

## Metalworking Technology at the End of the Early Bronze Age in the Southern Levant

This paper concerns a complex period once considered a 'Dark Age' in the history of the Levant, from about 2200–2000 B.C. It has been known alternatively as Middle Bronze I, Intermediate Early Bronze-Middle Bronze, and Early Bronze IV. According to Dame Kathleen Kenyon (1979), it was associated with a great invasion by a group of nomadic people known as 'Amorites', a name that has associations with descriptions in the Biblical Books of Numbers and Joshua. These invasions are believed to have led to the collapse of the Early Bronze Age city states and to the First Intermediate Period in Egypt. However, many new archaeological discoveries have changed our understanding of this period. Foremost amongst them is the archive of cuneiform inscribed tablets from a large urban site in Syria recognised as ancient 'Ebla'. Additionally, archaeo-metallurgical research now contributes new evidence of trade in metal, particularly from the south.

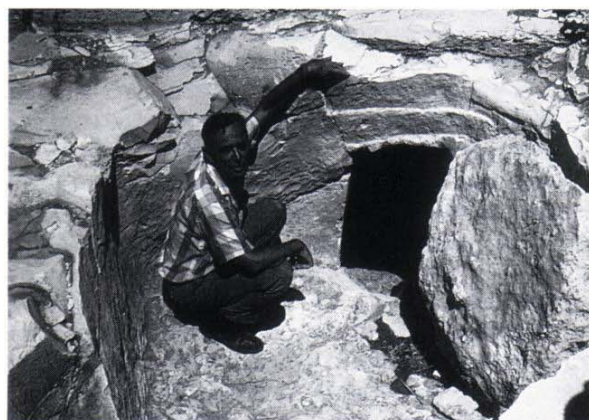
In the southern Levant, metalwork from the final phase of the Early Bronze Age (the so-called EB IV Period, c. 2200–2000 B.C.) is characterised, in part, by an increase in the use of bronze for weapons and other implements. Copper-tin alloys are seen to begin replacing the earlier, wide spread use of unalloyed copper as well as copper-arsenic alloys. Most of the EB IV metalwork from the Jordan Valley, north-eastern Negev and Hebron Hills has been recovered from burials, such as the cemeteries at Jericho and Jebel Qa'aqir (Fig. 1). Daggers, javelins and pins are the prevalent metal objects from the tombs.

From the archaeological evidence, it was assumed that the EB IV life-style in the southern Levant was pastoralist and nomadic with a local tradition of metalworking. Bar ingots (Fig. 2) are distinctive for the period and seem to indicate local production of copper implements. In contrast, large urban sites, such as ancient Ebla (Mardikh), dominate in this period to the north (Fig. 3). Based upon information from the Ebla archives of cuneiform inscribed clay tablets, it is now known that the large urban sites were involved in an extensive and far-reaching trade in copper (Waetzoldt and Bachmann, 1984). As metal implements are investigated from additional sites, especially remote EB IV sites in the south such as Jebel Qa'aqir, it is possible to achieve a better understanding, both chronologically and geographically, of the introduction of bronze into this southern area. While there is still little progress toward identification of distant tin and arsenic sources, there are several new lines of investigation (conducted

by several members of the IAMS Scientific Committee and other research teams) which together significantly improve our knowledge of this complex, regional trade in copper and the production of alloys for the late third millennium B.C.

The archaeological site of Jebel Qa'aqir is representative of the EB IV Period in the southern Levant. It was excavated by W. G. Dever (1972) and has been the subject of other specialist studies (London, 1987). From a total of 25 copper-based objects recovered from the Jebel Qa'aqir tombs, eleven daggers and seven javelins were selected for archaeo-metallurgical study. The daggers have been conveniently divided into three general types, primarily on characteristics of shape

Fig. 1. Entrance to an EB IV tomb at Jebel Qa'aqir.





