This pdf of your paper in *Eastern Mediterranean Metallurgy* belongs to the publishers Oxbow Books and it is their copyright.

As author you are licenced to make up to 50 offprints from it, but beyond that you may not publish it on the World Wide Web until three years from publication (May 2015), unless the site is a limited access intranet (password protected). If you have queries about this please contact the editorial department at Oxbow Books (editorial@oxbowbooks.com).
## Contents

*Preface* by V. Kassianidou and G. Papasavvas vii  
*List of contributors* xi  
*Abbreviations* xiv

1. Reminiscences: working with Jim Muhly  
   *R. Maddin*  
   1

2. Late Bronze Age copper production in Cyprus from a mining geologist’s perspective  
   *G. Constantinou*  
   4

3. Metallurgical production and trade on Bronze Age Cyprus: views and variations  
   *A. B. Knapp*  
   14

4. Pyrgos-Mavrorachi in Cypriot metallurgy  
   *M. R. Belgiorno, D. Ferro and D. R. Loepp*  
   26

5. Tinker, tailor, farmer, miner: metals in the Late Bronze Age economy at Kalavasos  
   *A. K. South*  
   35

6. Standing on ceremony: the metallurgical finds from Maroni-Vournes, Cyprus  
   *R. C. P. Doonan, G. Cadogan, and D. Sewell*  
   48

7. From regional gateway to Cypriot kingdom. Copper deposits and copper routes in the chora of Paphos  
   *M. Iacovou*  
   58

8. The role of the Apliki mine region in the post c. 1400 BC copper production and trade networks in Cyprus and in the wider Mediterranean  
   *N. H. Gale and Z. A. Stos-Gale*  
   70

9. ‘Reconstructing’ the Enkomi tombs (British excavations): an instructive exercise  
   *D. Pilides*  
   83

10. Metallurgy and metalwork in Enkomi: the early phases  
    *V. Kassianidou*  
    94

11. The Enkomi cup: niello versus *kuwano*  
    *A. Giumlia-Mair*  
    107

12. Profusion of Cypriot copper abroad, dearth of bronzes at home: a paradox in Late Bronze Age Cyprus  
    *G. Papasavvas*  
    117
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Author(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Cyprus and Crete: the transformation of the Minoan metalworking industry</td>
<td>P. P. Betancourt</td>
<td>129</td>
</tr>
<tr>
<td>14</td>
<td>Metallurgy and metalworking in the harbour town of Knossos at Poros-Katsambas</td>
<td>N. Dimopoulou</td>
<td>135</td>
</tr>
<tr>
<td>15</td>
<td>Cyprus and Sardinia, beyond the oxhide ingots</td>
<td>F. Lo Schiavo</td>
<td>142</td>
</tr>
<tr>
<td>16</td>
<td>On the cessation of local copper production in the Aegean in the 2nd millennium BC</td>
<td>Y. Bassiakos and T. Tselios</td>
<td>151</td>
</tr>
<tr>
<td>17</td>
<td>Late Bronze Age Alalakh and Cyprus: a relationship of metals?</td>
<td>K. A. Yener</td>
<td>162</td>
</tr>
<tr>
<td>18</td>
<td>The evidence for metallurgical workshops of the 2nd millennium in Ugarit</td>
<td>E. Dardaillon</td>
<td>169</td>
</tr>
<tr>
<td>19</td>
<td>The merchants of Ugarit: oligarchs of the Late Bronze Age trade in metals?</td>
<td>C. Bell</td>
<td>180</td>
</tr>
<tr>
<td>20</td>
<td>A unique casting mould from the new excavations at Timna Site 30 (Israel): evidence of western influence?</td>
<td>E. Ben-Yosef</td>
<td>188</td>
</tr>
<tr>
<td>21</td>
<td>New perspectives on Iron Age copper production and society in the Faynan region, Jordan</td>
<td>T. E. Levy, E. Ben-Yosef and M. Najjar</td>
<td>197</td>
</tr>
<tr>
<td>22</td>
<td>Alloying and resource management in New Kingdom Egypt: the bronze industry at Qantir – Pi-Ramesse and its relationship to Egyptian copper sources</td>
<td>T. Rehren and E. B. Pusch</td>
<td>215</td>
</tr>
<tr>
<td>23</td>
<td>On ancient tin and tin-bronze in the Asian Old World: further comments</td>
<td>V. C. Pigott</td>
<td>222</td>
</tr>
<tr>
<td>24</td>
<td>Just a few rusty bits: the innovation of iron in the Eastern Mediterranean in the 2nd and 1st millennia BC</td>
<td>H. A. Veldhuijzen</td>
<td>237</td>
</tr>
</tbody>
</table>

