Type, Shape and Composition: The Middle Bronze Age II Daggers in Rishon le-Zion, Israel

Tal Kan-Cipor-Meron, Sana Shilstein, Yosi Levi and Sariel Shalev

Keywords

Israel, Archaeometallurgy, Middle Bronze Age, Daggers, XRF, Arsenical Copper, Tin Bronze

Abstract

A rich assemblage of Middle Bronze Age II daggers from the Rishon le-Zion excavations in Israel was studied. These daggers were found to be made of tin-bronze, arsenical copper or copper with tin and arsenic. Relations between type, shape and composition are established, showing that greater control of composition and shape are directly related to the production of more stylish decorated objects.

Introduction

Hundreds of copper-based objects dated to the Middle Bronze Age II (MB II; ca. the first half of the second millennium BCE) have been unearthed, mostly in burials, all over the Levant. In this period, the development of more complex weapons (decorated daggers, complex battle axes, etc.) was made possible by alloying copper either with arsenic (As), tin (Sn), or both, to produce arsenical copper and tin-bronze (Philip, 1991; Shalev, 2009).

After two thousand years, during the Chalcolithic and Early Bronze Ages (fourth to third millennia BCE), of mainly copper and arsenical copper metallurgy in Israel and Jordan (e.g., Golden, Levy and Hauptmann, 2001) and before the predominance of tin-bronze and intensive Late Bronze Age Mediterranean trade in copper and tin ingots (ca. second half of the second millennium BCE; cf. Budd, et al., 1995), the Middle Bronze Age represents a transitional period in metal alloying technology (e.g., El-Morr and Pernot, 2011; Philip, 1995a; 1995b; Shalev, 2009). It is therefore usually assumed that the MB copper-based objects alloyed with arsenic (As) are probably 'older' than similar objects that are alloyed with tin (Sn) and, often, lead (Pb), and that they are part of a newly arrived fashion. Recently, a synthetic summary of the state of research dealing with MB II weapons (Shalev, 2009) showed a current lack of correlation between metal composition and spatial and temporal distribution of identical types; that is, all possible alloys could be found region-wide throughout the period. However, within these alloys, in identical objects, extreme quantitative variability is apparent, the cause of which (i.e., how much of it is really the original metal and how much of the quantitative variations are caused by depositional changes) has yet to be studied. An additional source for content variation is the strong effect of corrosion, sometimes dependent and other times independent of the method of analysis.

Table 1a. Comparison between the concentration's results of neutron diffraction (ND) and XRF of MBAII axes (after: Shalev, et al., 2014).

Axe	% Sn by ND C_{min} / C_{max}	% Sn by XRF C_{min} / C_{max}	% As by ND C_{min} / C_{max}	% As by XRF C_{min} / C_{max}
Flat shaft axe BA3 (L506; B5077)	5 / 10	8 / 12		
Flat shaft axe BA6 (L654; B6362)	5 / 11	8 / 18		
Duckbill axe BA8 (L743; B7327)	8.5 / 12.5	8 / 20		
Flat shaft axe BA10 (L1085; B9247)	9.5 / 13.5	9.5 / 24.5		
Flat shaft axe BA12 (L1118; B9418)			1 / 2.6	1.5 / 9

Table 1b. Comparison between the concentration results of XRF analysis in electron microscope with wave length dispersion (WDS) and of atomic absorption spectroscopy (AAS), from one side, and XRF, from another side, for several MBAII daggers.

Dagger	Method	%As	%Pb	%Sn
Ribbed dagger (L22; B155)	AAS	1.3	2.0-5.0	7.0-10.0
	XRF	1.4-1.9	1.8-4.6	7.0-10.0
Flat dagger (L100; B1038)	AAS	0.8	0.1	0.6
	WDS	0.9-2.0	0.04	0.4
	XRF	0.6	0-0.1	0.3-0.5
Flat dagger (L705; B7016)	WDS	2.1	0.5	5.2
	XRF	1.0-1.7	0.5-0.9	6.0-6.3

In the present research, we seek a higher resolution of correlation within a single group of objects (daggers) between shapes (typology) of the daggers, and their metal composition (metallurgy). This correlation is definitely not new in archaeometallurgy (e.g. Key, 1980; Shalev, 1996) and the overall connection between shape, size and color of metal objects and their metal composition is one of the better-established aspects of archaeometallurgy (i.e., Shalev, 1996). In this study we wish to examine such relations and variability in one, relatively large group of 62 MB II daggers, submitted to non-destructive X-ray fluorescence (XRF surface) analysis and to connect the results into the archaeological context. These results are partially reported in Kan-Cipor-Meron, et al. (2018).

All the analyzed daggers derive from a single vast MB II cemetery excavated by Y. Levi from the Israel Antiquities Authority (IAA) in Rishon le-Zion (RL), south of Tel-Aviv on the Mediterranean coast of Israel (Levi and Kletter, 2018). Thus, this paper will discuss a narrow typological range of daggers found in this cemetery (for the wider typological picture, see El Morr, 2011; 2017; El Morr and Mödlinger, 2014; Gernez, 2007; 2008; Kan-Cipor-Meron, 2017; Philip, 1989; 2006).

The Archaeological Context

Hundreds of different grave types were found in the Rishon le-Zion (RL) MB II cemetery rescue excavations supervised by Y. Levi (IAA). Many skeletons were found in these graves accompanied with grave goods assemblages that included, in several cases, also weapons (Levi and Kletter, 2018). The weapons—axes, daggers and spearheads—were found in a consistent pattern near or on the adult skeletons. Formerly, scholars called such burials 'Warrior Burials' and some interpreted them as reflecting a social class or (aristocratic?) status group within Middle Bronze Age society (Kletter and Levi, 2016). Numerous similar graves have been found throughout the Levant (i.e., Doumet-Serhal, 2003; Doumet-Serhal and Kopetzky, 2011/2012; Garfinkel, 2001, p.143, 157; Gernez, 2008; Hallote, 1995, 2001, 2002; Philip, 1989; 1995c; 2006).

The Dagger typology

The daggers found at the Rishon le-Zion cemetery are the largest group from a single site available for study. The division of daggers into different types is based on past studies (e.g., Maxwell-Hyslop, 1946; Philip, 1989; 2006), but in this paper the typological and metallurgical analyses have been combined to determine their manufacturing process. The integration of the metallurgical data with the typological data has led us to accept Philip's distinction (2006, pp.42-55) and divide the daggers into two main groups (A+B) with eight types (1–8) according to their shape, size, and mode of manufacture. Group A (Types 1 and 2) includes the decorated stylish blades as termed by Philip (1989, pp.117–122, 435–436, Fig. 37, Type 13; 2006, pp.42–47), while Group B (Types 3–8) consists of flat, undecorated blades (Philip, 2006, pp.52-55). All have parallels in Middle Bronze Age II burial sites in the southern Levant (Kan-Cipor-Meron, 2017).

TYPE 1: Decorated ribbed daggers

(Table 2a, Figure 1a)

32 daggers with 3–5 ribs found at Rishon le-Zion included in this research. The ribs form protruding lines on the surface of the blade that join into one point toward the tip. The dagger is leaf-shaped; the blade is curved at the sides and has a pointed tip. To strengthen the dagger, the center of the blade is thicker than its sides. The central midrib is doubled with a channel between the two ribs; the two central ribs develop into 3–5 ribs (Ziffer, 1990, pp.72-73). The ribs taper into the point and usually protrude above the surface. Their length varies from 15.5 to 25.0 cm and their width is 3.7-5.0 cm.

