the basis of XRF analyses of LBA bronzes from the Menelaion, Mycenae, Ayios Stephanos, Kalithea in Achaia (to be published by REJ), and Nichoria (G. Rapp, R. E. Jones, S. R. B. Cooke, and E. L. Henrickson, 'Analyses of metal artefacts', in G. Rapp and S. E.

Aschenbrenner (eds), *Excavations at Nichoria*, i (Minneapolis, 1978), 166–81. See now E. Mangou, *Μελέτη αρχαίων χαλκινών αντικείμενων από τον Ελλαδικό χώρο*, unpublished Ph.D. thesis, Univ. of Patras (1994).

²² see n. 5.

(ii) *Silver vessels*

The silver vessels were made of two types of alloy: silver with small quantities of copper and gold, making up the body of the vessel in objects **7336**, **2489**, and **390**, and silver with copper in minor amounts (1–2%), used for the base and handle of the kylix (**390**) and the base of the cup (**2489**). The former alloy appears to be darker, as if it had undergone some surface treatment. This silver–copper–gold alloy used for making the body of all three vessels must have had good working properties, since it was possible to raise what must have started as a metal plate.

The black inlay on the men's beards (**2489**) is characterized by a copper–gold alloy with some evidence for silver, and the same applies to the top of the handle of cup **7336**. It is interesting to note that the black inlay on the loose heads of bearded men (**7842**) from Pylos, which stylistically are very similar to those decorating the body of cup **2489**, appears quite different in composition since it consists of copper only (perhaps as an oxide or sulphide). Furthermore, the black inlay in **7842** (beard and hair) shows signs of advanced oxidation. Nowhere else does the black inlaid decoration on either the bronze daggers or the silver vessels show any signs of having weathered at all. **7842** may suggest an 'unsuccessful' attempt on the part of another workshop to replicate decoration like that of **2489**.

(iii) *Cup handles and fragments*

The remaining two bronze fragments are different from the bronze daggers in that they were made in their entirety of bronze with gold and silver, or copper with gold and silver. In that respect they are reminiscent of the figurine of Tutankhamun discussed above. There is also the possibility of a leaded bronze–gold alloy being used for the handle, **2874**, which is subsequently ornately inlaid with gold foil. The decorative bands on the columnar shaft of **7639** display several compositions. They range from gold with more than 10% silver and traces of copper (electrum?) in the gold band, to copper-rich silver with traces of gold in the silver bands, similar in composition to the body of the silver vessels, and finally, to the black inlay characterized by copper and gold with traces of silver (no tin). In contrast, the black surface on fragment **7640** has a typical bronze–gold–silver composition.

Turning to the composition of the gold and silver foils, there is scarcely any evidence for pure metal. Gold foils consist of gold and silver but with copper or bronze impurities. On the dagger **8446**, the silver foils are of silver with about 9% copper and 1% gold. Gold alloys are either of the gold–copper composition (with varying amounts of copper according to the intended colour effect, for instance yellow versus red (**395**: lion mane and lion's body) or the gold–copper composition with small amounts of silver (**390**: gold palm and rim) or gold, copper, tin and silver (**8339**: the gold nautilus).

Two small samples from fragment **7843**, which was part of **7842** (analysed by XRF), were analysed by AAS and XRD. The AAS analysis (TABLE 5) corroborates the presence of the low tin bronze and gold alloy with small quantities of silver attested by XRF. The black patinated alloy is therefore used for inlaying on both bronze and silver. XRD revealed identical mineralogical phases: (a) tenorite and cuprite, both oxides of copper, CuO and Cu₂O respectively; (b) a copper–gold metallic phase, similar to bogdanovite ferroan—Au₅(Cu,Fe)₃(Te,Pb)₂, which can also incorporate iron and lead; and (c) a copper–tin phase Cu₅6Sn. Phase (a) was prominent in the first sample, phase (b) in the second. The copper–tin phase was the least prominent in both.