Colour Plates 251
This paper presents a small copper ingot mould, which probably dates to the 11th century BC, recently unearthed in the Timna Valley, Israel. Clay moulds are extremely rare in the archaeological record, and very few are reported from Iron Age contexts in the southern Levant. The mould has general features of the oxhide ingot type (Buchholz’s type 2 and sub type 3) and may link the southern Levant with the Mediterranean world at the end of the 2nd millennium BC. Furthermore, the presence of a casting mould in a major primary smelting site, its extremely fragile texture and growing evidence of similar finds in other parts of the southern Levant give some insight into the materials used for casting ingots in antiquity.

In recent years there have been ongoing research efforts to reassess the Iron Age copper exploitation in the southern Levant with a focus on the archaeometallurgical sites at Faynan, Jordan (Levy et al. 2004; Levy et al. 2008a; Levy et al. this volume; Ben-Yosef et al. 2010). As part of these efforts we have revisited Site 30 in Timna, Israel, the only site in the southern Arabah that was published as an Iron Age II smelting camp (Layer I) (Rothenberg 1980) (Fig. 20.1). The main goal of the new project (UCSD and HUJI, see acknowledgments below) was to establish the chronology of the site using careful excavation methods in limited probes from surface to bedrock, accompanied by a large suite of Accelerator Mass Spectrometry (AMS) radiocarbon dates. The results of the excavations (carried out during the spring of 2009) have changed completely the previous chronological framework of the site and called for a comprehensive revision of the chronological framework for the Late Bronze and Iron Age copper exploitation in the southern Arabah and the Timna Valley (Ben-Yosef et al. forthcoming). In essence, eleven new AMS radiocarbon dates based mostly on short-lived samples show that the site was occupied only between the late 12th/11th and 9th centuries BC, similar to the activity patterns identified recently for Iron Age Faynan. Unlike the so-called ‘Egyptian sanctuary’ (Site 200) located nearby, Site 30 does not have any evidence of LBA – New Kingdom occupation (14th–12th centuries BC) as was previously believed. The new chronological framework for Site 30 is the basis for ongoing comparative studies of the Iron Age copper exploitation in Timna and Faynan, and for an archaeomagnetic study of the slag deposits of the site (Shaar et al. 2011).

Site 30 is located in the southern Arabah Valley, among several other sites that were intensively investigated by Beno Rothenberg and the Arabah Expedition between 1959 and 1984 (Fig. 20.1). This pioneering archaeometallurgical research concluded that most of the copper smelting remains visible in this region belong to the LBA and were operated under Egyptian New Kingdom control, probably by a local semi-nomadic population (Rothenberg 1999). Site 30 is one of the largest smelting camps in the region, extending over little less than one acre and surrounded by a stone-built fence (Fig. 20.2). It was excavated in 1974 and 1976 (Bachmann and Rothenberg 1980; Rothenberg 1980), and the results of these excavations were the basis of several important technological studies and experimental reconstructions concerning ancient metal production (e.g. Bamberger and Wincierz 1990; Merkel 1990; Rothenberg 1990). In the middle of the site there is a c. 2m high ‘slag mound’ that was partially excavated in the 1970s (Fig. 20.2). According to the publications of the Arabah Expedition, this small mound represents the entire chronology of the site and includes three stratigraphic layers that span the 14th–12th and the 10th centuries BC (Rothenberg 1980) (Fig. 20.3). As our primary goal was to clarify the chronology of the site we focused on re-excavating and cleaning the section exposed by the Arabah Expedition on the east side of the ‘slag mound’ in addition to excavating 2.5 × 5m probe in an undisturbed metallurgical area nearby.