The ribbed daggers were probably cast in a double stone mold similar to that found at Tell el-Dab'a (El Morr, 2011, p.136, Fig. 37; Philip, 2006, p.195, Fig 78:1, 4804) and at Tell Arqa, north of Byblos (El Morr, 2011, p.72, Fig. 19; Gernez, 2008, Pl. 1:3). The daggers' tangs vary in shape as a result of hammering and annealing. The tang

Figure 1. Type A – Decorated daggers (Subtypes 1-2): a) Type 1, decorated ribbed dagger (RL L.1108, B.9409.2); b) Type 2, decorated dagger with wide thick midrib (RL B.1086). (Photos: IAA)

has 1–3 holes for rivets by which it would have been attached to a wooden handle. The rivets often survive. After casting, the edges of the blades were also hammered and annealed, to harden them. According to hardness analyses, the blades were hardened to 208 Hv on their edges (compared to 149 Hv on the center; see Shalev in: Kan-Cipor-Meron, 2017). These daggers had a wooden or metal hilt with a spherical stone pommel.

The ribbed daggers were common all over the Levant (Ziffer, 1990, pp.72-73). They are known from many sites in Lebanon, Israel, and the Nile Delta. Most examples come from Israel and seem to be of a local, southern Levantine manufacture. Based on tombs from Tell el-'Ajjul and other sites, these daggers should be dated to the end of the MB IIA and the early MB IIB (Bunimovitz, 2000, pp.269-272, Figs. 13.4:1, 2 and 13.5:1, 2; Damati and Stepansky, 1996, Fig. 14:1, 2; El Morr and Modlinger, 2014, Fig 2: 26757; Gernez, 2008, Pls. 4:4, 8; Gernez, 2012, Pl. 2, Fig. 3; Maxwell-Hyslop, 1946, pp.25-26, Types 24, 25; Philip, 1989, pp.117-118; Philip, 2006, pp.42-47, 142; Shalev, 2000).

TYPE 2: Decorated daggers with wide thick mid-rib

(Figure 1b)

Five daggers of this type were found at Rishon le-Zion. In addition to their wide, thick mid-rib, all of these daggers have an elongated, pointed tip, angular shoulders, and a short rectangular tang with rivet holes. Type 2 daggers appear in sites in Israel and in the Nile Delta (Philip, 2006, pp.47-50, 143). The parallels are dated to the end of MB IIA and MB IIB periods (Damati and Stepansky, 1996, Fig. 15:1, 2; Maxwell-Hyslop, 1946, p.27, Type 26; Philip, 1989, Fig 39:674; Philip, 2006, pp.47-50, 143-145). These daggers, which replaced the other ribbed kind, are considered a 'Hyksos' type, shaped under a Syrian-Canaanite tradition (Ziffer, 1990, p.94, 72-73). Such daggers appear side by side with narrow-bladed socketed axes of Types 2 and 3 dated to the MB IIB (Miron, 1992, pp.77-78; Ziffer, 1990, pp.72-73).This type of dagger represents a continuation of ribbed daggers, albeit with one wide, shallow central midrib instead of the several ribs, as was the case in earlier such daggers (Philip, 1989, Type 17).

Due to their scarcity in archaeological contexts these daggers' metallurgical analyses are not included here.

TYPE 3: Flat-tanged daggers

(Table 2a, Figure 2a)

The daggers of Types 3-8 are mostly undecorated and flat, as a result of their production process and metallurgical composition. The former included casting, mostly in open molds, and then cycling of hammering and annealing in order to strengthen the blade. Their size and shape vary owing to the treatment to which they were subjected (Kan-Cipor-Meron and Shalev, 2018).

Fifteen such daggers found at Rishon le-Zion are included in this research. These rounded point daggers typically have long, narrow tangs without rivets. They were joined to the hilts by insertion into channels cut into the hilts. The pressure, perhaps with the addition of glue, held the parts together. The remains of the handles on the shoulders of the blades indicate that the handles covered the entire tang. This method is simpler than riveting, and the blades also appear simpler (Philip, 1989, p.113; Shalev, 2002, p.311). It seems that such daggers were manufactured by casting into open molds, then went through massive hammering and annealing cycles (Shalev, 2002, p.311; 2010, p.46). The blades are thin, undecorated, and have concave edges, probably a result of repeated sharpening following use as a slicing weapon, unlike the former types, which had sharp point probably used for stabbing.

These daggers have been found in various sites in Israel dated to the MB IIB period (e.g., Gershuny and Aviam, 2012, p.34, Fig 13:2; Maxwell-Hyslop, 1946, p.29, Type 28; Philip, 1989, p.113; Shalev, 2002, p.308, Fig. 8.2). In addition to its appearance near the deceased, this type