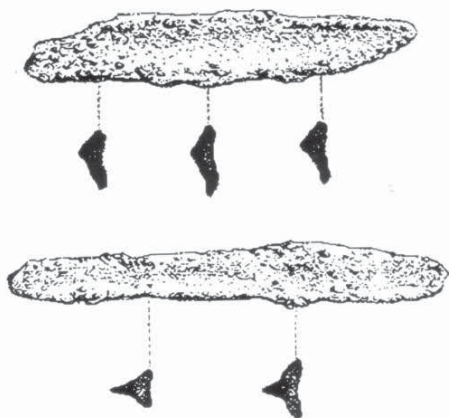


Fig. 2. Typical EB IV bar ingots and cross sections.

(Fig. 4). Due to the destructive analytical techniques involved, it was decided to exclude (and thus fully preserve) seven of the 'best' examples of metal weapons and pins from this study.

Metallographic examination of the daggers and javelins from the EB IV Period indicated a competent level of metalworking skill utilising casting, coldworking and annealing. For example, production of dagger Q408 involved these standard steps in production. In metallographic section (Fig. 5), non-metallic inclusions appear elongated especially at the cutting edge of the dagger indicating the degree of coldwork. In the final step of production, only the cutting edge of the dagger was preferentially coldworked, i.e. deliberately work-hardened. Note in section, how the deformation decreases away from the edge. Toward the central midrib, the dagger was left in a recrystallised state with a correspondingly lower hardness. From EB IV Jericho, only one flat, blunt dagger was found that may be interpreted as a cast blank ready for working into a final form. The other daggers and javelins at Jebel Qa'aqir were produced by the same metalworking techniques, in a qualitative sense, but the edges of the javelins were not coldworked to the same degree. These microstructures indicate that the metalworkers exercised basic control over the properties of annealing and work-hardening. Similar conclusions have been published for metal weapons from other EB IV sites.

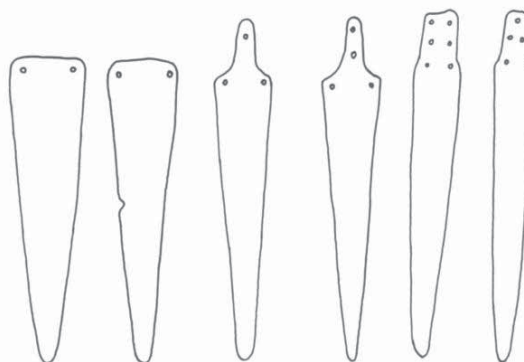
In comparison to the uniform application of standard metalworking techniques like casting, coldworking and annealing, the compositional data also suggest deliberate alloy selection based upon concentrations of tin and arsenic. The compositional data may reflect local socio-economic conditions during the EB IV period, when tin was only just beginning to be used. In the two Type 3 bronze daggers from Jebel Qa'aqir, except for tin, the concentrations of arsenic, zinc, lead, iron and nickel are all within the ranges determined for the unalloyed objects. On this evidence, we conclude that tin was added deliberately to available copper. The low tin concentrations in some of the other weapons at about 0.1% and 0.2% are believed to represent recycling and mixing of bronze scrap, rather than tin impurities resulting from the copper ore, or use of iron ore flux in



Fig. 3. Map of the major EB IV sites in Syria and Palestine (after Dever).

smelting. Furthermore, although these Type 3 daggers are only rarely found in the EB IV of the southern Levant, they are rather common in archaeological deposits at Byblos, Ugarit and elsewhere. Since many of the unlooted tombs had few or no grave goods it has been suggested that Jebel Qa'aqir was a relatively poor site. The less frequent occurrence of bronze at Jebel Qa'aqir (about 10% of the objects analysed) in contrast to other sites such as Jericho (with 25% bronze) reflects in part the remoteness of the site, a lower general wealth and poorer trade connections. Tin was a valuable commodity and thus generally used wisely when

Fig. 4. Examples of the three characteristic dagger forms from Jebel Qa'aqir.