The results of the excavations of Site 30 and their chronological implications will be published elsewhere. Here we are concerned with a unique artefact associated with the main ‘slag mound’ in the centre of the site. While clearing the old section and preparing it for sampling (Fig.
20.3), we uncovered a fragment of a casting mould with parts of three edges intact (Figs 20.4–20.5). The fragment is c. 20 × 17cm in size and has a well defined narrow curve where probably the narrower end of the original elongated mould was. This curve is clearly the meeting point of two broken ‘handles’. The other edges of the originally long side are slightly curved inwards towards the centre of the original mould (concave) and it seems that the complete mould was more or less symmetrical. The edges are about 2cm wide and they rise up to 3cm above the surface of the mould. The thickness of the bottom ranges between 2 and 3cm. Our reconstruction of the complete mould appears in Fig. 20.6 and indicates a mould for a c. 50cm long and 20cm wide ingot, with four 17cm tapering ‘handles’. The ingot could be up to 3cm thick. This suggestion is based on the assumption of symmetry and the necessity to reconstruct a closed shape that could maintain the liquid copper. The lack of any other known metal tools or ingot shapes that might fit this mould fragment (as far as we are currently aware) supports our suggestion. Furthermore, the primary smelting sites of the southern Levant show no evidence of bronze production (all the reported final products were usually small copper pins, figurines and other ‘trinkets’, e.g. Gale et al. 1990), and since utilitarian tools in the early Iron Age southern Levant were usually made of bronze (and increasingly iron) we strongly believe that the mould fragment represents an ingot and not a final metal product; this is in accordance with the interpretation of a few other small ceramic fragments found at Timna by the Arabah Expedition (see below).

The mould is handmade and consists of unfired reddish clay with 1–2mm fragments of slag (Fig. 20.4C); it has signs of use with some evidence of heat impact and gray and black residues on the casting surface (Fig. 20.4A). The
The mould fragment is extremely fragile and was broken when we attempted to lift it in the field (Fig. 20.4). A small part from the edge was completely decomposed when it broke; the other was glued in the conservation laboratory at the Hebrew University of Jerusalem.

Unfortunately, the mould was not found directly in the cleaned section of the ‘slag mound’. Its exact context (locus 900, basket 501) was in the lower part of the collapse material from the original section excavated in the 1970s. As mentioned above, the entire section of the ‘slag mound’ from which the mould was retrieved now dates between the 11th and 9th centuries BC (no earlier than 1130 BC, modelled calibrated 2-sigma age boundary, see Shaar et al. 2011). Based on its relative elevation, context, and the new AMS dates, it is reasonable to assume that the mould dates to the 11th century BC.

The basic features of the Timna 30 mould recall the oxhide type of ingots found in various locations around the Mediterranean (e.g. Yalcin et al. 2005; Lo Schiavo et al. 2009). Although oxhide ingots show a wide variety of forms, sometimes even in a single context (e.g. Bass 1967), the common type has relatively large dimensions and weighs up to about 40kg; for example, the oxhide ingots from the Cape Gelidonya wreck (where more than 34 ingots were found, most of them complete or nearly complete pieces) are about 4cm thick and average 60 × 45cm in length and width. Estimations of weight for complete ingots range between 16 and 25kg (Bass 1967). Three of the largest copper ingots, said to originate from Enkomi, measure up to 72 × 42cm, have a thickness of 3.75–5.5cm and weigh up to 39.18kg (Kassianidou 2009, 43) (Fig. 20.7). The oxhide ingots have been studied for more than a century and were the focus of various studies concerning their provenance (e.g. Gale 1991), typology and chronology (e.g. Buchholz 1959; Bass 1967),
iconographic representation and symbolic meanings (e.g. Papasavvas 2009), role in trade and international connections (e.g. Knapp and Cherry 1994; Kassianidou and Knapp 2005) and more. Hundreds of fragments of such ingots have been found (see distribution map in Maddin 2009, 497), while the main assemblages of complete ingots come from the two well-studied shipwrecks found along the coast of Turkey, near Uluburun (c. 1300 BC, Yalçin et al. 2005) and near Cape Gelidonya (c. 1200 BC, Bass 1967).

Although the mould found at Timna 30 represents an ingot that is quite different in size and dimensions from the common oxhide type, it does resemble what Buchholz labeled as ‘type 2’ (the outward curvature of the elongated sides) and ‘sub-type 3’ (the narrow angle between the two handles on each narrow side) (1959, 7) (Fig. 20.6). ‘Type 3’, according to Buchholz and Catling (1964, 281), is the latest type, common around 1200 BC and later. However, the chronology of the different types is debated (e.g. Bass 1967); probably there is no direct connection between typology and age, and the ingot inventory for each period varied in shapes and sizes. General parallels to the shape of the Timna 30 mould can also be found in the iconography of the oxhide ingots (see in particular Buchholz 1959; Bass 1967; Papasavvas 2009). Some of these parallels are presented in Fig. 20.7 and include the Knossos tablets, the Bomford figurine, miniature bronze ingots from Cyprus (probably from Enkomi) and a painting from an Egyptian tomb. All these depictions have a narrow curve connecting the handles at each end, and a slight inward curvature of the long edges. Interestingly, some of the tin ingots from
the Uluburun shipwreck have similar shapes to the Timna 30 mould (Pulak 1998, fig. 13; 2000, fig. 21–22).