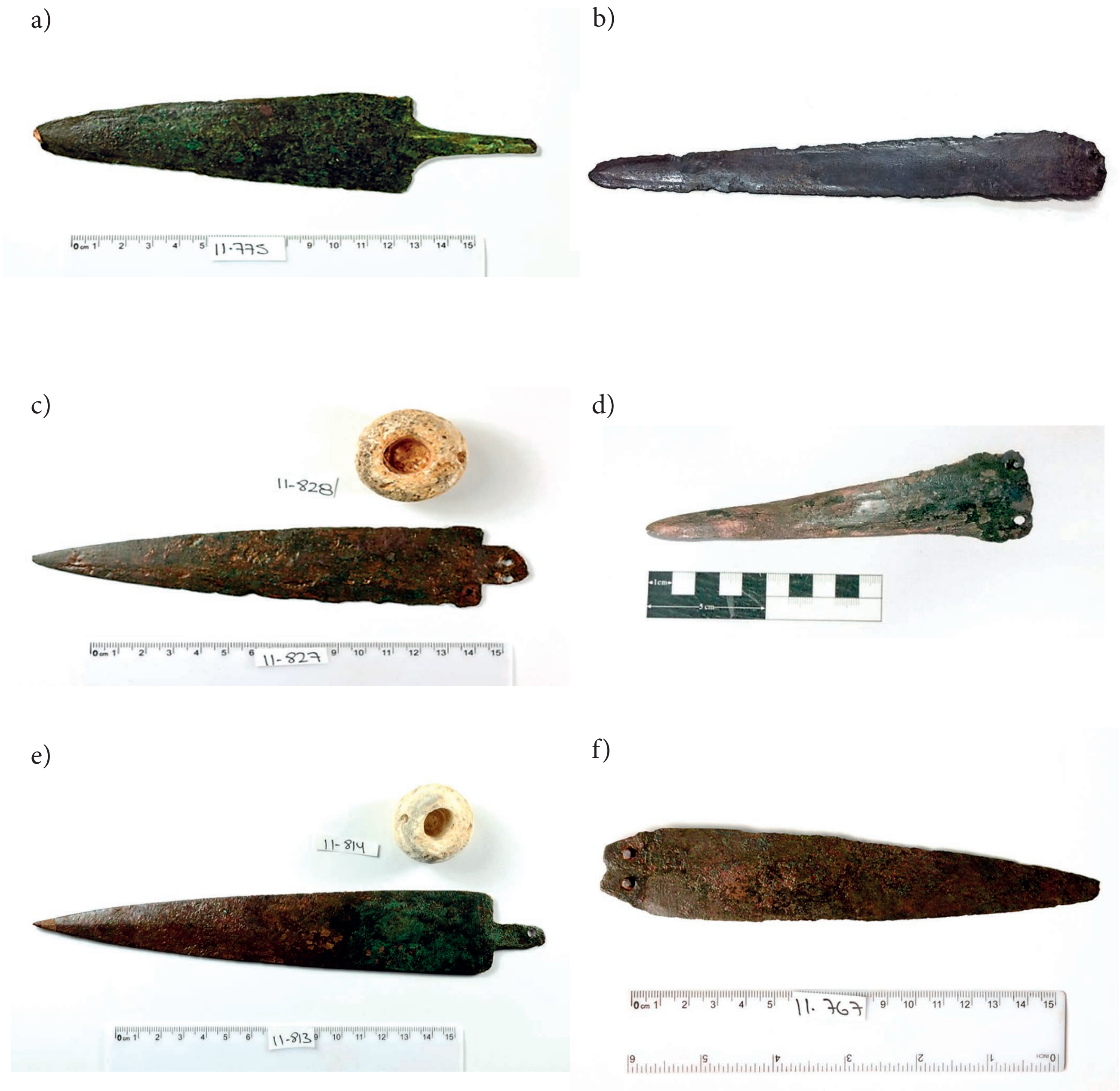

Figure 2. Type B – Undecorated daggers (Subtypes 3-8): a) Type 3, undecorated flat tanged dagger (RL L.268, B.3249); b) Type 4, broad-bladed dagger (RL L.743, B.7324); c) Type 5, broad blade dagger with rectangular blades (RL L.768, B.8028); d) Type 6, dagger with wide, triangular blades and no protruding tangs (RL B.6420); e) Type 7, dagger with elongated, flat and quite narrow blades (RL L.742, B.7304); f) Type 8, daggers with elongated flat-bladed daggers with a round trough (RL L.1086, B.9303). (Photos: IAA)

of dagger was also found on ceramic bowls beside animal bones, indicating the cutting function of these daggers in the funeral ceremony (Kan-Cipor-Meron, 2017).

TYPE 4: Broad-bladed daggers

(Table 2a, Figure 2b)

One broad-bladed flat dagger was found at Rishon le-Zion is included in this research (Table 2a:57) and possessed a round point and short wide tang. It is a fairly large and wide (22.5 x 3.8 cm) dagger with a trapezoidal tang. At its rear end, two rivet-holes were preserved. Examples of this type from Byblos (El-Morr and Pernot, 2011) were found to have been cast in a mold. Afterward, the blades were subjected to cycles of hammering and annealing to strengthen them. This type of dagger is common in the MB IIA and early MB IIB periods in the northern Levant with parallels from Byblos and Megiddo (Philip, 1989, p.466). It seems that its origins lay in third-millennium BCE Syria (Maxwell-Hyslop, 1946, p.22; Philip, 1989, p.131-132, Type 30, Fig. 44; cf. 466).

Table 2a. List of daggers considered in this study.

NN	Object	Type	Min dimensions (mm)	Max Blade Size	Comment	Period
Ribbed daggers with 5 ribs						
1	L640 B6214	A-1	175x42	190	broken point	MBIIA + MBIIA-MBIIB
2	L553 B6554	A-1	184x42	205	broken point	MBIIA + MBIIA-MBIIB
3	L1059 B9045	A-1	181x43	196	broken and corroded	MBIIA + MBIIA-MBIIB
4	L1049 B6955	A-1	183x40	195		MBIIA + MBIIA-MBIIB
5	L1050 B6969	A-1	181x45	195	Full Corrosion, broken tongue	MBIIA + MBIIA-MBIIB
6	L511 B5085	A-1	175x43	191	Broken blade tips	MBIIA + MBIIA-MBIIB
7	L768 B8004	A-1	148x41	173	Full Corrosion	MBIIA + MBIIA-MBIIB
8	L654 B6394	A-1	164x42	180	broken point	MBIIA + MBIIA-MBIIB
9	L686 B6419	A-1	172x41	189	Full Corrosion	MBIIA + MBIIA-MBIIB
10	L1108 B9409	A-1	190x47	210	Full Corrosion	MBIIA + MBIIA-MBIIB
11	L1086 B9294	A-1	164x46	181	broken point and tongue	MBIIA + MBIIA-MBIIB
12	L764 B8077	A-1	164x39	173	broken tongue	MBIIA + MBIIA-MBIIB
13	L656 B6393	A-1	190x44	211		MBIIA + MBIIA-MBIIB
14	L1064 B9081	A-1	170x42	198	broken point	MBIIA + MBIIA-MBIIB
15	L1017 B6228	A-1	165x42	175	broken	MBIIA + MBIIA-MBIIB
16	L1037 B6872	A-1	167x45	177	Full Corrosion, broken tongue	MBIIA + MBIIA-MBIIB
17	L1025 B6724	A-1	190x45			MBIIA + MBIIA-MBIIB
18	L1031 B6811	A-1	170x50			MBIIA + MBIIA-MBIIB
19	L1081 B9233	A-1	170x44		Full Corrosion	MBIIA + MBIIA-MBIIB
20	L1015 B6687	A-1	175x45			MBIIA + MBIIA-MBIIB
21	L1085 B9246	A-1	166x45		Full Corrosion	MBIIA + MBIIA-MBIIB
22	L607 B6084	A-1	182x46	202	Full Corrosion, broken blade tips	MBIIA + MBIIA-MBIIB
23	L1036 B6924	A-1	175x3.8	193	very damaged and broken	
24	L22 B155	A-1	154x38	169	broken tongue	MBIIA + MBIIA-MBIIB
Ribbed daggers with 3 ribs						
25	L1051 B6974	A-1	171x45		Full Corrosion	
26	L718 B7227	A-1	182x39	200	Full Corrosion	
27	L1055 B9012	A-1	137x35		3 ribs?- slightly broken tongue	
28	L1064 B9114	A-1	180x41	194	slightly broken	
29	L728 B7603	A-1	140x38			
30	L606 B6161	A-1	180x41	200	Full Corrosion, 3 ribs	
31	L1048 B6945	A-1	155x38	174	Full Corrosion, 3 ribs	
32	L647 B6310	A-1	175x40	177	broken tongue	

NN	Object	Type	Min dimensions (mm)	Max Blade Size	Comment	Period
Flat Daggers						
33	L755 B7727	B-3	156x42	193		MBIIB
34	L551 B6598	B-6	142x38	No tongue		MBIIB
35	L768 B8003	B-5	155x22	19	very damaged and broken	MBIIA + MBIIA-MBIIB
36	L768 B8030	B-5	134x31	151		MBIIA + MBIIA-MBIIB
37	L769 B8130	B-3	153x50	199		MBIIB
38	L694 B6447	B-3	135x47		tr Sb	MBIIB
39	L768 B8028	B-5	166x38	181	Broken point	MBIIA + MBIIA-MBIIB
40	L1064 B9267		207x40	230	broken	
41	L1086 B9303	B-8	160x31	176	Full Corrosion	MBIIB
42	L742 B7304	B-7	203x37	225		MBIIB
43	L1090 B9295	B-8	137x48	16	broken	MBIIB
44	L742 B7305	B-7	125x24	150		MBIIB
45	L1069 B9165	B-5	146x28	200	No tongue, folded tip	MBIIA + MBIIA-MBIIB
46	L767 B8002	B-3	146x47	200		MBIIB
47	L1033 B6830	B-3	110x35	135	broken point	MBIIB
48	L1027 B6833	B-3	140x37	173	broken	MBIIB
49	L1031 B6824	B-8	130x30			MBIIB
50	L1076 B9239	B-6	140x33	155	Broken, tongue part of blade	MBIIB
51	L1053 B9000	B-3	120x31	147		MBIIB
52	L769 B8133	B-3	170x43	210		MBIIB
53	L1075 B9206	B-5	148x39	162	broken point	MBIIA + MBIIA-MBIIB
54	L1017, B6868	B-8	125X32			MBIIB
55	L100 B1038	B-3	149x40	187		MBIIB
56	L705 B7016	B-3	93x30	137	broken point	MBIIB
57	L743 B7324	B-4	213x33	227	snack engraved decoration on the blade	MBIIA + MBIIA-MBIIB
58	L641 B6202	B-3	147x36	177		MBIIB
59	L209 B2818	B-3	136x46	180		MBIIB
60	L25 B184	B-3	111x33	136		MBIIB
61	L94 B1250	B-3	130x39	163		MBIIB
62	L268 B3249	B-3	140x46	181		MBIIB

