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Archaeometallurgical investigation of thirteenth–twelfth centuries BCE bronze objects from Tel Beth-Shemesh, Israel

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ABSTRACT

Recent studies in the southern Levant have clarified that bronze – the commonly used metal during the Middle and Late Bronze Ages – continued to be produced throughout the entire Iron Age I. In order to gain more information concerning the metallurgical industry in southern Canaan during the Late Bronze–Iron Age transition, we performed an archaeometallurgical study of three well-preserved bronze objects – a 13th century BCE axe and 12th century BCE hoe and handle – discovered in the renewed excavations at Tel Beth-Shemesh, Israel. Analyzing the composition, microstructure and microhardness of the objects, the study aims at reconstructing their manufacturing processes. The chemical analysis revealed that the three objects were made of bronze, with up to 6.2 wt% Sn and up to 4.0 wt% Pb. Giving their properties and shape, the objects were first cast, most likely in an open mould and then brought to the desired final size and shape probably through cold-forging and annealing cycles. The results of the present research contribute to the accumulating knowledge concerning the Canaanite metallurgical industry during the Late Bronze II–Iron Age I transition.

1. Introduction

Archaeological and archaeometallurgical studies in recent decades have revolutionized our perceptions concerning the transition from bronze to iron in the southern Levant. Apparently, bronze – the commonly used metal during the Middle and Late Bronze Ages – continued to be produced through the entire Iron Age I, and iron became a utilitarian metal only at the beginning of the Iron Age II (about the ninth century BCE). Moreover, previous ideas about shortage in tin and copper due to the collapse of the eastern Mediterranean commercial network in the 'crisis years' of the twelfth century BCE, have turned out to be exaggerated if not completely erroneous. Tin was available in Iron Age I no less than before, and the Cypriote copper imported to Canaan during the Late Bronze Age seems to have been replaced by copper produced at the mining sites of Wadi Faynan and Timna in the Arabah (for all these issues see e.g., Waldbaum, 1978; Yahalom-Mack, 2009; Bunimovitz and Lederman, 2012; Yahalom-Mack et al., 2014; Levy et al., 2014; Yahalom-Mack and Eliyahu-Behar, 2015).

In order to gain more information regarding the metallurgical industry in the southern Canaan during the transition from the Late Bronze Age to the Iron Age, in this article we present an archaeometallurgical study of three well-preserved bronze artefacts dating from the Late Bronze IIB–Iron Age I (13th–12th centuries BCE): an axe (Fig. 1), a hoe (Fig. 2) and a handle (Fig. 3). The bronze objects were retrieved during the renewed excavations at the site of Tel Beth-Shemesh, located in the northeastern Shephelah (lowland) of Judah, about 20 km west of Jerusalem (for past and current research at the site concerning the periods under consideration see Bunimovitz and Lederman, 2009: 114–124; Bunimovitz et al., 2013; Brandl et al., 2013). The description of the three artefacts, including their preservation condition, dimensions and weight is summarized in Table 1. Their archaeological context, typology and chronology are discussed below. Typological and archaeometallurgical observations might help in determining the technological abilities of ancient cultures (Ashkenazi et al., 2012: 531). The aim of the present study, based on the artefacts' typology, chemical composition, microstructure and microhardness, is to understand the objects' manufacturing process, as well as to ascertain if these three artefacts were made of the same ore deposits.

1.1. The bronze artefacts: archaeological context, typology and chronology

The three bronze artefacts were found in 2004 and 2008 in primary contexts of Level 8 (Late Bronze IIB, 13th century BCE) and Level 7 (Iron Age IA, first half of the 12th century BCE) of the renewed excavations at Tel Beth-Shemesh.