What do these overall results signify? They point to great versatility in working with copper (or bronze)–gold–silver alloys. The relative proportions of the three components (copper/bronze, gold, and silver) appear to alter in keeping with the desired decorative effect. Furthermore, they present a more dynamic and versatile range of effects than the Levantine counterparts mentioned in the introduction, assuming the latter are indeed of the same type of composition and also predate the Mycenaean pieces.

A bronze or a copper/bronze alloy with small quantities of gold and silver is primarily yellow to red in colour, depending on the relative amounts of the constituents present. The black surface, a patina, is an intentionally produced layer, the aim of which was to add a fourth colour to the craftsman's palette. Recent research on black copper alloys, with or without inlaid decoration of precious metal foils, from later periods, such as late dynastic Egypt (600–100 BC) and the Greek and Roman worlds, has revealed two main origins for their black patina: first, a typical bronze with a black patina of copper sulphides produced perhaps by the reaction of a sulphur-rich organic material with bronze, as seen on some Hellenistic and Roman statues,²³ and second, copper containing small but significant quantities of gold, silver, lead.²⁴ In this second type the alloy acquired its patina not only on account of its composition, but also because of subsequent surface treatment with naturally occurring etching reagents. Cuprous oxide or cuprite, rather than copper sulphide, is thought to make up the patina of these objects.²⁵

Although no analytical work has yet been carried out on the method of formation of the patina on the surfaces of the Mycenaean objects, close examination of the black patina on the Patras dagger revealed that it was probably intentionally formed only on the surface to be decorated.²⁶ This may also be the case with the black patina on the panel of dagger **6416**, although the results are not clear-cut. The gold area exposed in this panel, although only qualitatively analysed (TABLE 5), is superficially similar in composition to the black area except that it is richer in gold; the gold/copper ratio in the XRF spectrum remained constant as the X-ray tube filament current was increased from 1 mA to 2 mA, thereby increasing the penetration of the X-rays. One implication of the latter observation is that the black patina is relatively thin and thus could easily have been removed either during burial and/or in the course of earlier conservation work. Similar loss of patina appears to have occurred on other daggers in the Museum's collection—**1874** and **1816**, both from the tholos at Vapheio²⁷—but this observation has yet to be confirmed by analysis.

Craddock and Giumlia-Mair²⁸ have recently drawn attention to the evidence for the

²³ H. Born, 'Multi-coloured antique bronze statues', in S. La Niece and P. T. Craddock (eds), *Metal Plating and Patination: Cultural, Technical and Historical Development* (Oxford, 1994), 19–29.

²⁴ P. T. Craddock and A. R. Giumlia-Mair, 'Hsmn km, Corinthian bronze, shakudo: black-patinated bronze in the ancient world', in S. La Niece and P. T. Craddock (eds), *Metal Plating and Patination: Cultural, Technical and Historical Development* (Oxford, 1994), 103–4, Fig. 9.1, Tables 9.1 and 9.2. Two objects in the British Museum dating to 600–100 BC have similar compositions: (1) a figurine of Ptah (EA 27363), a black patinated and gold foil inlaid figure with Cu 90.5%, Sn 2.15%, Au 2.71%, Ag 0.45%, As 0.57%, Pb 0.12% (determined by AAS); (2) Osiris (EA 64477) with composite necklace of electrum and black bronze inlaid into the body (Cu 68.1%, Sn 10.6%, Au 3.8%, Ag 2%, Pb 3.5%, and possible presence of arsenic (XRF surface analysis)).

²⁵ Copper–gold alloys with fine inlaid decoration in gold silver and copper were first extensively studied in medieval Japanese sword guards made of that alloy and called *shakudo*. Intricate recipes for the preparation of organic reagents consisting of plant juices are employed even today, into which decorative objects made of the alloy are dipped and boiled in order to acquire the rich blue-black patina. For *shakudo* see S. La Niece, 'Japanese polychrome metalwork', in E. Pernicka and G. Wagner (eds), *Archaeometry 90* (Basel, 1990), 87–94; N. R. Notis, 'The Japanese alloy shakudo: its history and patination', in R. Maddin (ed.), *The Beginning of the Use of Metals and Alloys* (London, 1988), 315–27.

²⁶ See n. 5.