TYPE 5: Broad blade daggers with rectangular blades

(Table 2a, Figure 2c)

Five of these daggers found at Rishon le-Zion are included in this research. These daggers have a wide, triangular blade with concave or straight edges. The tip is pointed, the tang is short and wide and riveted to the hilt. The tang is semicircular and has 2-3 rivets. Type 5 daggers look like a simple imitation of the ribbed Type 1 dagger (Philip, 1989, p.132; 2006, pp.52-53). The blade was first cast and then the tang was attached by hammering and annealing; hence, their different shapes and size. Parallels for this type are found mostly in the southern Levant in the MB IIA and early MB IIB (Bunimovitz, 2000, pp.270-272, Figs. 13.4:4, 5 and 13.5:4, 5; Maxwell-Hyslop, 1946, p.22, Types 20, 21; Philip 1989, pp.132-133, Type 31; 2006, pp.52-53; Shalev, 2000, pp.278-287).

TYPE 6: Daggers with wide, triangular blades and no protruding tangs

(Table 2a, Figure 2d)

Two such daggers found at Rishon le-Zion are included in this research. The rear end is concave or straight, the handle was attached to the blade by two rivets located on the two sides of the blade (Philip, 2006, p.50, 141, 187). The blade is very thin and after casting went through hammering and annealing cycles (Shalev, Shilstein and Yekutieli, 2006, p.135). Since the point is mostly rounded it seems the blade was not used for stabbing, but for slicing. Parallels for this type are known mainly from MB IIB Israel (Bunimovitz, 2000, p.272, Figs. 13.4:6 and 13.5:6; Damati and Stepansky, 1996, Fig. 17:2; Philip, 2006, pp.53-54; Shalev, 1997, p.349, Photo IV.C.2; Shalev, 2000, p.278).

TYPE 7: Daggers with elongated, flat and quite narrow blades

(Table 2a, Figure 2e)

Two such daggers found at Rishon le-Zion are included in this research. These daggers have a triangular shape and have long, narrow tangs with a row of rivet holes. The tang was entered into a notch in the hilt and then riveted to it. This means of connection to the hilt is typical for this type (Shalev, 1997, p.349). These daggers were cast into an open mold and went through cycles of massive hammering and annealing that create their different shapes and sizes (Shalev, 1997, p.349). Such daggers appear in Syria in the early MB IIA period while in the southern Levant they are dated to the MB IIB (Bunimovitz, 2000, p.272, Figs. 13.4:3 and 13.5:3; Maxwell-Hyslop, 1946, pp.27-28; Philip, 1989, pp.136-137).

TYPE 8: Daggers with elongated flat-bladed daggers with a round trough

(Table 2a, Figure 2f)

Four of such daggers found at Rishon le-Zion are included in this research. These daggers have 'simple' blades that have straight edges, which taper toward the rounded tip. The shoulders of the blade that join the tang are rounded. There are two holes for nails. The width of the tang varies according to the location of the holes. Often the nails survive, as has one flattened stone pommel (Philip, 1989, pp.135-136). These daggers were cast in an open mold and subjected to massive hammering and annealing that create their different shapes and sizes. These daggers are found mainly in the northern Levant with some parallels from Cyprus and Ras Shamra/Ugarit, where they are dated by the Cypriot pottery found next to them to the MB IIB (Bunimovitz, 2000, pp.269-270, Fig 13.4:4; Doumet-Serhal, 2003, p.47:13; Getzov and Nagar, 2002, p.12, Fig 10:1; Philip, 1989,135-136, 474-478, Type 33, Fig. 51; Shalev, 2000, p.278, Table 13.1:17).

Metallurgical Method

The metal composition of the daggers was determined by XRF analysis of their surface, using a bench-top model EX-310LC energy-dispersive spectrometer produced by Jordan Valley Co. (for a detailed technical description, see Shalev, Shilstein and Yekutieli, 2006; Shilstein and Shalev, 2011). A voltage of 35 kV and a specially added filter made of pure Al on the detector window (0.24 mm in thickness) were used for the Cu-based alloys. A limit of detection of about 0.05–0.10 wt. % was achieved for metals such as Sn, Pb and As. The relative accuracy of the measured concentrations using this XRF technique was determined to be 5% on average, as was demonstrated by a study of modern copper alloy Euro coins (Shilstein and Shalev, 2011). The accuracy level was determined by measuring certified alloy standards of tin-lead bronze and compare them to additional project-oriented specially prepared standards of mixtures of the metal oxides with defined concentration ratios. The results were used for calibrating the relationship between the measured intensities of the XRF lines and the mass ratios of the components. For alloys with Pb and Sn contents higher than 5 wt. %, a correction for the mutual attenuation of Pb and Sn peak lines was introduced. The relative accuracy of measuring higher concentrations of up to 20 wt. % Pb and Sn is circa 10-15 wt. %. The limit of detection for As in such high Pb concentration is not lower than 0.3 % (Shalev, Shilstein and Yekutieli, 2006).

The original treated and analyzed surface is composed of metal mixed with remains of surface corrosion, causing a change in the ratios of the analyzed elements. To avoid this effect, as much as possible, each dagger was measured in 2-8 different areas. Alloys with relative quantities higher than 14 wt. % Sn and 3 wt. % Pb were treated as surface enrichment by corrosion. This consideration is based upon the results (Shalev, et al., 2014) of comparing XRF surface analysis of MBII axes from the Rishon le-Zion cemetery to their bulk metal composition, which was determined by neutron diffraction analysis. In this study, it was shown that XRF measurements of less than 14 wt. % Sn and 3 wt. % Pb are in agreement (difference of less than twice to similar) with the content of alloy in the bulk (Table 1a), especially if we take into account a significant inhomogeneity in the cast objects (up to twice in different phases of the as-cast bulk metal). For instance, the variation of the tin concentration inside these axes as determined by neutron diffraction was up to about two times.

In the case of the RL dagger group, only non-destructive XRF surface analyses with the aforementioned limits could be used (due to restrictions on destructive sampling). Therefore, the major aim is limited, by the aforementioned selected surface XRF analyses, to determining a clear compositional difference between the two major different types of daggers found in the same MB II RL cemetery.

In order to test the above compositional results of the axes, if they are indeed valid in the case of the more homogenized daggers, metal samples were taken by drilling and cutting 3 daggers out of the group of 62 objects. The results are presented in Table 1b.

In several cases, when samples could be taken, we determined, for additional control, the 'real' concentrations on the sectioned samples using atomic absorption optical spectroscopy (AAS) and wavelength dispersive spectroscopy (WDS) using an electron microprobe. The data regarding shape of daggers (lengths and widths) were used for all daggers, including the corroded ones.

The data about fully corroded daggers (no points with less than 3 wt. % Pb and 14 wt. % Sn) were not used for subsequent discussions.

Results and Discussion

It is clear from the collected data that the sizes of the ribbed daggers are more standardized than the flat daggers (Table 2a, Figure 3). For instance, the deviations of the length from mean value (177 mm) are about 6 % for ribbed daggers, and deviations for the flat daggers are significantly higher (up to about 14 % for a mean value 147 mm). Thus, the production of the flat daggers seems to be less controlled than in the more decorated ribbed daggers.