1.1.1. Axe, Reg. No. 5991.01 (Fig. 1)

Context: Area A, Layer L1519, Level 8. Area A is located at the northern slope of the site and reveals a long stratigraphical sequence

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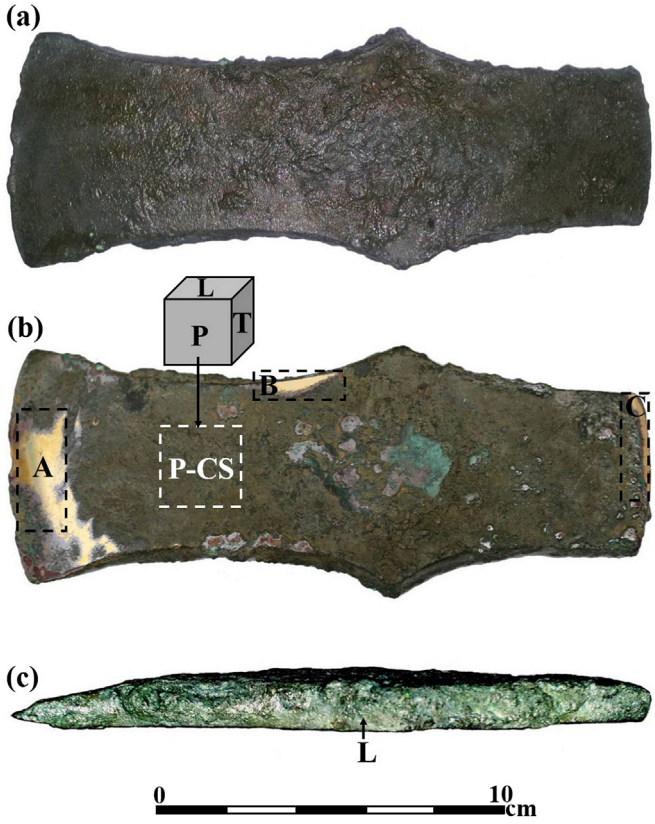

Fig. 1. The bronze axe from Tel Beth-Shemesh: (a) upper view (P-CS); (b) examined areas A, B and C after the removal of the oxide layers; and (c) side view (L-CS) (Photos by D. Ashkenazi).

of occupational layers from the Middle Bronze IIB to the end of Iron Age I (17th–10th centuries BCE; more upper levels were eroded but exist in other excavation areas). The axe was found within occupational debris that covered a pebble floor (F903) in a room of domestic nature in Level 8. This level, dating from the 13th century BCE, comprised a series of spacious buildings established over the ruins of a large Canaanite palace from the Amarna period (14th century BCE).

Typology: Lugged axe blade. Axe blades of this kind from Canaan were thoroughly discussed by Miron (1992: 31–44). According to his typological classification, our blade belongs to Type IV since the lugs are located nearer to the butt and the blade's back part narrows towards the butt (for parallels see his catalogue and Pls. 11–14 there). Three lugged axes of the same type are known from the previous excavations at Tel Beth-Shemesh: one from Duncan Mackenzie's (1912–1913: 98, Pl. XIV: 7), and two from Stratum III (Iron Age I) in Grant's (1932: 27, No. 1478; 31, No. 1736, Pl. XLVII: 33, 34; all three are better redrawn in Miron, 1992: Pl. 13: 205–207).

The functional definition of lugged blades and the distinction between axe and adze are notorious problems (Miron, 1992: 37–38). Indeed, Bass (1967: 95–99, Fig. 111) refers to lugged blades found in the cargo of the Cape Gelidonya shipwreck as adzes. However, the typological indications that, according to Miron (1992: 37–38; also Bonn et al. 1993: 208), show that most of the lugged blades were used as axes, are also applicable to our blade.

Chronology: Lugged blades first appeared in the southern Levant in the Middle Bronze IIA period but were mainly popular during the Late Bronze II–Iron I periods. They are rare in the Aegean and Cyprus and were most probably manufactured in Canaan (Catling, 1964: 87–88; Miron, 1992: 38–44; Yahalom-Mack, 2009: 115–116). The chronological and cultural contexts of the lugged blades found in all three cycles of excavations at Tel Beth-Shemesh concur with these insights.

