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Preliminary neutron diffraction study of two fenestrated axes from the 'Enot Shuni' Bronze Age cemetery (Israel)

El'ad N. Caspi [a,*], Hanania Ettedgui [a], Oleg Rivin [a], Martin Peilstöcker [b], Beni Breitman [c], Izhak Hershko [c], Sana Shilstein [d], Sariel Shalev [e]

[a] Physics Department, Nuclear Research Centre – Negev, PO Box 9001, 84190 Beer-Sheva, Israel
[b] Israel Antiquities Authority, PO Box 1230, 61012 Tel Aviv, Israel
[c] NDT Department, Nuclear Research Center – Soreq, Yavne 81800, Israel
[d] Kimmel Center for Archaeological Sciences, Weizmann Institute of Science, 76100 Rehovot, Israel
[e] Department of Maritime Studies, University of Haifa, Mount Carmel, Haifa, Israel Kimmel Center for Archaeological Sciences, Weizmann Institute of Science, 76100 Rehovot, Israel

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ABSTRACT

Neutron diffraction (ND) analyses of ancient metals show that this method is capable of detecting differences in the inner composition and microstructure of ancient metal objects. Here, ND measurements were conducted on two 'eye shaped' axes from the end of the 3rd-beginning of the 2nd millennium BC. The objects were excavated from the ancient cemetery of 'Enot Shuni' Israel; one is made of bronze and the other of silver. Both artefacts are rare finds, with the silver axe unique in the archaeology of Israel, and therefore had to be analysed locally. For that purpose, a newly assembled diffractometer (KARL) at the IRR-1 of the Nuclear Research Centre (Soreq, Israel) was used. ND measurement on the bronze axe revealed the existence of an α-phase with a range of Cu/Sn ratios (Cu–Sn solid solutions) and some amount of a δ-phase (intermetallic compound of Cu and Sn). The silver axe ND pattern shows the existence of an α-phase (Ag–Cu solid solution) and some amount of copper metal. Our ND data are discussed in comparison with XRF surface measurements and thermal neutron radiography. The results are shedding more light on the in-depth material composition profile, as well as on the objects' structural and compositional affinities, and help to better understand the production processes and assist in conservation decisions.

1. The finds

In the summer of 2001, during the Israel Antiquities Authority's (IAA) excavations of an Early Bronze IV/Middle Bronze Age cemetery in 'Enot Shuni' (Peilstöcker and Sklar-Parnes, 2005; Peilstöcker, 2008) near the coast of the Mediterranean, some 55 km north of modern Tel Aviv in Israel, two rare metal battle axes were found. The axes were unearthed in tomb 59 and in tomb 79 (Nos. 50037 and 7300, respectively, Fig. 1) from the Intermediate Bronze Age (Early Bronze IV/Middle Bronze I [EB/MB]) – early Middle Bronze (MBIIa) period, and were therefore dated to the 21st–20th century BC. The bronze axe (No. 7300) measures 11.7 cm (shaft) and 7.5 cm (max. width), with two openings, one of 3×4.2 cm and one of 3×4.3 cm. The oval shaft varies from 2×1 cm on one side to 2.5×1.5 cm on the other. The silver axe (No. 50037) measures 9.2 cm (shaft) and 7.5 cm (width), with openings of 2.5×3.8 cm and 2.5×3.9 cm, respectively, and a variation in the shaft between 1.5×2 cm and 1.8×2.6 cm.

2. Archaeological and historical background

In his introduction to the *Archaeology of the Land of the Bible*, Amihai Mazar describes the general archaeological and historical characteristics of the period the two axes from 'Enot Shuni' belong to, as an interlude in the urban history of Palestine: "For about three hundred years following the collapse of the Early Bronze III urban culture [and before the emerging of the Middle Bronze II 'new' cities], Palestine was sparsely populated, mainly by pastoralists and village dwellers" (Mazar, 1990: 151).

Who were the people of Palestine in the EBIV/MBI period? Could indigenous processes explain this change, as W.G. Dever first suggested, or were they perhaps 'new comers', either Indo-Europeans, as suggested by C.F.A. Schaeffer, or west Semitic tribes of pastoral nomads (i.e. 'Amorites'), and, if so, could this period be identified,

* Corresponding author. Tel.: +972 8 656 7468; fax: +972 8 656 7878.
E-mail address: caspie@nrcn.org.il (El'ad N. Caspi).