²⁷ Xenaki-Sakellariou and Chatziliou (n. 1), pl. 8. 1–2 (**1874**) and 3 (**1816**).

²⁸ See n. 24.

preparation of an alloy of copper, tin, gold and silver in the *Iliad* (xviii. 474–5), used for the manufacture of no commonplace object but Achilles' shield and prepared by no ordinary craftsman but Hephaistos himself. Although there is no direct reference to the body of the shield being black, it can be inferred that if the shield was to carry such rich decoration, as it did, then a solid black background must have been most appropriate. These decorations could only have been carried out in inlaid foils. There is, however, one verse in the same book of the *Iliad* in which the colour of the metal is indeed described in direct relation to its composition; the ploughed earth is shown black 'although it was gold, this was the great marvel of the art' (548–9).

The uniqueness of these objects and the bronze daggers in particular has led Vermeule²⁹ to speculate that some inlaid weapons must have been stolen from old tombs and shown around classical Greece inspiring Euripides to write: All along the blade of the deadly sword, hooves pounding, horses leap; black above their backs the dust blows' (*Elektra*, 476).

Since black inlaid decoration of the composition discussed here is known to exist in Greek and Roman artefacts, it is possible that the swords alluded to by Euripides, far from being stolen from tombs, may have been reproduced in one form or another during the Classical period.

CONCLUSIONS

The bodies of the bronze daggers consist of high and low tin bronze. On that basis they could have been made by one or more craftsmen, all of whom followed the same basic recipe of alloy preparation. The black inlay in the shape of a panel inserted within a designated grooved area is always a low tin bronze with 5–10% gold and small quantities of silver (c.1–2%). On the basis of style and composition, the black inlay on dagger **8446** from Prosymna appears different; its black inlay consists of copper and gold only.

The three vessels (kylix **390**, and two cups **2489**, **7336**) are essentially of silver, more specifically a silver alloy consisting of 85–95% silver, 5–15% copper, 1–5% gold (in the case of **7736** gold ranges 5–10%). Some areas of the silver vessels (**2489** and **390**), such as their bases and the handle (in **390**), are of a different alloy consisting of 98% silver and 2% copper, i.e. almost pure silver. The black inlay on the cups is a copper–gold alloy, not containing tin, and a small amount of silver. All three vessels appear to have been made using the same technique of alloy preparation and surface treatment, and as such could have been made in the same workshop. The cup from Dendra (**7336**) seems to have more gold, but that could be explained by the empirical nature of the process.

On the other hand, **7842**, consisting of heads of bearded men originally from a silver cup (cf. **2489**), is most likely the product of a separate workshop (at Pylos?) and is in any case later in date (fourteenth–early thirteenth century BC). Its black inlay consists of copper oxide (or sulphide) and represents a rather unsuccessful attempt at simulating the decoration on the contemporary and stylistically very similar, if more refined, cup from Mycenae (**2489**). Furthermore, these individual heads seem to have been set on a silver base which appears by qualitative analysis to be considerably 'debased', that is, it contains high amounts of copper.

The body of two fragments (**2874** and **7640**) is made entirely of black bronze: 84–85% Cu,

²⁹ E. Vermeule, *Greece in the Bronze Age* (Chicago, 1972), 100.

7% Au, 1–2% Ag, 2–5% Sn, and 2–5% Pb. The black bands on **7639** are, however, a copper–gold alloy. These three fragments, all from Mycenae, could represent the same workshop employing variations on one technique.

As the evidence currently stands, the decorated Mycenaean bronze daggers and silver vessels exhibit such a wide range of alloy compositions and corresponding expertise in manufacture to achieve the desired aesthetic effects that they outclass their contemporary counterparts from Egypt or the Levant. The apparent absence of similar material from Crete complicates the matter of who made these objects, since, although the scenes and motifs on the inlaid daggers and vessels have close parallels in Minoan iconography, it cannot be convincingly argued that Minoan craftsmen working in Crete or on the mainland were responsible for their manufacture. Finally, in connection with Laffineur's question about whether the later inlaid objects were the products of foreign or Mycenaean craftsmen, there are no features of the composition data that potentially discriminate between the objects on a simple chronological basis.³⁰

National Archaeological Museum, Athens
Chemistry Laboratory, National Archaeological Museum, Athens
University of Glasgow
Scottish Analytical Services for Art and Archaeology, Glasgow

K. DEMAKOPOULOU
E. MANGO
R. E. JONES
E. PHOTOS-JONES

³⁰ Laffineur (n. 12), 275.