The composition of 20 ribbed daggers and 28 flat daggers (excluding fully corroded daggers) are presented in Table 2b and Figure 4. Clearly, there is tendency for a higher tin concentration in the ribbed daggers in comparison with the flat daggers, a trend that has been established in other cases (e.g., El-Morr and Pernot, 2011, Fig. 6). Other significant differences in the composition of the flat daggers in comparison with the ribbed daggers could also be observed. For instance, the majority of the ribbed daggers (19 out of 32) have a relative deviation from mean value of the tin concentration (9.5%) of not more than 20%, in contrast to greater variation for the flat daggers. In comparison, a similar deviation from the mean value of arsenic concentration (1.4 wt. %) is observed in 40 % of flat daggers and from the mean value of tin concentration (3.2 wt. %) in 70 % of flat daggers.

In addition, it is rather interesting that of 32 studied ribbed daggers, 13 are fully corroded, but of 30 flat daggers only 2 are fully corroded. On the other hand, the ribbed daggers contain much more tin than flat daggers. Therefore, we may state that high tin concentration appears to be a contributing factor in the extent of heavy corrosion.

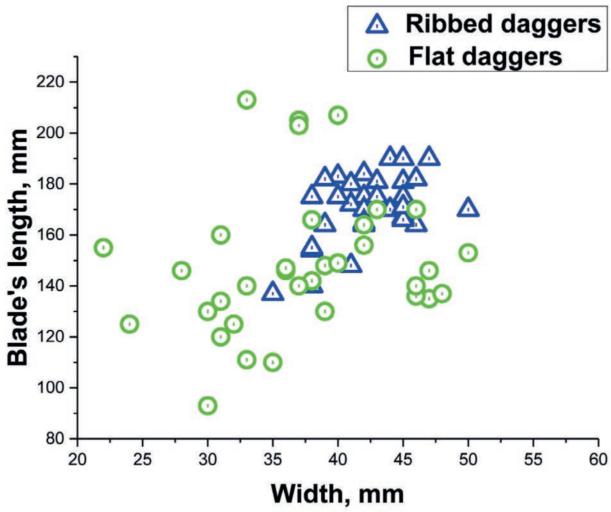

Figure 3. Length to width ratio of daggers.

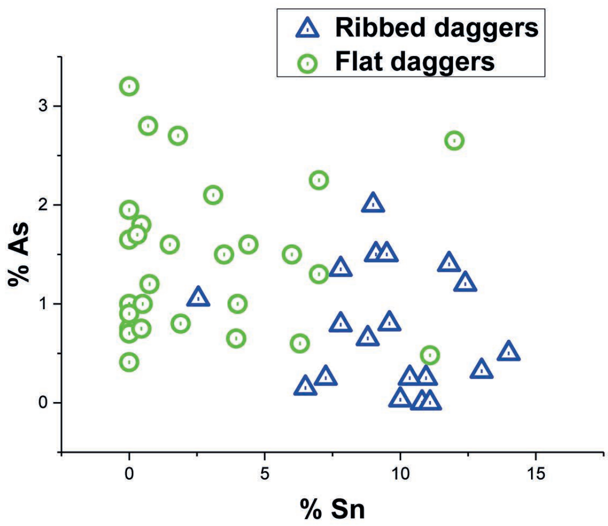

Figure 4. Bi-plot of tin and arsenic values of daggers determined by XRF.

Table 2b. XRF data.

NN	Object	Point	Type	%As	%Pb	%Sn
Ribbed daggers with 5 ribs						
1	L640 B6214	1	A-1	0.65	0.37	7.7
		2		0.68	0.31	7.7
		3		1.04	0.37	8.1
2	L553 B6554	1	A-1	0.2	5.5	16.5
		2		0.2	3	12.2
		3		0.2	10.7	14.6
		4		0.4	4.7	14
		5		0.3	2.5	9.7
		6		0.2	3.6	10.7
		7		0.3	5.4	15.6
		8		0.3	4.2	18.2
3	L1059 B9045	1	A-1	1.1	0.6	12.2
		2		1.3	0.8	12.6
		3		1.5	0.9	14.8
		4		1.6	1.5	15.6
		5		1.7	1.1	16.4
		6		1.1	0.6	12.4
4	L1049 B6955	1	A-1	0.7	6.2	17.2
		2		0.4	7.5	15.1
		3		0	2.6	10.8
5	L1050 B6969	1	A-1	7.5	6.3	
		2		4.6	4.1	
		3		5.2	4.8	
		4		9.4	6.9	
6	L511 B5085	1	A-1	0.3	1.7	8.5
		2		10	22	30
		3		0.2	2	6
7	L768 B8004	1*	A-1	0.3	5.1	11.4
		2		1.6	19	16
		3		0.9	4	14
8	L654 B6394	1	A-1	1.4	0.9	9.8
		2		2.2	1.8	13
		3		0.8	0.5	6.4
9	L686 B6419	1	A-1		11.2	10.7
		2			4.3	10
		3			12.3	14.6
10	L1108 B9409	1	A-1	5.3	17.5	2
		2		4.4	12.3	2.6
		3		9.5	19	2.5
11	L1086 B9294	1	A-1	0.8	0.5	10.5
		2		1.5	2	13
		3		tr	tr	5.3
12	L764 B8077	1	A-1		2.7	10.5
		2		0.1	2.6	9.3
		3			1.8	10.3
13	L656 B6393	1	A-1	2	0.6	10.3
		2		0.8	0.45	8.3
		3		1.6	0.5	9.8
14	L1064 B9081	1	A-1	0.45	4.2	10
		2		0.1	1.7	7.3
		3		0.2	1.4	5.6
15	L1017 B6228	1	A-1	2.5	1.8	0.4
		2		5.5	1.7	
		3		2.3	2.3	
16	L1037 B6872	1*	A-1	3.2	16.9	16
		2		2.8	21	12
		3		0.7	10.3	18
17	L1025 B6724	1	A-1	tr	2.7	11.1
		2		tr	3.5	17
		3		tr	7	17
18	L1031 B6811	1	A-1	1.2	0.8	10.4
		2		1.7	1	11.3
		3		1.4	0.4	14.1
19	L1081 B9233	1*	A-1	1.1	13	17.7
		2		0.6	13	15.6
		3		1	14	19.1
20	L1015 B6687	1	A-1		5.1	13.9
		2		0.8	6.8	17.6
		3		0.5	2.5	14
21	L1085 B9246	1*	A-1	0.4	8.9	13.7
		2			30	65
22	L607 B6084	1*	A-1	1	7.7	26.5
		2		2	13	31
		3		2	13	32
23	L1036 B6924	1	A-1	0.55	tr	5.7
		2		0.5	tr	9.2
		3		0.7		11.6
24	L22 B155	1*	A-1	1.9	4.6	10
		2		1.4	1.8	7.1
		AAS		1.3	2 to 5	7 to 10
Ribbed daggers with 3 ribs						
25	L1051 B6974	1 (near *handle)	A-1	2.6	7.7	0.6
		2 (center)		7.2	10	1.1
		3 (point)		8.3	10.3	1.1
26	L718 B7227	1*	A-1	3.4	4.6	tr
		2		4	5.4	tr
		3		2.7	3.7	tr
27	L1055 B9012	1	A-1	0.15	4.2	21.4
		2		0.3	2.5	13.1
		3		0.2	0.7	7.6
28	L1064 B9114	1	A-1	1.3	1.5	2.3
		2		0.8	1.5	2.8
		3		2.7	4.5	2.2
29	L728 B7603	1	A-1	0.2	4.6	13.1
		2		0.25	2.8	12.6