Except for the shipwreck assemblages mentioned above, relatively few complete ingots were recovered from the archaeological record around the Mediterranean. Most of the finds consist of fragments, some of which are rather small, and some may represent smaller ingots with a narrower connection of the handles similar to the shape of the Timna 30 mould (e.g. Lo Schiavo 1998, fig. 9:1? 12:12?), although it is often hard to reconstruct the entire shape of the artefact. The majority of the finds from land sites are from the three Mediterranean islands of Cyprus, Crete and Sardinia, with lead isotope studies showing that most of the ingots, even those found in Sardinia, originate in the Cypriot copper mine fields (Gale 1999; Hauptmann 2009). The oxhide ingots are therefore commonly interpreted as representing an ‘island oriented’ trade network, and as having unique economic as well as symbolic significance for the metal workers and traders of those islands in particular (e.g. Papasavvas 2009). The use of ingots of the oxhide shape lasted for a few centuries, at least into the 11th century BC, with little known about the intensity and means of metal trade in the successive period of the Iron Age. Although copper was gradually replaced with iron, it was
still a major factor in the economy of the Mediterranean at least in the early part of this period.

The destination of the copper products from Timna during the heyday of Mediterranean metal trade in the later part of the Late Bronze Age has not been thoroughly assessed. It was generally assumed that it ended up in Egypt and was considered a rather local southern Levantine – Egyptian exploitation (e.g. Ogden 2000). As mentioned above, we now know that the extensive smelting operation at Site 30 took place somewhat later, and the mould probably represents the shape of an 11th century BC ingot. There are two ways to interpret the typology of this artefact; it can be related to the Mediterranean world of oxhide ingots (homologous) or it may be the result of local development, and the similarity is simply because of the utility of the shape (analogous). There are strong reasons to believe that the metalsmiths of Timna during the 11th century BC were aware of the common metal trade customs of the Mediterranean world including the preferred shapes of ingots. They may have adjusted the prototype a little to suit their needs or to identify themselves among the other production centres, but the typological influence came from the west, and the smaller mining district adopted the dominant fashion. We should also mention here the intriguing, albeit controversial, suggestion of Rothenberg (1998) that the copper workers at Timna (the ‘Midianites’) can be seen as one of the Sea Peoples immigrating to this region at the end of the Late Bronze Age. Rothenberg based his arguments on characteristics of the local pottery and a few local rock drawings that depict the metalsmiths with costumes similar to those of the Sea Peoples in Egyptian art. The Timna 30 mould with its oxhide features fits such a reconstruction well, which may explain the origin of its typology. There is not enough field (or other) evidence to support Rothenberg’s suggestion; nevertheless, extensive immigration of ‘Sea Peoples’ did take place around this time in the Eastern Mediterranean and Egypt, and it is possible that some of those immigrants were specialists in metalwork and influenced the local industry, if only by spreading new ideas of technology and style.

Interestingly, in Egypt, the probable destination of the copper ingots from Timna.
Timna copper, there is a depiction of several ingots that show some similarity to the Timna 30 mould. They are drawn on the walls of the Ramses III (1192–1160 BC) temple at Medinet Habu, not far from the drawings of the Egyptian battles against the Sea People (Fig. 20.8). The ingots are depicted in two different sizes, both having a very narrow curve at their narrow ends, and slight inward curvature on their long edges. These may represent ingots from the southern Arabah, possibly shipped by boats through the Gulf of Aqaba and the Red Sea. Buchholz notes on his ingot distribution map (1959, 14) a ‘type 3’ ingot at ‘Ezion-Geber’, the Biblical port of King Solomon. The actual site is Tall el-Kheleifeh, located at the head of the Gulf of Aqaba and excavated by Nelson Glueck in the late 1930s (Glueck 1939). Reassessment of the excavated material indicated occupation no earlier than the 8th century BC (Pratico 1993) (thus the identification of the site as Biblical Ezion-Geber is probably not valid). In any case, a ‘type 3’ oxhide ingot on a port site may further connect the inventory of the Arabah to Egypt and the Mediterranean. Unfortunately we could not track down the publication of this artefact.

Another possible interpretation of the typology of the mould from the southern Arabah is not connected to the Mediterranean world of the Late Bronze Age. Buchholz (1959, 23) offers two examples of ingots similar in shape to the Timna 30 mould (Fig. 20.9). One is a gold ingot from Zimbabwe and the other is tin ingot from southern England. The fact that those ingots are made of different materials and originate from remote locations suggests that the shape developed separately, solely due to its functionality and utility. As can be seen in many artistic depictions from Egypt and the Aegean (e.g. Bass 1967), the oxhide shape and in particular the ‘handles’ render the ingot portable; it is easier to carry a heavy piece of metal that has ‘handles’ and the depictions show more than one way of doing so.