(a)

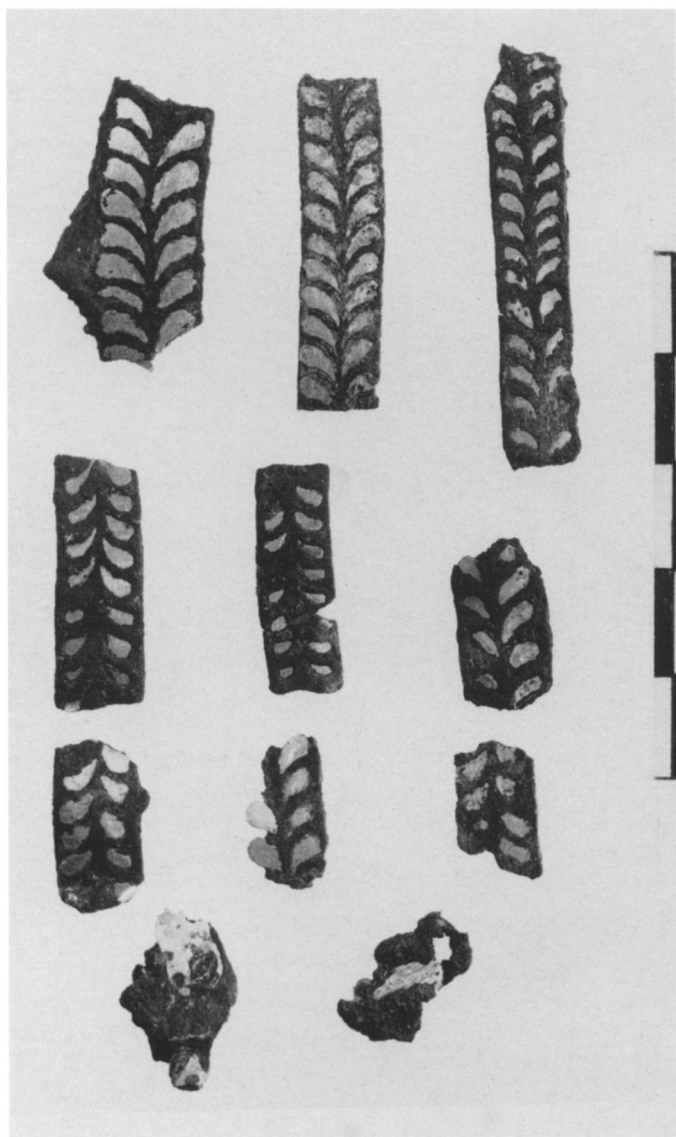


(b)

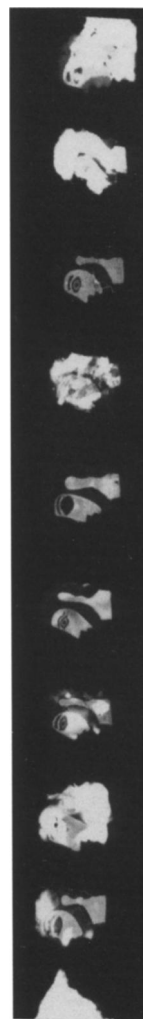
DEMAKOPOULOU *ET AL.*

MYCENAEAN BLACK INLAID METALWARE

(a). Dagger (NM 8339) from Routsi (Pylos) tholos tomb 2 with nautilus in marine landscape on both sides. (b) Kylix (NM 390) from Mycenae grave circle A, shaft grave IV with floral decoration.