NN	Object	Point	Type	%As	%Pb	%Sn
		3		0.4	3	13.3
30	L606 B6161	1*	A-1	0	3.8	17.3
		2		0.3	6	26.2
31	L1048 B6945	1*	A-1	4.2	4.8	0.5
		2		7.1	10.4	0.5
		3		3.1	3.9	0.3
32	L647 B6310	1	A-1	0.35	12.6	22.5
		2 (center)		tr	2	9
		3 (blade)		0.4	6.6	14.6
Flat daggers						
33	L755 B7727	1	B-3	2.1	0.2	
		2		1.8	tr	
		3		1.1	0.2	
34	L551 B6598	1	B-4-6	0.56	0.3	3.8
		2		0.56	0.3	3.8
		3		0.83	0.25	4.2
35	L768 B8003	1	B-4-6	1.4	0.3	2.6
		2		2	0.4	3.7
		3		1	0.2	4.1
36	L768 B8030	1	B-4-6	1.9	0.7	6
		2		4.2	3.4	7.8
		3		4.4	3.8	7
		4		2.6	1	8.1
37	L769 B8130	1	B-3	1	0.25	1.4
		2		3.3	0.6	1.5
		3		0.5	0.25	1.7
38	L694 B6447	1	B-3	0.7	0.4	0.5
		2		1	0.55	0.3
		3		3.7	2	0.55
39	L768 B8028	1	B-4-6	1.3	0.3	4.4
		2		2.3	0.5	5.2
		3		1.1	tr	3.7
40	L1064 B9267	1		0.73	0.3	5.1
		2		0.35	1.2	14.5
		3		1.9	0.6	9
41	L1086 B9303	1*	B-8	5.7	8.3	
		2		4.7	5.5	
42	L742 B7304	1		2.3	0.2	
		2		2.6	0.2	
		3		4.6	tr	
43	L1090 B9295	1	B-8	0.85	0.1	tr
		2		0.52	tr	tr
		3		0.78	0.1	tr
44	L742 B7305	1	B-7	0.31	0.8	9
		2		0.75	1	13.2
45	L1069 B9165	1	B-5	2.5	0.5	tr
		2		0.8	0.2	
46	L767 B8002	1	B-3	0.25	tr	
		2		0.71	tr	tr
		3		0.28	tr	
47	L1033 B6830	1	B-3	2.9	1.4	12.7
		2		2.4	0.9	11.3
48	L1027 B6833	1	B-3	2.4	1.25	tr
		2		0.3	0.3	
		3		0.32	0.3	
49	L1031 B6824	1	B-8	0.65	0.4	6.3
		2		0.55	0.45	6.2
		3		0.6	0.4	6.4
50	L1076 B9239	1	B-4-6	0.7	1.3	
		2		0.7	1.5	
51	L1053 B9000	1	B-3	1.67	tr	0.65
		2		1.25	0.15	0.8
		3		0.55	tr	0.85
52	L769 B8133	1	B-3	3.8	1	4.1
		2		0.82	0.25	2.7
		3		1.6	0.4	2.5
53	L1075 B9206	1	B-4-6	9.4	4	4
		2		6.9	4	3.6
		3		2.7	2.1	1.8
54	L1017 B6868	1	B-8	0.4		
		2		0.7		
		3		1.7	tr	
55	L100 B1038	1	B-3	0.6	tr	0.3
		2		0.64	tr	0.3
		3		0.65	0.1	0.5
		AAS		0.8	0.1	0.6
		WDS		0.9 to 2.0	0.04	0.4
56	L705 B7016	1	B-3	1.7	0.9	6.3
		2		1.2	0.5	6.3
		3		1	0.5	6
		WDS		2.1	0.5	5.2
57	L743 B7324	1	B-4-6	0.2	1	13.4
		2*		0.3	1.2	18.7
58	L641 B6202	1	B-3	1.3	2	0.5
		2		3	7.2	tr
		3		2.1	2.9	tr
59	L209 B2818	1	B-3	1.3	tr	tr
		2		0.7	tr	0.8
		3		1.1		0.8
60	L25 B184	1	B-3	1	0.2	1.8
		2		0.6	0.2	1.8
		3		0.9	0.2	2.1
61	L94 B1250	1	B-3	1.25	0.8	4.7
		2		0.7	0.9	3.5
		3		0.9	0.5	3.8
62	L268 B3249	1	B-3	2	0.6	0.7
		2		2.4	0.9	0.6
		3		4	1.7	0.8

As there is no clear dating for the contexts in the Rishon le-Zion graves, other dated parallels for these daggers types from other burial sites in the southern Levant are needed, in order to determine which alloy was used in which period. It seems that the ribbed daggers contain higher tin concentrations than flat daggers and can be dated to the MB IIA and the early MB IIB according to parallels from other archaeological sites in the southern Levant. The flat daggers which according to their archaeological context can be dated mostly to the MB IIB period contain more arsenic (As) than tin (Sn).

Conclusion

A rich collection of MB II daggers was studied by non-destructive XRF method. The described results fit well within a model of gradual transition from less controlled production of the flat daggers composed of arsenical copper to better controlled production of the more decorated ribbed daggers produced from tin-bronze. According to the dating of these two groups of ribbed daggers and flat daggers, it may be concluded that, while the assumption that the use of arsenical copper would precede that of tin-bronze, the archaeological and scientific data indicate the use of both alloy types contemporaneously.

Therefore, this innovative result may be explained as an outcome of social circumstances that are particular to the MB IIA, as well as economic and political developments in the wider region, including the expansion of trade networks, which enabled the circulation of the principal raw materials, such as copper and tin. As there are no tin sources in the Levant and no evidence that local copper sources were exploited at this time (Levy, Najjar and Ben-Yosef, 2014; Yahalom-Mack, et al., 2014, p.173), a priori, either the raw materials or the finished products must have been brought to the Levant. Trade routes that connected Mesopotamia with Anatolia as well as the Levant in the early second millennium are well-documented in both texts and from archaeological evidence. The Mari and Kültepe/*karum* Kanish archives from the MB IIA support this portrait of long-distance trade connections and provide some detailed information about the metal supply system during this period, mainly of copper and tin (Bonacossi, 2014, p.429; Kulakglu, 2010; Larsen, 2015, pp.171-189).

In the second half of the Middle Bronze Age (MB IIB), with the increased Asiatic presence in the eastern part of the Egyptian Delta, trade contacts with Anatolia decreased (Ben-Tor, 2011, p.27; Oren, 1997). These extensive political and socio-economic changes in the MB II period may explain the change in availability of raw materials and metal products‘ change in composition, but need to be further explored, analytically and quantitatively.

Acknowledgements

We thank the Israeli Antiquity Authority (IAA) and especially the excavator of the Rishon le-Zion cemetery, Y. Levi, and the IAA conservation laboratory, headed by Z. Greenhut, for their ample help and important cooperation. We also thank the IAA photographer for the photos.

We would like to thank the reviewers for most helpful advises comments and suggestions which made this paper more clear, accurate and relevant. We would also like to thank E. Marcus for his helpful advises and editing.

Kan-Cipor-Meron prepared the typology of the objects and historical- archaeological explanation, Shilstein and Shalev conducted the analyses, and Shalev processed the raw data and wrote the archaeometallurgical synthesis.

References

Ben-Tor, D., 2011. Egyptian-Canaanite Relations in the Middle and Late Bronze Ages as Reflected by Scarabs. In: S. Bar, D. Kahn and J. J. Shirley, eds. 2011. *Egypt, Canaan and Israel: History, Imperialism, Ideology and Literature. Proceeding of Conference at the University of Haifa, 37 May 2009*. Leiden: Brill. pp.23-44.

