iams

Number 17

June 1991

ISSN 0261-068X

Institute for Archaeo-Metallurgical Studies

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The Trustees and Director of IAMS wish to dedicate this issue to the memory of their colleague, Professor R. F. Tylecote

Archaeo-Metallurgy on the Trail of History

Archaeo-metallurgy, the study of extractive metallurgical processes and metal working technology, has made impressive progress during the last generation, but the impact of these studies on a better understanding of the metal-related social and economic aspects of ancient communities and, more so, on wider historical developments, is not yet really noticeable. The fact that most archaeo-metallurgists come from the field of material science and not from the humanities seems to have pre-determined the direction of archaeo-metallurgical research so far. Following up *Researches in the Arabah*, and as part of its endeavour to evolve archaeo-metallurgy as a better tool of historical research, IAMS has lately initiated several trial programmes, dealing with metal objects excavated in Israel. Since these programmes involved work by different specialists, who do not always 'look in the same direction' nor agree on interpretations, and also work by others from outside our IAMS group, it was thought appropriate to let each of our colleagues speak for himself on the following pages. A concluding epilogue draws together the relevant historical implications of these specialised scientific reports and notes.

FOREWORD

The investigation of the metal finds of an ancient culture often shows a specific metal implement or object, by itself and in relation to other objects in the same context neither very impressive nor outstanding, as being characteristic for its technology and style. In this sense it may often be considered as representative for many aspects of its culture, including problems of chronology and, especially, of provenance. For this reason we initiated detailed scientific studies of several such 'type-objects' – which by themselves had important archaeo-metallurgical results – to serve as possible pathfinders into complex historical enigmas.

1. A Chalcolithic mace head from a cave in the Judean Desert.

In 1960, in the context of the famous Judean Desert Expedition directed by Y. Yadin, the archaeologist P. Bar-Adon discovered in a cave in Nahal (Wadi) Mishmar a huge hoard – wrapped in a reed mat and hidden in a crevice in the bottom of the cave – of unusual metal implements of unique type and beautiful design, dated to the Chalcolithic Period, fourth millennium B.C. (Bar-Adon 1971 in Hebrew, English final version 1980). Archaeological evidence found in the cave related these metal objects to the Ghassulian–Beersheba culture, excavated mainly in the southern Jordan Valley and in the region of Beersheba.

The Ghassulian–Beersheba enigma

This extraordinary discovery raised a great deal of interest in previous excavations by J. Perrot (1955), where this unique culture had been identified in a group of settlements along the Nahal (Wadi) Beersheba, in the northern Negev. The economy of these settlements was basically agriculture, as was shown by a whole range of vessels, tools and remains of cultivated plants, like cereals and fruits, found in the excavations. There was, however, something rather unusual about them: large groups of interconnected, dug out, 'underground dwellings', were found by the excavator (Perrot 1955; 1984) to contain numerous stores of vessels and goods, also hearths, silos and stone mortars; in short, the typical equipment of a farming community. Even if we accept the quite convincing argument (Gilead 1987, 110–17), that these subterranean cavities were not habitations but storage structures, the organisation of these villages remained rather unusual, especially when seen within the chain of the pre- and proto-historical habitational developments of this region. If we add here the extraordinary cult and prestige objects of ivory and metal found in these villages – most of which were obviously most valuable imports from a very different social and cultural environment and extremely difficult to fit into the picture of an indigenous farming community in the semi-arid northern Negev – we are definitely facing a unique culture-historical enigma.

Furthermore, the discovery of the Ghassulian–Beersheba treasure in the caves of the Judean Desert and the extraordinary technological as well as aesthetic level of these hundreds of cult or prestige artefacts, should be taken as strong indication that we are dealing with an intrusive culture, perhaps groups of newcomers who emigrated into this region, soon mixing with and dominating the indigenous population. But who were these people and where did they come from? If archaeology cannot find an answer to these basic questions, could archaeo-metallurgy come to its assistance ?

It should be mentioned here that no traces of the Ghassulian-Beersheba culture have yet been found in the Southern Negev, the Arabah, Sinai and North-west Arabia. The Chalcolithic settlements and mining and smelting sites of these areas remained essentially confined within the mainstream of the autochthonous cultural development of this arid region, untouched by the newcomers in the north.