Notwithstanding the hundreds of fragments of oxhide ingots found all over the Mediterranean, only one casting mould made of stone has been found so far, at Ras Ibn Hani near Ugarit (Lagarce et al. 1983). Although the current lack of moulds in the archaeological record has been explained by the practice of casting in sand (Hauptmann 2009, 505), a casting technique that is apparently supported by experiments (Merkel 1986; Nibbi 1998; van Lokeren 2000) and ethnographic observations (Levy et al. 2008b), we believe that the situation mainly reflects the poor preservation of clay casting moulds and the difficulty of identifying such artefacts in excavations. The casting mould from Timna 30, made of unfired clay, was preserved by mere chance and started to crumble when collected in the field. Such moulds were made for a single use. They are easily constructed from local clay, and they were broken after casting to extract the ingot. The debris was thrown into the waste pile, probably together with the other metallurgical waste. Indeed, it is now clear that ‘slag mounds’ such as the one excavated in Timna 30 and in other locations in Faynan (Ben-Yosef et al. 2010) are usually made of less than 40% slag material and the rest is mostly decomposed clay artefacts derived from broken furnace fragments, tuyères and most probably moulds. The bulk of discarded mould material would be no more than wads of clay embedded in the deposits of metallurgical debris.

Although Timna 30 was excavated for two long seasons in 1974 and in 1976, it was not until the material was re-examined carefully in the laboratory that the researchers of the Arabah Expedition identified 21 clay fragments as pieces of casting moulds (Rothenberg 1990). The main reasoning for this identification was that the clay pieces did not match any of the reconstructed furnace types; Rothenberg (1990, 54) concludes: ‘We would like to suggest that similar crude mould fragments also exist at other sites of copper production, but have not been identified as such because they are very similar to furnace fragments.’ Mould fragments can easily be mistaken for crude pottery, especially if the casting workshops were part of a settlement with various domestic ceramic types. Recently, more evidence of clay moulds was found in the Arabah. The excavations of the UCSD Edom Lowland Regional Archaeology Project at Khirbat en-Nahas in Faynan yielded a considerable amount of small fragments of flat clay vessels, interpreted as casting moulds. These were found mostly in Area F, where refining of the raw
metal product and ingot casting took place (publication in preparation). The growing evidence of moulds from the Arabah supports the assumption that ingots, and especially the carefully shaped oxhide ingots, were cast in clay moulds and not just in sand. The probable symbolic value of such an iconic shape and the need for standardization in commercial interactions also support casting in clay moulds whose shape could be more controlled. A recent study concerned with the reconstruction of mould materials used for casting the Uluburun ingots concluded, based on evidence in the ingots’ metal texture and the results of experiments, that clay was the most suitable material for the moulds, and definitely not sand (Larson 2009). The fragmentary quality of the archaeological record is misleading; nevertheless, excavating with careful attention to such elusive artefacts will reveal more information in the future.

Lastly, it seems appropriate to mention in this forum the miserable conditions of Site 30. The site is unprotected, and so is its main slag mound discussed here. Although rains are rare in this region, when storms do occur they are relatively strong; we have found that the original face of the section had retreated about a meter (!) in the 33 years that passed since it was originally exposed by the Arabah Expedition. This situation is quite regrettable, as at this rate the small ‘slag mound’ will soon disappear and with it an invaluable record of the history of metallurgy. The preservation of different types of slag (and technologies) in one sequence, furnace fragments, tuyères, moulds (?) and other archaeometallurgical artefacts, together with rich organic materials (textiles, hide, ropes, grape, date and other seeds) is unique on a worldwide scale. The new project at Timna 30 demonstrates how research methods and analytical technologies change and progress as generations replace one another; as it is now, at Timna 30 nothing will be left for the next one.

Acknowledgements
The new excavations at Timna Site 30, directed by the present author (license #: G-38/2009), are a collaborative effort of the Department of Anthropology at the University of California, San Diego (UCSD) and the Institute of Earth Sciences at the Hebrew University of Jerusalem. The new research at Timna is supported by NSF grant number EAR 0944137.

Bibliography


Larson, T. S. (2009) Experiments concerning the mould materials used in the production of the copper ingots from the Late Bronze Age shipwreck excavated at Uluburun, Turkey (unpublished M.A. thesis). Texas A&M University, Texas.