1.1.2. Hoe, Reg. No. 4404.01 (Fig. 2)

Context: Area D, Layer L1227, Level 7. Area D is contiguous with Area A to its east and reveals the same tight stratigraphical sequence from the Middle Bronze Age to the end of Iron Age I. The hoe was found on a floor (F696/L1227) just north of an olive oil production installation (F831) of Level 7. Of domestic nature, this level is the first in a sequence of four Iron Age I levels (7–4) at the site, which testify to the continuation of Late Bronze Canaanite cultural traditions until the end of Iron Age I. Level 7 spans the first half of the twelfth century BCE (Bunimovitz and Lederman, 2009: 120–122).

Typology: Hoe blade with split tubular socket, parallel edges, and blunt rounded end. There is some ambiguity as to whether such implements functioned as hoes or plowshares (Catling, 1964: 79–80; Bass, 1967: 93 with further references), but it stands to reason that only those with a pointed end were used as plowshares.

Chronology: Similar hoes are known from Late Bronze IIB–Iron Age I contexts in the southern Levant (13th–12th centuries BCE; Bonn et al., 1993: 205–206; Yahalom-Mack, 2009: 125–126). They have also been found at Ugarit, Greece, Cyprus, and the Cape Gelidonya shipwreck, and are considered there to be of Near Eastern origins (Catling, 1964: 79–82; Bass, 1967: 88–90 [Type 3], 93, Figs. 103, 105, 106). The hoe from Level 7 at Tel Beth-Shemesh integrates well into this framework.

1.1.3. 3) Handle, Reg. No. 4203.01 (Fig. 3)

Context: Area D, Layer L1177, Level 7. The handle was found within debris of Level 7 excavated under a floor (L1177) of a house that was part of a domestic quarter of Level 6 (for description and contextual details concerning both levels see above and Bunimovitz and Lederman, 2009: 121–123).

Typology: Ω-shaped suspended handle. This handle seems to have originally hung from two ring suspensions attached to a bronze vessel. A close parallel comes from a bowl found in the Tel Jatt metal hoard (Artzy, 2006: 29 [Handled bowl J-65], 56, Fig. 2.2: 4; Pl. 4: 1-1c). Another, more crude example of a Ω-shaped handle, was found hanging on a bronze bowl from Tomb 387 – the "Mycenaean" tomb – at Tel Dan (Gershuny, 1985: 9, Pl. 7: 85; 2002: 200, Pl. 2.154: 113). In Cyprus, suspended handles, although of a different type, were found on *situlae* and cauldrons (Catling, 1964: Pl. 21: a, Fig. 17: 9). There is no clue, however, as to which type of vessel the Tel Beth-Shemesh handle was attached to.

Chronology: The aforementioned examples of suspended handles from the southern Levant span the chronological range from Late Bronze IIA (Tel Dan; late 14th/early 13th centuries BCE; Gershuny, 2002: 206) to late Iron Age I (Jatt hoard; second half of the 11th century BCE; Artzy, 2006: 95). The Tel Beth-Shemesh handle that was found in the Level 7 context (first half of the 12th century BCE) fits well this range, even if it was intended to be recycled and actually originated from Level 8 (13th century BCE).

1.2. Metallurgical background to the research

Copper and its alloys were extensively used during antiquity (Dilo et al., 2010: 985). Pure copper is easily cast; nevertheless, the resulting product typically has a dendritic microstructure and contains defects such as interdendritic porosity, as well as spherical porosity, which is a result of gas being entrapped in solidifying cast metal (Scott, 1991: 5–6; El Morr and Pernot, 2011: 2621). For example, an Iron Age I axe from Tel Dan, made of relatively pure copper alloy (with only 0.4 wt% Sn), was left unfinished due to many casting defects (Shalev, 1993: 63–64; Yahalom-Mack, 2009: 64). The casting quality of tin-bronze is better than that of pure copper and the alloy is harder than worked copper (Ashkenazi et al., 2012: 531). Moreover, bronze can be further hardened by forging (Reardon, 2011: 73; Gouda et al., 2012: 1338; Tylecote, 1992: 18). The copper–tin microstructure at full equilibrium, which is never attained in ancient materials, contains the ε phase which appears only after very long annealing; therefore, all ancient bronzes up to about