The Nahal Mishmar Treasure of over 400 copper objects consisted of 'crowns', standards and sceptres, horns, jars and mace heads of exquisite workmanship, but also a small number of simple copper working tools, like axes, chisels and a shafted hammer. C. A. Key (1964, also in Bar-Adon 1980, 238–43) discussed the results of his spectrographical investigation of a selected group of metal objects from the Treasure, as well as a standard from Abu Matar (Beersheba) and a mace head and axe from Nahal Seelim, which belong to the same cultural context. Key concluded that the metal objects of the Treasure must be metallurgically separated into two main groups which were probably manufactured in 'two different workshops – one for secular and one for ritual objects'. The tools, the secular objects, which he found to contain only some traces of silver and, occasionally, nickel, may have been forged from native copper, i.e. metallic copper found in nature. The ritual objects, i.e. the main part of the treasure, were cast by the lost wax technique from arsenical copper which was smelted from complex sulphidic copper ores – most likely originating from Armenia or Azerbaijan.

Mace heads

Conspicuous among the numerous cult objects of the Nahal Mishmar Treasure by their sheer quantity were about 240 copper mace heads (Fig. 1) of different sizes, weight, shape and colour. The mace head was a key weapon for hand-to-hand fighting in prehistoric times – until the appearance of the helmet (Yadin 1963, I, 120–5) – and was evidently also a symbol of status. It is found in excavations in Egypt, Palestine and Syria and is present in almost each of the Chalcolithic settlements recently excavated in the Beersheba region.

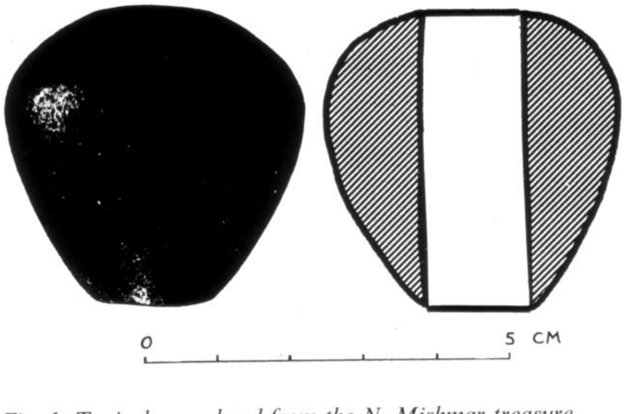

Fig. 1. Typical mace head from the N. Mishmar treasure.

Two, almost identical, copper-based mace heads were also found in a cave in a tributary (N. Badir) of N. Seelim (Aharoni 1961, 11–24). In the early 60's one of the pair was investigated by Key (1964; 1980, table) and the other was made available to our group for metallurgical studies. We soon ran into difficulties. The results from the investigation of our N. Seelim mace head (high Sb and As, probably from 'gray ore', fahlerz) were significantly different from the analytical results obtained by Key from his N. Seelim mace head and from the 'ritual' objects of the Treasure. After discussing the problem with Ronnie Tylecote (Tylecote 1977, 314 and M38 on Table 9), and because it was not possible to clarify this problem without the scientific study of other objects from the Judean Desert finds – which remained unaccessible for scientific research for almost a whole generation – Tylecote and myself put the issue temporarily aside.

A new approach

Several years later Michael Notis (Notis *et al.* 1984, 242) investigated once more our mace head from N. Seelim and we have now returned to it in the context of the research programme outlined above. In the meantime, Shiqmim, another important site in the area belonging to the Beersheba culture, was excavated and its metallurgy investigated by S. Shalev and P. Northover. The latter wrote a short report for us on recent, so far unpublished, analytical work on metal objects from the Treasure which has important implications for the problems discussed here.

To return to the historical implications of our archaeometallurgical studies in line with the programme outlined above, we turned to the problem of the nature and provenance of the metal, and technology, of our mace head, to serve as a path-finder into the Ghassulian–Beersheba enigma.

Provenance studies by way of the trace element groupings in the metal – until recently very fashionable among scientists dealing with archaeological materials – have been rather disappointing. Already in the 60's, studying the metallurgical debris at Timna, it struck me that it would be impossible to trace the copper prills from the smelting slag of Timna to the copper ore deposit nearby, which must evidently have been the source of the ores for the copper smelters of Timna. The obvious reason for this is the basic fact that the copper smelting process requires in almost every case the use of fluxes. In Timna iron oxide ore was available as a good flux from the same or similar geological horizon as the copper ore – and with the addition of such fluxes, the trace element picture becomes either significantly distorted or even totally altered (Rothenberg 1972, 237).