Bonacossi, D. M., 2014. The Northern Levant (Syria) During the Middle Bronze Age. In: M. L. Steiner and A. E. Killebrew, eds. 2014. *The Oxford Handbook of the Archaeology of the Levant, c. 8000-332 BCE*. Oxford: Oxford University Press. pp.414-433.

Budd, P., Pollard, A. M., Scaife, B. and Thomas, R. G., 1995. Oxhide ingots, recycling and the Mediterranean metal trade. *Journal of Mediterranean Archaeology*, 8(1), pp.1-32.

Bunimovitz, S., 2000. Metal Artefacts – Typological Discussion. In: M. Kochavi, P. Beck, and E. Yadin, eds. 2000. *Aphek-Antipatris* I. Tel Aviv: Tel-Aviv University. pp.265-277.

Damati, E. and Stepansky, Y., 1996. A Middle Bronze Age II Burial Cave on Mt. Canaan, Zefat (Wadi Hamra). *Atiqot*, 29, pp.1-29.

Doumet Serhal, C., 2003. Weapons from the Middle Bronze Age Burials at Sidon. *Archaeology and History in Lebanon*, 18, pp.38-57.

Doumet-Serhal, C. and Kopetzky, K., 2011/2012. Sidon and Tell el-Dab'a: Two Cities-One Story: A Highlight on

Metal Artefacts from the Middle Bronze Age Graves. *Archaeology and History in the Lebanon*, 34, pp.9-52.

El Morr, Z., 2011. *La metallurgie du Levant au Bronze Moyen à travers les armes*. PhD, Archéologie et Préhistoire, Université Michel de Montaigne, Bordeaux III.

EL Morr, Z., 2017. Metal and society in Middle Bronze Age Byblos. In: B. Armbruster, A. Gorgue and K. Rebay-Salisbury, eds. 2017. *Materials chains in Late Prehistoric Europe and the Mediterranean*, Memoires, Edition Ausonius, Bordeaux, pp.123-140.

El Morr, Z. and Pernot, M., 2011. Middle Bronze Age Metallurgy in the Levant: Evidence from the Weapons of Byblos. *Journal of Archaeological Science*, 38, pp.2613-2624.

El Morr, Z. and Mödlinger M., 2014. Middle Bronze Age Metal artifacts and Metallurgical practices at the sites of Tell Arqa, Mougharet el-Hourryieh, Yanouh and Khariji in Lebanon. *Levant*, 46/1, pp.27-42.

Garfinkel, Y., 2001. Warrior Burial Customs in the Levant during the Early Second Millennium B.C. In: S. R. Wolff, ed. 2001. *Studies in the Archaeology of Israel and the Neighboring Lands*. Chicago, Il.: Oriental Institute of the University of Chicago. pp.143-161.

Gernez, G., 2007. *L'armement en métal au Proche et Moyen-Orient, Des origines à 1750 av. J.-C.* PhD, University of Paris I, Panthéon-Sorbonne, Paris.

Gernez, G., 2008. Le métal de Tell Arqa à l'Age du Bronze. *Bulletin d'archéologie et d'architecture libanaise*, 12, pp.221-264.

Gernez, G., 2012. La Collection D'Objects en Bronze DeTell Sougha (ca. 2000AV.J-C) Et La Question Des „Porteurs De Torques" Au Levant. *Syria*, 89, pp.101-127.

Gershuny, L. and Aviam, M., 2010. Middle Bronze Age Tombs at Fassuta. *Atiqot*, 62, pp.17-42.

Getzov, N. and Nagar, Y., 2002. Graves from the Middle Bronze Age II. In: Z. Gal, ed. 2002, *Eretz Zafon*. Jerusalem: Israeli Antiquities Authority, pp.1-49. (in Hebrew)

Golden, J., Levy, T. E. and Hauptmann, A., 2001. Recent Discoveries concerning Chalcolithic Metallurgy, *Journal of Archaeological Sciences*, 28, pp.951-963.

Hallote, R. S., 1995. Mortuary Archaeology and the Middle Bronze Age Southern Levant. *Journal of Mediterranean. Archaeology*, 8, pp.93-122.

Hallote, R. S., 2001. Tombs, Cult and Chronology: A Reexamination of the Middle Bronze Age Strata of Megiddo. In: S. R. Wolff, ed. 2001. *Studies in the Archaeology of Israel and the Neighboring Lands*. Chicago Il.: Oriental Institute of the University of Chicago. pp.199-214.

Hallote, R. S., 2002. Real and Ideal in Middle Bronze Age Tombs. *Near Eastern Archaeology*, 65, pp.105-111.

Kan-Cipor-Meron, T., 2017. *Metal Weapons of Middle Bronze Age II in the Eastern Basin of the Mediterranean Sea – Economical and Social Aspects*. PhD, University of Haifa. (in Hebrew)

Kan-Cipor-Meron, T. and Salev, S., 2018. Metal Finds. In: Y. Levi and R. Kletter, eds. 2018. *Rishon le-Zion, The Middle Bronze Age II Cemeteries*, Volume I/2: Finds and Conclusions. Münster: Zaphon. pp.493-542.

Kan-Cipor-Meron T., Shilstein S., Levi Y. and Shalev S., 2018. A comparison study of Middle Bronze Age II daggers and their rivets as a tool for a better understanding of their production. *Archaeometry*, 60 (3), pp. 535-553.

Key, C. A., 1980. The Trace Element Composition of the Copper and Copper Alloys of the Nahal Mishmar Hoard. In: P. Bar-Adon, ed. 1980. *The Cave of Treasures*. Jerusalem: Israel Exploration Society. pp.238-243.

Kletter, R. and Levi, Y., 2016. Middle Bronze Age Burials in the Southern Levant: Spartan Warriors or Ordinary People? *Oxford Journal of Archaeology*, 35, pp.5-27.

Kulakglu, F., 2010. Kultepe Kanesh Karum: The Earliest International Trade Center in Anatolia. In: F. Kulakoglu and S. Kangal, eds. 2010. *Anatolia's Prologue Kultepe, Kanesh, Karum: Assyrians in Istanbul*. Kayseri, Turkey: Kayseri Metropolitan Municipality. pp.40-51.

Larsen, M. T., 2015. Ancient Kanesh. *A Merchant Colony in Bronze Age Anatolia*. Cambridge: Cambridge University Press.

Levy, T. E, Najjar, M. and Ben-Yosef, E., 2014. The Iron Age Edom Lowlands Regional Archaeology Project: Research, Design, and Methodology. In: T. E. Levy, M. Najjar and E. Ben-Yosef, eds. 2014. *New Insights into the Iron Age Archaeology of Edom, Southern Jordan*. Los Angeles: UCLA Cotsen Institute of Archaeology Press. pp.1-86.

Levi, Y. and Kletter, R., 2018. *Rishon le-Zion, The Middle Bronze Age II Cemeteries Volume I/2: Finds and Conclusions*. Zaphon: Münster.

Maxwell-Hyslop, R., 1946. Daggers and Swords in Asia. *Iraq*, VIII, pp.1-65.

Miron, E., 1992. *Axes and Adzes from Canaan. Prähistorische Bronzefunde Series*, 19. Wiesbaden: Franz Steiner.

Oren, E. D., 1997. The Hyksos Enigma - Introductory Overview. In: E. D. Oren, ed. 1997. *The Hyksos: New Historical and Archaeological Perspectives*. Philadelphia: University of Pennsylvania Museum. pp.XIX–XVI.

Philip, G., 1989. *Metal weapons of the Early and Middle Bronze Ages in Syria-Palestine. BAR International Series*, 526. Oxford: British Archaeological Reports.