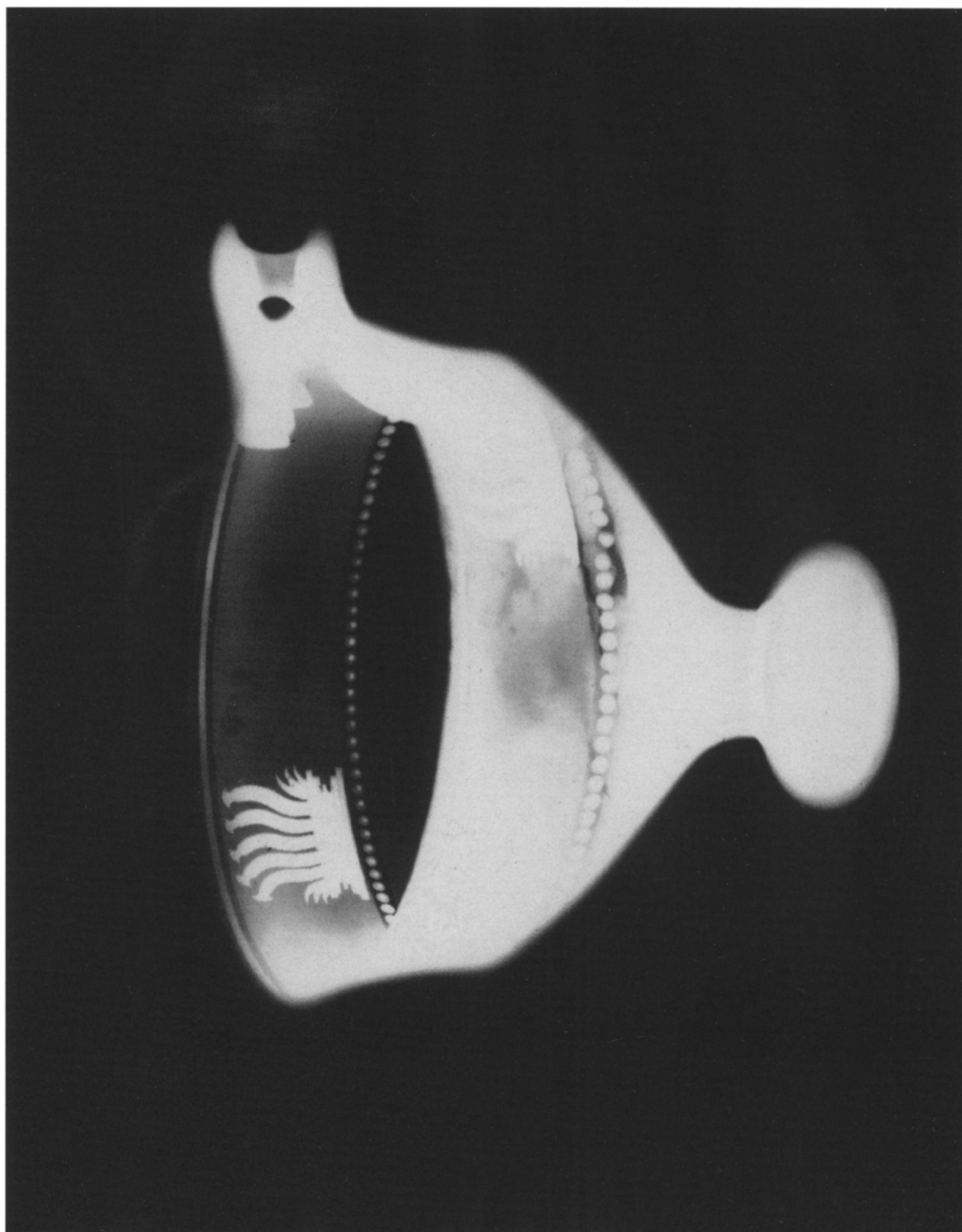


(a)