To establish the provenance of metal by its lead isotope composition is also far more complicated than was assumed during the initial years of the use of this new method, especially if we expect definitive, positive statements about the origin of a metal object from a certain ore body. Such definitive statements would only be possible on the basis of comprehensive chemical-mineralogical data about the ores, fluxes, fuel, slag and refractories – each a contributor of trace elements – as well as the composition and structure of the primary metal product. In addition, information would be needed concerning the smelting and refining processes, and in particular the partition of the trace elements during these processes – all of which resulted in the production of the metal object whose origin we were investigating. If this information is not available, the lead isotope composition may be consistent with the derivation of a metal object from a certain ore source, but will not be consistent with its trace element pattern. This situation is fundamentally similar to the problem of trace element provenancing in Timna, as described above and, as at Timna, can only be properly overcome by detailed extractive metallurgy.

Yet, even a negative statement, i.e. the exclusion of certain regions and their ore deposits on the strength of lead isotope ratio pattern, can be of considerable assistance to the archaeologist and still be an indication of possible provenance. Z. A. Stos-Gale investigated the lead isotope ratio composition of the N. Seelim mace head, and of the copper ingot discussed below, and her report, though only partly positive, is of considerable significance in the present context.

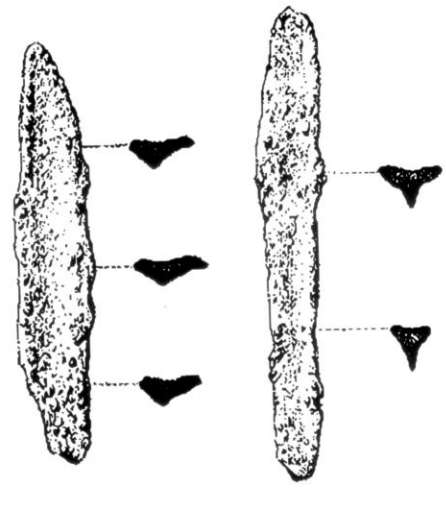

Fig. 2. EB IV bar-ingots.

2. Bar-shaped copper ingots from Early Bronze IV settlements in the Negev (Fig. 2)

The work reported below continues the series of investigations discussed in 'Metalworking Technology at the End of the Early Bronze Age in the Southern Levant' by J. F. Merkel and W. G. Dever (*IAMS Newsletter* No. 14, 1989, 1–4), and 'The Discovery of a Copper Mine and Smelter from the End of the Early Bronze Age (EB IV) in the Timna Valley', by B. Rothenberg and C. T. Shaw (*IAMS Newsletter* No. 15/16, 1990, 1–8).

The 'EB IV enigma' briefly outlined in the latter paper, was seen to be intimately connected with the 'composite' character of the EB IV population/culture of the region, i.e. the influx of more advanced newcomers from the metal-rich north which introduced the use of tin-bronze, and their integration into the local, indigenous population which previously had only known and worked unalloyed copper, presumably from local sources. It was therefore not surprising that systematic studies of EB IV metal objects from the Levant had established the co-existence of two distinctly different but contemporary metalworking technologies: one was a rather simple casting technology of unalloyed copper, followed by a certain amount of cold working for final shape and hardening of the working edges, mostly employed for the production of tools and other unsophisticated copper objects. This copper technology was found all over inland Palestine, the Negev and Sinai, evidently going back to Chalcolithic times. The second technology was based on the use of copper-based alloys – arsenical copper and proper tin-bronze – often involving the use of sophisticated 'lost wax' casting techniques. Most of the EB IV tin-bronzes (mainly weapons but also intricate jewellery as well as 'torques'), were found to the north of the more arid parts of the region, where unalloyed copper remained the commonly used metal throughout EB IV. Occasionally, there was an 'infiltration' of tin-bronze objects into the south, especially of weapons and other prestige objects, but not a single workshop containing metalworking installations, crucibles and slag, relating to the use of tin-bronze has so far been unearthed in any of the numerous excavations of EB IV sites of the south.