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Fig. 1. Photos of the (a) bronze axe (No. 7300) and (b) silver axe (No. 50037).

following W.F. Albright's suggestion, as the time of the Hebrew Patriarchs described in the Bible (for a summary of history of research and bibliography see: Mazar, 1990: 169–171)?

Although the origin of the people of Palestine during the EBIV/MBI period is still unclear, the change in the socio-economic background of this period is clearer. "In most of western Palestine, the change in the way of life between the two periods was extreme: a thriving, hierarchical urban culture with a city-state political system, surplus economy, and foreign trade relations was replaced by an egalitarian society based on pastoralism and agriculture, without any distinct political system" (Mazar, 1990: 170–171). Current ethno-archaeological models, coupled with Egyptian and Biblical written sources (e.g. Barta, 2003: 171–195), interpret the archaeological data of this period as reflecting a Bedouin culture of nomadic tribes of shepherds, whose economy was based upon herding sheep or goats. However, recent archaeological research, in particular in the central and northern regions of the country (Peilstöcker, in press), produced a number of small settlements and in many cases burials and cemeteries that could be associated to them. The picture that emerges is of a rural but sedentary society, in contrast to the urban society of the following Middle Bronze Age II period. It has to be mentioned here that other regions, for example the northern Syrian Coastal plains, where axes like the ones under discussion here were found, are characterized by urban societies. This stands in sharp contrast to the situation in Palestine. In this research we wish to examine whether 'modern' scientific methods could assist in shedding additional light on and help to better clarify the abovementioned archaeological and historical interpretations.

3. Archaeometallurgy

During the Late Bronze period in the southern Levant, fenestrated metal battle axes in the shape of an eye (e.g. Miron, 1992; Philip, 1989) were found mainly in burials and in hoards associated with sacred places in Syria/Palestine and Iran (Miron, 1992: Catalogue nos. 225–232, pp. 57–58). In all, less than 12 bronze 'eye axes' are known in Syria/Palestine and less than 6 gold or silver ones were found, all in two caches that were deposited in temples at Byblos (e.g. Dunand, 1954: Pl. CXIV, CXIX, CXX, CXXXVII). The bronze axe from 'Enot Shuni' is therefore a rare find, and the silver axe is the first and only example of such an axe found outside Byblos in Lebanon.

An intact double stone mould for casting such axes was found in the tomb of the 'seigneur aux caprides' in Ebla, Syria, together with two bronze fenestrated axes that were cast in a different mould, as could be seen from their 'vein like' decoration (Matthiae, 1993). Two other similar steatite moulds were found in Byblos (Dunand, 1954: 10, Fig. 5, 98, pl. 184). The stone moulds show that this type of axe was cast with no runners or risers and the metal was poured from a sprue attached to the centre of the blade. A cylinder core (not found, possibly made of clay and disposed of after casting) was inserted at the base of the stone mould for creating the hollow socket of the axe. Thin scratches in the mould on both sides of the sprue were probably used as venting channels permitting the escape of gasses during the casting process, in order to ensure a smooth and solid cast. Three small holes (one at the bottom and one on each side of the upper part) were used to insert small wooden pegs for ensuring the exact fitting of the two mould pieces before casting.

After casting, the stone mould was opened, the core removed, and the blade was cleaned and polished from the sprue metal fill. In this research we tried to test whether these axes were left as-cast or were homogenised after casting, and if remains of hammering (i.e. crystal deformation) could be detected in the blade area. The results might help in shedding more light on the original possible uses of these objects: as efficient weapons or as ceremonial objects.

4. Experimental rationale

Due to the rarity of these artefacts and their fragile and corroded condition, the routine methods for their archaeometallurgical study (i.e. cut section with preserved solid metal for optical and electron microscopy metallography and/or drilled sample for metal compositional analysis, etc.) were not feasible. Therefore, a different research program was defined, using non-destructive XRF analyses of the surfaces of these 'museum pieces' coupled with thermal neutron radiography and neutron diffraction analyses of their mass volume. In this research, we aimed at 'seeing beneath' the surface corrosion layers by 'entering' into the mass body of the artefacts with neutrons, in order to determine, by analyzing their diffraction, the volume of the preserved metal and if it was left as-