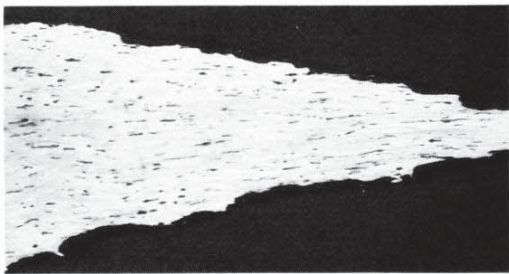


Fig. 5. Metallographic section of dagger Q408 ( $\times 50$ ).

available. The observation that composition and object types are occasionally related (but not always as at Jericho) may indicate an intermittent supply of tin and re-use of bronze during this period of several hundred years. The evidence from Jebel Qa'qir, as well as other sites, suggests that the trade in tin and copper were not necessarily linked at this time.

The association of bar ingots with metal objects in hoards found in the Negev (at Beer Resisim and Har Yeruham) suggests that the apparently local metalworking involved itinerant copper-smiths. In a technical study of EB IV bar ingots, Maddin and Stech Wheeler (1976) concluded that the bar ingots were secondary castings. Recent compositional analysis has shown that these ingots are not alloyed with either arsenic or tin. Thus, the ingots were smelted and refined metal intended for alloying, and not recycled available scrap with low, dilute concentrations of arsenic or tin. These results attest to secondary, deliberate alloying as well as casting and finishing having taken place at the remote sites.

One of these bar ingots (No. 64-883) was also analysed for lead isotopes by R. H. Brill and I. L. Barnes (1988). Since EB IV mining and smelting sites have been found at Timna and Feinan in the Arabah, it is not unexpected that these lead isotope ratios for the EB IV bar ingot plot in the field for Timna, published by N. Gale and Z. Stos-Gale (1984; their graph is reproduced again here, Fig. 6). Although only one bar ingot has so far been analysed for lead isotope ratios, there is sufficient correspondence between the trace element patterns for this ingot and the others, to recognise Timna and Feinan as the source for, at least, a portion of the copper used at the time. We are hoping to proceed with further investigations of bar ingots and metal implements from the EB IV period relating to this interesting trade from the south. The recent find of a hoard of EB IV bar ingots (being investigated by IAMS) in a settlement of this period at Ain Ziq, alongside the ancient route from the south (Timna) to the central Negev, may indicate the actual road of the copper trade from the mines to the settlements of the Negev.

The dominant proportion of the metal in the southern Levant is still believed to have come by trade through the large urban sites in the Levant. From the Ebla tablets, H. Waetzoldt and H. G. Bachmann (1984) discussed the ancient technical terms referring to copper and copper alloys for the EB IV Period in Syria. For example, among the various terms is one inter-

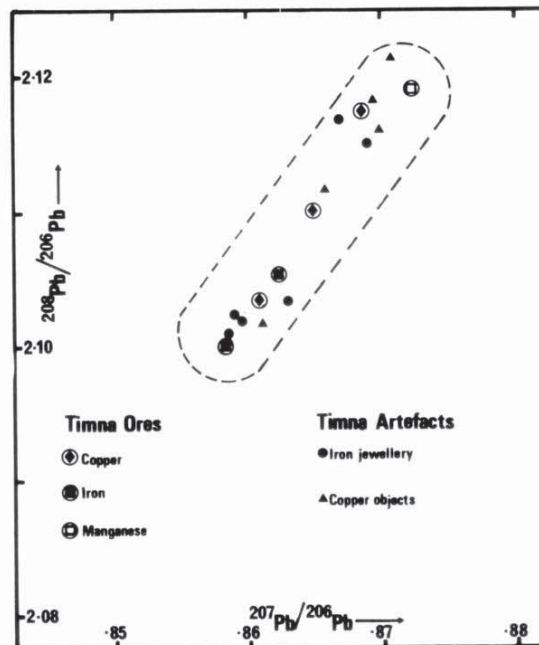


Fig. 6. Lead isotope ratios for metal ores from Timna.

preted as meaning 'pure copper for alloying'. The bar ingots from the Negev could thus serve as an illustration for this technical term. From Ebla there are also directions for the proportions of copper and tin to be mixed for bronze objects (Pettinato 1981). Due to the general correspondence of the dates, along with trade connections, the local metalworking tradition in the remote southern sites may be viewed as an extension of the regional metal industry evidenced from the Ebla clay tablets.