Typologically, EB IV tin-bronzes have been found all over the Levant and several types of prestige objects could be followed even as far as the Balkans. At present our IAMS group is trying to follow the trail of these objects and systematic lead isotope studies are part of our programme. Following up the discovery and excavation by our group of an EB IV copper smelter in the Timna Valley (Rothenberg and Shaw 1990), we initiated a systematic study of the indigenous copper technology of the south. Besides the EB IV copper mining and smelting centre (Sites 250 and 149) in the Timna Valley and several mining-related EB IV settlements nearby in the Arabah, a number of EB IV copper smelting sites, as well as numerous food producing settlements, were located in the copper mining regions of South Sinai. In our deliberations on EB IV local metal production we have, of course, to take into consideration this wide distribution and the almost industrial scale of EB IV copper production in the arid south.

Special attention was paid to the appearance of triangular (in section) bar-shaped ingots of unalloyed copper from several EB IV settlements in the Central Negev (Beer Resisim, Har Jeruham, Ein Ziq), and also in the Hebron Hills, allegedly near the village el-Hadab, north of Dhahariyeh (Dever and Tadmor 1976, 163–9) and occuring at Lachish, about 50km north of Beersheba (Tufnell 1958, Pl. 21). Evaluating the archaeological and archaeo-metallurgical evidence unearthed in the EB IV smelter of Timna revealed not only advanced smelting installations and techniques for the production of primary copper on a scale previously unknown in the smelters of the region, but there was evidently also crucible extraction and refining of crude copper and probably casting of bar-ingots (Rothenberg and Shaw 1990, 8).

The next step in the research programme was the metallurgical investigation of some bar-ingots and, most significant, their provenancing by lead isotope studies. Previous investigation of several bar-ingots (Maddin and Stech-Wheeler 1976) had shown that they were secondary castings and 'made from weathered copper ores containing galena and iron ores were added as flux' (more likely oxidized copper ore with iron oxide flux containing lead, as established at Timna). To cast a bar-ingot would only require a flat stone with a triangular groove carved into its surface, not easy to recognize among the masses of discarded stones of a smelting site.

One bar-ingot from the Har Jeruham hoard was previously analyzed for lead isotopes (Brill and Barnes 1988) and found to plot into the field of Timna (Fig. 4).

This result, strengthened by the correspondence of the trace element pattern between Timna copper ingots (Roman 1988), the Har Jeruham bar-ingot and other bar-ingots from the Negev, strongly indicated the Timna region (and perhaps also Feinan, in the north-eastern Arabah – see below) as a copper source for the EB IV settlements of the Negev and also further afield. However, further analyses were obviously required to establish what we tentatively assumed to have been the EB IV copper trade route from the south, i.e the local parameters of the EB IV enigma.

The Ein Ziq bar-ingots

The recent find of an EB IV hoard of 12 bar-shaped, triangular ingots, as well as stray finds of another bar-ingot and some fragments, in a settlement near the spring Ein Ziq (Cohen 1986, 295–6), provided suitable samples for this additional research. The hoard of bar-ingots was found hidden underneath the threshold of a house but no process-related metallurgical debris has been reported from this or any other of the houses in this settlement.

The EB IV site, located on a hill top near the bank of Nahal (Wadi) Ziq, north of the Ramon Crater, is one of the largest settlements of this period in the Negev mountains (Cohen 1986, 252–70). Its geographical location, deep south in the Negev mountains, made its connection with the copper mines of the southern Arabah (Timna, N. Amram), or even Sinai, much more likely than a connection with the copper mines in the region of Feinan, south of the Dead Sea – providing, of course, that there was at all such a connection to local copper sources.

Beno Rothenberg

3. A Mace head from a cave in N. Seelim

This mace head is similar in shape and form to those illustrated by Bar-Adon (1980, 119); the inside of the shaft hole still retained the clay core around which the head had been cast. The clay is not completely enclosed in cast metal, as is shown on p. 235 of Bar-Adon. Microprobe examination of the polished metallographic section (Fig. 3) indicated the majority of the structure to be a two-phase material. The major phase, occupying about 90% of the cross-sectional area, is a Cu-Sb-As alloy giving the following approximate analysis : 95.3 Cu – 2.4 Sb – 2.4 As (wt. %). The minor phase appears to be a complex intermetallic sulfide with approximate composition 61.3 Cu – 25.3 Sb – 7.8 As–bal. S (wt. %). In addition to these phases there are at least two other types of inclusions found in much smaller amounts : copper sulfide with a small amount of Sb and As, and a copper-bismuth phase with small amounts of Sb and S. The overall alloy composition appears to have a combined Sb + As analysis of 9. + 0.6 (wt. %).

