Appendix 5

X-RAY FLUORESCENCE ANALYSIS OF MIDDLE AND LATE HELLADIC BRONZE OBJECTS

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[Editor's note: this section was revised in 2003.]

In 1977 the writer carried out in Sparta Museum a non-destructive analysis by X-ray fluorescence spectrometry of some 20 bronze objects from the excavations at Ayios Stephanos. The purpose of the analysis was to determine the composition of the bronzes with respect to the main alloying metals, and with this data to look for possible correlations between composition and function or type of object, as well as to make comparisons with chronologically and typologically similar bronzes analysed from other sites. The results reported here form part of an ongoing investigation by the Fitch Laboratory (British School at Athens) into the composition patterns of prehistoric and Early Iron Age bronzes from sites on the Greek mainland and Crete, some results of which have already been published.[1]

1. METHOD

The analyses were made non-destructively by X-ray fluorescence, using an Isoprobe.[2] An Americium 241 gamma-ray source was used to excite tin fluorescence at 25 KeV, while an X-ray source (operating at 15KV, 0.7ma) was used for all the other elements. The writer has described the analytical procedure and performance characteristics of this system.[3] Only the following points need to be emphasised:

(1) The state of preservation of the bronzes varied considerably, as did the quality of the small area cleaned on each object in advance of analysis. The quality of the prepared surface, which greatly affects the ability to obtain a reliable estimation of the composition, was graded on a scale from A, no corrosion (good metallic surface) to E, heavy corrosion (green malachite patina predominating). The intermediate C represented a metal surface showing corrosion to the extent of a red cuprous oxide layer.
(2) The detection limits for Sn, Fe, Zn, Ni, Pb and As were 0.5, 0.5, 1, 0.5, 1 and 1% respectively.
(3) The overall error in the determination of the tin content (in the range 0–15%) was ± 15% for A and B grade surfaces and ± 20% for C and D grade surfaces. Above 15% tin content and/or in the presence of more than 5% lead, the tin content estimation had an error ± 20%.

In the light of these points, which highlight some of the limitations of the non-destructive approach to analysis, all the analyses reported below should be regarded as semi-quantitative.

2. RESULTS

The results of the analyses, presented in TABLE A5.1, make a small contribution to the corpus of composition data for Greek prehistoric bronzes.

The principal features of the MH objects at Ayios Stephanos are the predominance of low tin bronze and detectable amounts of arsenic. The visual similarity between the two earrings, **HS 210** and **HS 211**,[4] extends satisfactorily to their compositions. It is striking that the same characteristics of low tin and detectable arsenic extend into LH I. Thereafter, apart from the two copper rings **7011** and **7012**, the compositions change markedly: the LH III objects, albeit three of them being sheet metal, are tin bronzes with no detectable arsenic or lead. On this basis, the pieces of strip **8005** and **8006** are more likely to be of MH or early LH date rather than later. Overall, there is little or no apparent evidence of correlation between the objects' alloying metal content and their probable function.

[1] Catling and Jones 1976, 1977; Rapp, Jones, Cooke and Henrickson 1978; Jones 1980.
[2] Hall, Schweizer and Toller 1973.
[3] Jones 1980; Rapp *et al.* 1978.
[4] *AD* 19 (1964) B1 pl. 148a; Taylour 1972, 217.

TABLE A5.1. The contents (expressed as %) of tin, arsenic, lead and other metals in MH and LH copper/bronze objects (— = not detected).

Context and objects	Catalogue no.	Excavation no.	Sn	As	Pb	Other	Grade
Alpha burial 23 (MH III Late)							
Pin (MH III Late)	**HS 208**	63-585	trace	trace	—		B
Earring (MH III Late)	**HS 210**	63-503	1	—	2	Fe trace	B/C
Earring (MH III Late)	**HS 211**	63-504	2	1	2	Fe trace	B/C
Bracelet (MH III Late)	**HS 213**	63-613	10	1	—		B
Other MH							
Pin (MH)	**6012**	63-623	trace	0.5	—		B/C
Wire (MH)	**6013**	60-616	2	1	—		B/C
Ring (late MH to LH IIB)	**7011**	74-032	—	trace	—		B/C
LH							
Dagger (LH I?)	**HS 215a**	63-624	1	0.5	0.5		B
Dagger rivet (LH I?)	**HS 215b**	63-624	trace	—	0.5		B
Tweezers (LH I?)	**HS 216**	63-607	4	trace	—		B
Knife (LH I)	**HS 225**	60-612	2	trace	—		B
Small chisel(?) (LH I?)	**HS 226**	60-615	trace	1	—		B/C
Punch (LH I)	**6010**	74-215	trace	2	—		B
Ring (LH IIIA1)	**7012**	74-022	—	trace	—		B
Tweezers (LH IIIA1)	**7013**	74-026	10	—	—	Fe trace	B
Fibula (LH IIIC Early)	**HS 277**	63-563	6	—	—		B
Sheet (LH IIIC Early)	**7016**	74-820	9	—	—		B
Sheet (LH IIIC Early)	**7017a**	74-821	6	—	—		B
Sheet (LH IIIC Early)	**7017b**	74-821	6	—	—		B
Date uncertain							
Fillet	**7012a**	63-538	—	trace	—		B
Fillet	**7016a**	74-030	1	3	—		B

The general trends observed in the results as a whole accord with those outlined by Mangou and Ioannou and with Kayafa's synthesis of Bronze Age metallurgy in the Peloponnese.[5] The writer[6] has recently discussed the present results in relation to those obtained by the same technique of analysis, X-ray fluorescence, at the Menelaion (on LH IIIA bronzes) and at Nichoria (on MH and LH bronzes).

[5] Mangou and Ioannou 1999; Kayafa 1999.

[6] Jones forthcoming.