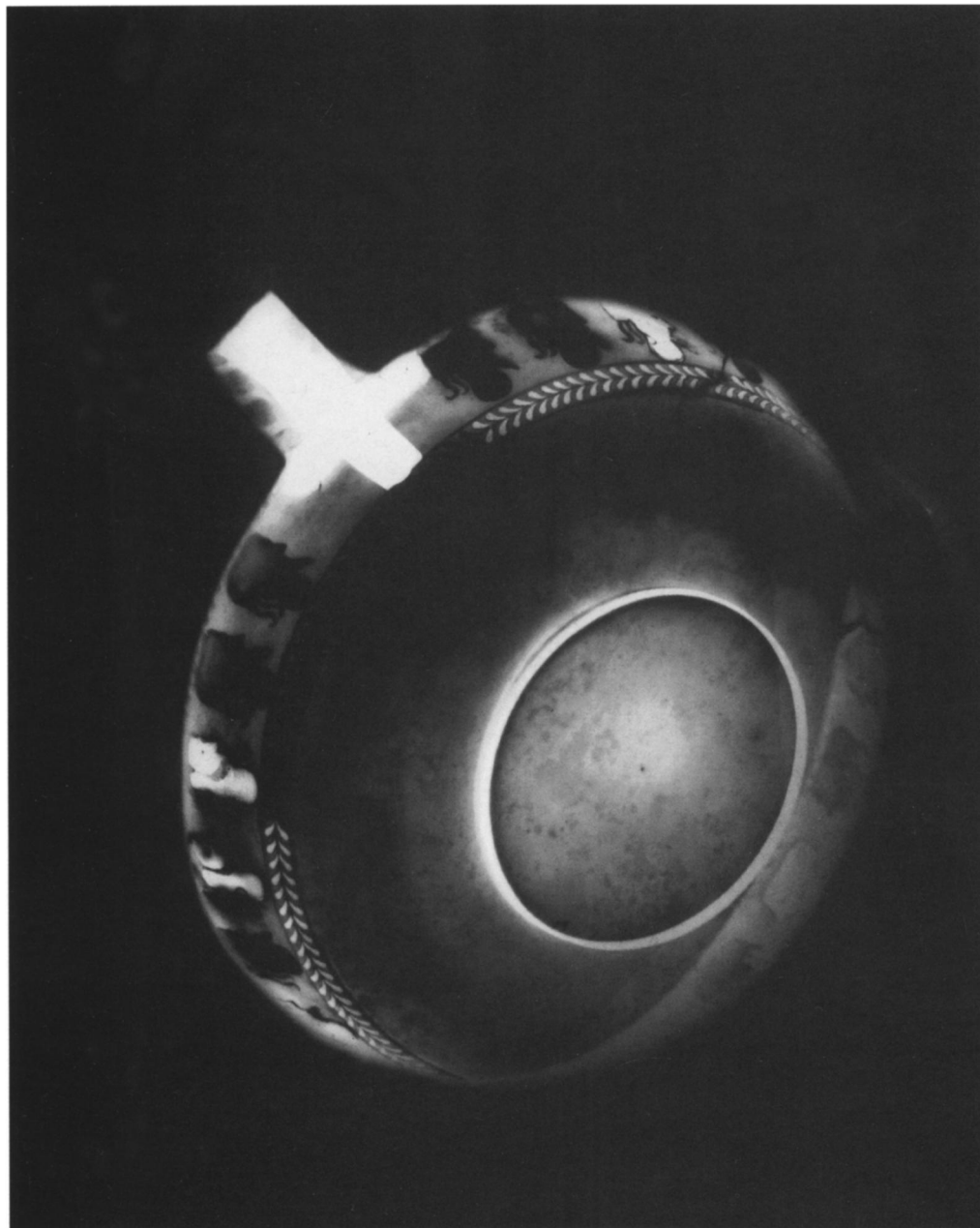


(b)

DEMAKOPOULOU *ET AL.*
MYCENAEAN BLACK INLAID METALWARE
(a) Fragments of black band (NM 7843) inlaid with silver leaves from same vessel as NM 7842. (b) Radiograph of NM 7842.



DEMAKOPOULOU *ET AL.*
MYCENAEAN BLACK INLAID METALWARE
Radiograph of NM 390.



DEMAKOPOULOU *ET AL.*
MYCENAEAN BLACK INLAID METALWARE
Radiograph of NM 7336.