It appears that this mace head has been smelted and cast from 'gray ore' or fahlerz containing tetrahedrite (Cu_3SbS_3) and chalcocite (Cu_2S). These types of ore may have an appreciable portion of the Sb replaced by As, and Bi concentrations typically run quite high. This ore is distinctly different from those found at Timna (Milton *et al.* 1976) and Abu Matar (Tylecote *et al.* 1974), but it also appears to be different from the mace heads found at N. Mishmar, N. Seelim, and Abu Matar, all of which have little Sb content (Bar-Adon 1980). It thus appears that considerably more detailed and updated micro-analysis is warranted on these mace heads as a group.

from M. R. Notis, H. Moyer, M. A. Barnisi, and D. Clemens (1984)

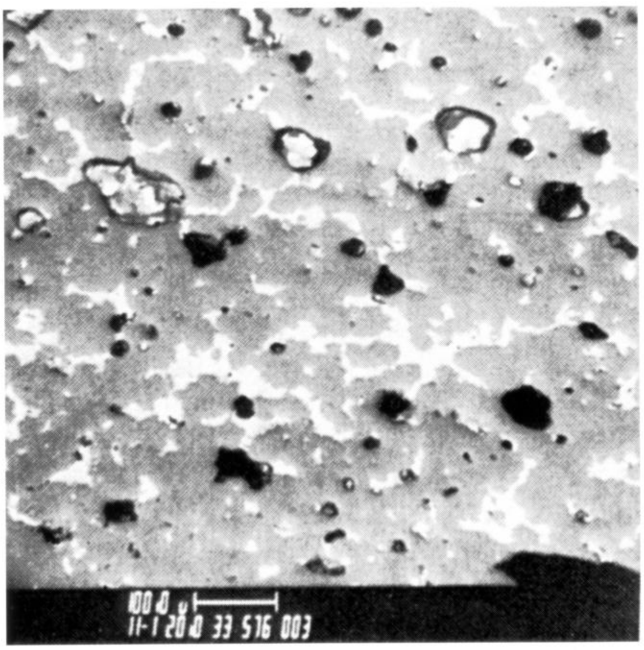

Fig. 3. Mace head from N. Seelim. Microprobe image indicating two-phase matrix and inclusions.

4. The Chalcolithic metal industry at Shiqmim and the Nahal Mishmar hoard

a. Pioneering metallurgical investigation of the N. Mishmar hoard was conducted by C. A. Key (1964, 1980) using emission spectrographic analysis. Key defined the technological differences between the two groups of objects as tools of 'unalloyed' copper and 'ornaments' (the cult/prestige objects) made of arsenical copper 'alloys' (1.9% – 11.9% As). On the basis of his analytical results, Key reached the following main conclusions: 1. The tools might represent the forging of native copper. 2. The 'ornaments' show that a complex sulphide ore was used for their manufacture, which required long distance cultural contacts with Transcaucasia, Armenia and Azarbaijan, and the knowledge of roasting the ore before smelting.

b. Metal objects found in the Chalcolithic village of Shiqmim showed that the same correlation of two different metal types with two types of artefacts (tools and prestige/cult objects), as in the N. Mishmar hoard, existed at habitation and burial sites in the Beersheba region (Shalev and Northover 1987).

Furthermore, the analysis of crucibles, slags and ores from Shiqmim and some additional sites demonstrated that the tools were locally manufactured (Shalev and Northover, ibid). We assumed that carefully selected rich ores were brought to the villages of N. Beersheba from a considerable distance, presumably from Feinan, and possibly also from Timna, to be used there in a single step crucible-based smelting-melting process.

Thus, the question concerning the tools of the N. Mishmar hoard could be answered by the archaeo-metallurgical investigation of similar tools and materials connected with their production at Shiqmim. Yet the situation of the cult/prestige objects from the N. Mishmar hoard examined by Key remained obscure. Recent investigation of a mace head from Shiqmim by Shalev and Northover (to be published) revealed the same manufacturing process – lost wax casting over a stone core – as the one mace head from the N. Mishmar hoard examined metallographically by Potaszkin and Bar-Avi (1980). However, the objects from Shiqmim showed a consistent, important compositional difference, mainly in the antimony content, from those analyzed by Key.