In conclusion, at Jebel Qa'qir the foremost question concerns the deliberate selection of available copper-arsenic alloys for metalworking, and not deliberate production from smelting. Non-urban, remote EB IV sites in the south were certainly not primary markets or destinations for metals smelted in Anatolia or elsewhere and traded through the urban sites; the quality of metal available at any one time in the southern Levant was the result of many factors: social, economic and technological. Surely copper from many ore sources was available for use or alloying as these conditions varied. Observed metal compositions have both foreign and local components. Although EB IV workshops with mould and crucible fragments have not been discovered yet, it does not necessarily follow that all finished copper-based objects were imported or ultimately derive from Syria. The technology involved in the production is straightforward and easily reconstructed (Fig. 7). While Syrian influence is clear for some metal types, such as the daggers, it cannot account for all metal types and variants found in the southern Levant. Hoards of bar ingots and scrap metal from southern EB IV sites (which we intend to analyse in the near future) suggest the activity of local metalsmiths. The uniformity and skill of standard metalworking, with annealing and coldworking techniques, seem to represent a local tradition present before the introduction of tin bronze. The low concentrations of arsenic and tin in copper-



based objects from Jebel Qa'aqir, and other sites like Jericho, are understood to reflect 'homogenisation' as the result of local recycling. Deliberate selection of arsenic-rich copper seems to have taken place for some of the daggers. The introduction and supply of tin for alloying was intermittent during the EB IV period, which accounts for the apparent relationship between composition and object type. There are clear local characteristics of the EB IV metalworking tradition. Copper containing high concentrations of arsenic was obviously the result of long distance trade; no such arsenic-rich ores are known to exist in the southern Levant. However, it is important to emphasise that during its transport and use, this material underwent considerable secondary selection, refining, mixing, alloying and recycling.

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Fig. 7. Dr John Merkel reconstructing casting metal ingots in one-sided flat moulds.

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## The Enigmatic Iron Object from the Great Pyramid – re-investigated

An iron plate was found by an excavation team in the Great Pyramid at Gizeh, Egypt, in 1837. This plate was said to have been found partly blocking an air passage high up on the south flank of the pyramid, but located within an undisturbed portion of the structure (Fig. 1).

The plate was not examined in any detail at the time and it has since been in the safe keeping of the British Museum in London. A small fragment of the plate has now been subjected to detailed examination by modern metallographic techniques. These techniques have shown, conclusively, that the plate consists of numerous laminates of wrought iron that have been inexpertly welded together by hammering (Fig. 2). The various laminates differ from each other in their grain sizes, carbon contents, non-metallic inclusions, and thicknesses. Some of the non-metallic inclusions consist of un-reacted (or incompletely reacted) fragments of the iron ore that was used to produce the iron metal. Other iron oxide 'inclusions' consist of the iron 'scale' that had formed between the inexpertly welded laminates. Yet other non-metallic inclusions are sodium- and potassium-rich 'ashy' remnants of the charcoal fuel.

The iron grains in all the laminates are equi-axial whilst the inclusions within the metal are all markedly

elongated. These features show that the welding process was carried out at modest temperatures that allowed only the iron grains to recrystallise. It is signifi-

Fig. 1. Section of the Great Pyramid looking west. The find spot of the iron plate is marked by a cross on the upper left (south) side of the casing by the air hole entrance. Scale 1:2500.