Philip, G., 1991. Tin, arsenic, lead: alloying practices in Syria-Palestine around 2000 B.C. *Levant*, 23, pp.93-104.

Philip, G., 1995a. Tell el-Dab'a metalwork patterns and purpose, In: W. V. Davies and L. Schofield, eds. 1995. *Egypt, the Aegean and the Levant*. London: British Museum Press. pp.66-83.

Philip, G., 1995b. The same but different: a comparison of Middle Bronze Age metalwork from Jericho and Tell ad-Dab`a. *Studies in the History and Archaeology of Jordan*, 5, pp.523-530.

Philip, G., 1995c. Warrior burials in the ancient Near-Eastern Bronze Age: the evidence from Mesopotamia, western Iran and Syria–Palestine. In: S. Campbell and A. Green, eds. 1995. *The archaeology of death in the ancient Near East*. Oxford: Oxbow Books. pp.140-154.

Philip, G., 2006. *Tell el-Dab'a XV: metalwork and metalworking evidence of the Late Middle Kingdom and the Second*

Intermediate Period. Wien: Verlag der österreichischen Akademie der Wissenschaften.

Shalev, S., 1996. Archaeometallurgy in Israel: The Impact of the Material on the Choice of Shape, Size and Color of Ancient Products. In: S. Demirci, A. M. Özer and G. D. Summers, eds. 1996. *Archaeometry 94: The Proceedings of the 29th International Symposium on Archaeometry, Ankara 9-14 May* 1994. Ankara: Tübitak. pp.11-15.

Shalev, S., 1997. Metal Objects from Hazor. In: A. Ben-Tor and R. Bonfil, eds. 1997. *Hazor V: An Account of the Fifth Season of Excavations, 1968. Jerusalem*: Israel Exploration Society. pp.348-352.

Shalev, S., 2000. Metal Artifacts: Archaeometallurgy. In: M. Kochavi, P. Beck and E. Yadin, eds. 2000. *Aphek - Antipatris I*. Tel-Aviv: Tel-Aviv University. pp.278-287.

Shalev, S., 2002. Metal Artifacts. In: A. Kempinski, ed. 2002. *Tel Kabri – The 1986-1993 Excavation Seasons*. Tel-Aviv: Tel-Aviv University. pp.307-318.

Shalev, S., 2009. Metals and society: production and distribution of metal weapons in the Levant during the Middle Bronze Age II. In: S. Rosen and V. Roux, eds. 2009. *Techniques and people: anthropological perspectives on technology in the archaeology of the proto-historic and early historic periods in the southern Levant*. Paris: De Boccard. pp.69-80.

Shalev, S., 2010. The Metal Objects from Fassuta. *Atiqot*, 62, pp.43-49.

Shalev, S., Caspi, E. N., Shilstein, S., Paradowska, A. M., Kockelmann, W., Kan-Cipor-Meron, T. and Levy, T., 2014. Middle Bronze Age II battle-axes from Rishon le-Zion, Israel: archaeology and metallurgy. *Archaeometry*, 56, pp.279-295.

Shalev, S., Shilstein, S. S. and Yekutieli, Y., 2006. XRF study of archaeological and metallurgical material from an ancient copper-smelting site near Ein-Yahav, *Talanta*, 70, pp.909-913.

Shilstein, S. S. and Shalev, S., 2011. Making sense out of cents: compositional variations in European coins as a control model for archaeometallurgy. *Journal of Archaeological Sciences* 8, 38, pp.1690-1698.

Yahalom-Mack, N., Galili, E., Segal, I., Eliyahu-Bahar, A., Boaretto, E., Shilstein, S. and Finkelstein, I., 2014. New insights into Levantine copper trade: analysis of ingots from the Bronze and Iron Ages in Israel. *Journal of Archaeological Science*, 45, pp.159-177.

Ziffer, I., 1990. *At That Time the Canaanites were in the Land: Daily Life in Canaan in the Middle Bronze Age 2, 2000–1550 B.C.E.* Tel Aviv: Eretz-Israel Museum.

Authors

Tal Kan-Cipor-Meron (Corresponding Author)
The Leon Recanati Institute for Maritime Studies
University of Haifa,
Mount Carmel, Haifa 31905, Israel
Charney School of Marine Sciences, University of Haifa
Department of Archaeology University of Haifa,
Mount Carmel, Haifa 31905, Israel
tkan-cipo@staff.haifa.ac.il

Sana Shilstein
Faculty of Physics
Weizmann Institute of Science
234 Herzl St. Rehovot, Israel
Leon Recanati Institute for Maritime Studies
University of Haifa
Mount Carmel, Haifa 31905, Israel
sana.shilstein@weizmann.ac.il

Yosi Levi
Israel Antiquities Authority,
POB 586 Jerusalem 901004, Israel
yosi@israntique.org.il

Sariel Shalev
Leon Recanati Institute for Maritime Studies
University of Haifa
Mount Carmel, Haifa 31905, Israel
Charney School of Marine Sciences
Department of Archaeology, University of Haifa
Mount Carmel, Haifa 31905, Israel
Weizmann Institute of Science
234 Herzl St. Rehovot, Israel
sariel.shalev@univ.haifa.ac.il

2018 | Nr. 24.1

METALLA

DBM

METALLA (Bochum)
Biannual journal (June/December)

Standing Order Price: 15 € per issue.
Single Order: 20 €.
Prices include postage and handling.

For orders contact Stephen Merkel at the
Deutsches Bergbau-Museum Bochum
Am Bergbaumuseum 31,
D-44791 Bochum, Germany
StephenWilliam.Merkel@Bergbaumuseum.de

Impressum

Publisher

Deutsches Bergbau-Museum Bochum
Museum Director: Prof. Dr. Stefan Brüggerhoff

Layout Design: Dipl. Ing. Angelika Wiebe-Friedrich

Printing: Print Art GmbH, Bochum

ISSN 0947-6229

Cover Images

1. Detail of a selection of finds from Třísov, an Iron Age *oppidum* in the Czech Republic. Metal objects such as these have been subjected to geochemical analysis, and conclusions regarding the metal supply at this settlement are presented by Danielisová, et al. Photo: A. Danielisová.

2. Detail of an elaborately decorated multi-ribbed dagger from a Middle Bronze Age II burial at Rishon le-Zion, Israel. This and other examples of MBA II daggers from burials from this site have been analyzed non-destructively to discuss the interrelationship of form and alloy and to gain information about technology and the supply of raw materials. See contribution by Kan-Cipor-Meron, et al. Photo courtesy of the Israeli Antiquity Authority.

3. Sampling of numerous Roman lead ingots has been carried out during the Corpus of Roman Lead Ingots (CRLI)-project. The present work discusses the analysis and historical context surrounding a special ingot with the inscription *metallo Messallini*. The contribution of Rothenhöfer, Bode and Hanel shows how the convergence of natural science, ancient history and archaeology can create a new and deeper understanding of past events. Photo: Rothenhöfer.

4. A cluttered office desk is commonplace in many professions. Archaeometallurgy is no exception. Writing and desk-based research belong to the daily life of archaeometallurgists, regardless of background, scientific training or career stage. The article of Sabatini and Mödlinger presents and discusses the results of an anonymous survey among archaeometallurgists that explores many aspects of this scientifically and socially diverse field. Photo: Mödlinger.

metallum, i, n:
Mine (often pl.)
Metal, also stone, mineral

μεταλλον, το:
Mine, shaft, gallery;
esp. a) Mine (usually pl.)
b) Quarry

Contents

DBM
Deutsches Bergbau-Museum Bochum

ISSN 0947-6229