These differences, i.e. the consistent low antimony content in Key's data, could be explained, as suggested by Notis *et al.* (see his contribution above), by the use of a distinctly different type of ore. Yet the typological and technological similarities between the mace heads from Shiqmim, N. Seelim and the N. Mishmar hoard, emphasized the puzzling discrepancy in their chemical composition.

We therefore re-investigated some of the material from the Judean Desert caves: nine artefacts from the N. Mishmar hoard and from N. Seelim were re-analyzed. In addition, we examined nine other objects, which had not been previously analyzed. All samples were analyzed by electron probe microanalyser (EPMA) in Oxford and by atomic absorption spectrometer (AAS) in Tel Aviv.

The results (soon to be published) showed striking discrepancies with Key's published data. Besides the identification of arsenic, the concentration of virtually all the other elements estimated by Key need to be altered. The most striking discrepancy is the constant minimal detection of antimony by Key, even when it is present in quantities larger than arsenic. These results correlate well with all the known data from other Chalcolithic sites and also with the additional nine samples from the N. Mishmar hoard. There is still much work to be done on the properties of such multi-phase ternary alloys, the provenance of the ores and the smelting technology involved. Comparisons with Early Bronze Age metalwork in Israel showed that the 'Chalcolithic Beersheba' technology was unknown there in this period.

It seems that incorrect analyses, as well as absence of more contextual archaeological evidence, led Key to his main conclusion concerning the origin of the Nahal Mishmar treasure. With our new data and re-evaluation of the metallurgy, a simpler working hypothesis can now be proposed. Not only can the small group of tools from the hoard be linked to a distinct temporal and spatial context, but also most of the prestige objects are found to bear a close metallurgical resemblance to similar objects found at Chalcolithic sites in the south. With this new data we can see the geographically well-defined distribution of these prestige/cult end-products and speculate about the existence of a production centre appreciably nearer than Anatolia or Transcaucasia.

Sariel Shalev and Peter Northover

5. Lead isotope studies – a bar-ingot and a mace head from the Negev

(1) The origin of the bar-ingot from Ein Ziq

The ingot was analyzed in the Isotrace Laboratory at Oxford and its lead isotope composition is fully consistent with its origin from Timna ores. The lead isotope ratios are as follows: 208/206 = 2.11906, 207/206 = 0.86996 and 206/204 = 17.959.

The same origin can be suggested for three samples of objects published by Brill and Barnes (Rothenberg, 1988, 219–22), they are Pb-1079, yellow glass from the Timna Temple; Pb-643, a pellet of copper from Timna, and Pb-1229, a triangular copper ingot from EBIV Har Jeruham, in the Central Negev.

Fig. 4 represents a diagram of both objects analyzed at Oxford (the ingot is marked 'ing', the mace head 'MH') together with the three objects analyzed by Brill, some ores and slags from other sites of Timna (Pb-208 is also from Brill and Barnes, the other ores are from the Oxford collection) and approximate ranges for Cyprus, Ergani Maden (Turkey) and Timna ores.

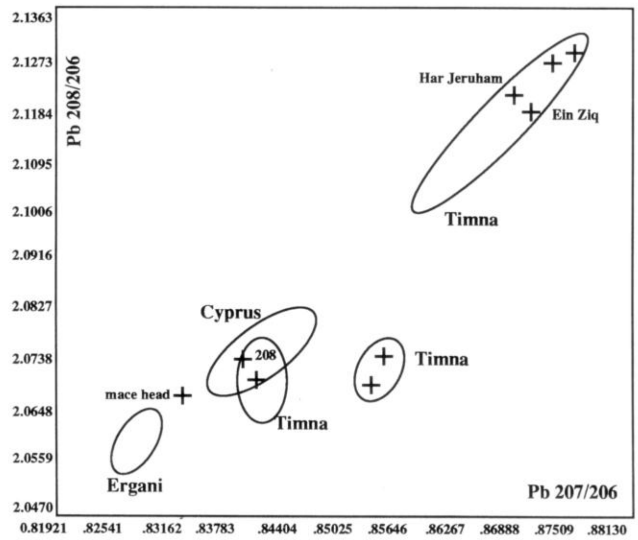

Fig. 4. Diagram showing the lead-isotope compositions of the EB IV bar-ingots compared with those of the Chalcolithic mace head, in relation to the lead-isotope fields of Timna, Cyprus and Ergani (Turkey).

(2) The mace head from N. Seelim

The mace head was analyzed isotopically twice; one sample was drilled from the external part of the object, the other from the interior. The lead isotope measurements of both samples do not show discrepancies. The lead isotope compositions of the mace head are: 208/206 = 2.06754 and 2.06770; 207/206 = 0.83179 and 0.83179, 206/204 = 18.904 and 18.905.

Currently we do not know an ore deposit which would be fully consistent with this composition. The ores from Timna analyzed so far plot separately from the

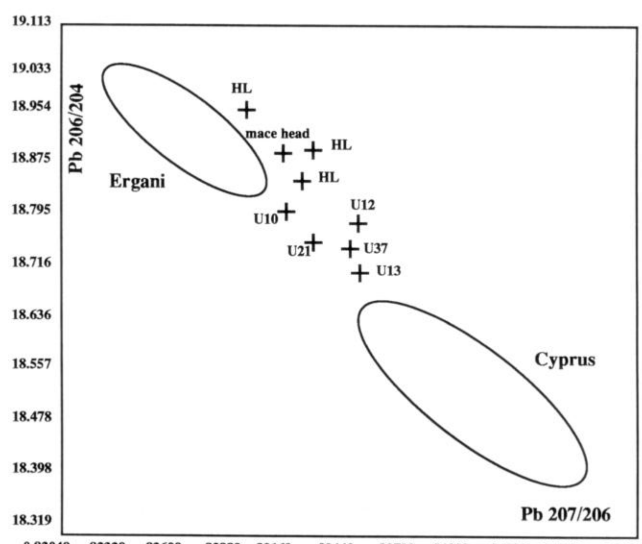

Fig. 5. Lead-isotope compositions of the N. Seelim mace head, compared with those of the metal groups of Ugarit and Ras ibn Hani, against the lead isotope field of Cyprus and Ergani.

mace head (Fig. 5). The lead-isotope composition of this object is not consistent with its origin from Cyprus or the copper mines of Ergani Maden in Turkey, or the Taurus Mountain. At present the geographical origin of the ore used for the mace head remains unknown. On the other hand, a large group of copper and lead objects (unpublished data from Oxford Isotrace Laboratory's lead isotope database) from Ugarit (Ras Shamra, a port in Syria) and Ras ibn Hani seems to have a common origin with the mace head. On Fig. 5 the objects from Ugarit are marked with letter the 'U', and the 'HL' points represent lead from Ras ibn Hani. *Zofia Stos-Gale*

EPILOGUE

The Ghassulian-Beersheba Chalcolithic enigma

The hoard of ritual/prestige objects found in a cave in N. Mishmar, in the inhospitable rock cliffs of the Judean Desert, can be seen either as a tribal treasure carried by fugitives or a rich trader's hoard. A small number of similar objects were also found in the Chalcolithic villages of the Beersheba Valley, characterized by peculiar subterranean habitations or working/storage 'caves'. Since many of the daily life installations and vessels of these villages can be related to the indigenous Chalcolithic culture and life style of the Southern Levant, it would seem that the 'Beersheba culture' is the result of the influx of newcomers from a totally different cultural environment in the process of integration into the local, indigenous population. The N. Mishmar treasure, as well as similar metal objects found in the Beersheba settlements, reflect in fact the same twofold, interlocked, cultural and technological 'strata': highly sophisticated metallurgy, far above the common, local, metal technology of this period in the Southern Levant and based on a type of metal totally foreign to this region. It would be rather difficult to see these outstanding objects as a local product, and no traces of a suitable workshop, nor any relatable metallurgical debris, have ever been found in any of the excavated settlements of the region. Although it is 'risky' to identify 'pots and people', it seems extremely difficult in our case not to do so. The ritual/prestige objects found in the Beersheba settlements and in the caves of the Judean Desert were apparently carried by foreign people penetrating into the region, and it would be highly interesting to know why they chose the semi-arid Beersheba Valley to settle down and why they were hiding in the caves of the Judean Desert.

The few tools, mainly chisels and small axes, found with the N. Mishmar hoard and in some of the Beersheba settlements, belonged to a different technological horizon and can be seen as reflecting an unsophisticated, local metallurgy, in line with the much more primitive autochthonic metal working tradition of the indigenous population. The archaeo-metallurgical study of metal objects and process debris from the excavations at Abu Matar (Tylecote *et al.* 1974) and Shiqmim (Shalev and Northover 1987), surely provided the evidence for the local manufacture of these tools – but the picture is still far from clear.

First, the source of the ore. Investigating the Abu Matar material, the ore was found to be 'mainly malachite and cuprite with a small amount of chalcocite and chalcopyrite' (Tylecote *et al.* 1974); at Shiqmim ore fragments are reported as 'mainly cuprite and malachite' or 'largely cuprite with a low iron content (0–1%)'. Such ores could not have derived from the Timna mines (Rothenberg *et al.* 1978: ore from Chalcolithic smelter Site 39) and the ores of the Feinan region, as recently published (Hauptmann 1989, Table 14, 1) also do not really seem to fit the above definitions. Further research is indicated to clarify this basic question, including lead isotope studies.

Second, the nature of the slag. When first investigated in 1974, there was no proper smelting slag among the metallurgical debris at Abu Matar (Tylecote *et al.* 1974, 32–4), and it was therefore concluded that only melting-casting operations had taken place at Chalcolithic Abu Mater. There remained, however, the problem of the ore fragments found at Abu Matar, and the suggestion that these ores 'must have had some other use perhaps, for example, as a cosmetic or for ritual purposes' was never considered really satisfactory. Recent investigations of additional slag samples from Abu Matar (which Tylecote *et al.* had not been shown by the excavator) identified proper fayalite slag (Hauptmann 1989, Table 14, 2) and provided the missing evidence for copper smelting at Abu Matar. We now have evidence for copper smelting in a Chalcolithic village of the 'Beersheba culture' the technology of which seems to be very much in line with local metallurgical tradition (Rothenberg 1990, 69, Table 1; Bachmann 1978, 21–2, Table 1).

However, recent investigations of similar metallurgical debris from Shiqmim (Shalev and Northover 1987, 363–4) did not find any proper smelting slag. More so, apparently most of the slag at Shiqmim was 'definitively associated with crucibles'. Based on this result, Shalev and Northover (1987, and above) proposed to see in the Shiqmim debris evidence for crucible smelting of copper; in fact, according to their 'process-model' tools were manufactured directly from carefully selected rich ores 'in a single crucible-based smelting-melting process'.

Obviously, this Epilogue is not the place for a detailed discussion of extractive process-models, but it must be stated that the Shalev–Northover hypothesis would not be consistent with the processes established for Chalcolithic smelting anywhere else in the region. It does not work with Timna nor any of the many other Chalcolithic copper smelters in the Southern Arabah (Rothenberg *et al.* 1978; 1990, 4–9); nor with W. Fidan (Feinan), where proper smelting furnaces were located dating to the Chalcolithic period (Hauptmann 1989, 122–6), and also not with Abu Matar, where slagged furnace lining was found as well as furnace fragments which indicated a furnace diameter of 30–40cm, quite similar to the Chalcolithic smelter at Site 39 in Timna (Rothenberg 1978). The crucibles of Abu Matar had a diameter of about 10cm and were incrusted with proper melting-casting slag.

Our 'path-finding' mace head from N. Seelim, which was the first indicator that there were problems with the analyses of the N. Mishmar hoard, already indicated a fahlore source for its metal (Notis *et al.*). The recent analyses of a whole series of metal objects from the N. Mishmar hoard (Shalev–Northover) confirmed this conclusion and made it imperative to look again for its place of origin. Since analyses of prehistoric metal showed fahlore as a rather common ore especially in Chalcolithic times, we put our trust in lead isotope research to find the source not only of the metal of the 'Beersheba culture' but also as a possible key to the enigma of the origin of the Ghassulian–Beersheba intrusive elements: people, trade, culture transfer or whatever would explain this enigmatic phenomena.

The lead isotope study of the mace head by Zofia Stos-Gale confirmed, first of all, the exclusion of a local source for this metal and its technology, including the Arabah mines, Timna, Feinan, and Sinai. It also seems to exclude some of the major sources of copper of the ancient world, leaving many others as candidates, pending further 'lead isotope mapping' of the mineral sources of south-east Europe, the Mediterranean region and even further afield.

The possible identification of the metal source of our mace head, and through it presumably also of the N. Mishmar hoard and other Ghassulian–Beersheba metals, with the origin of a large group of copper and lead objects from Ugarit and Ras ibn Hani represents a very significant first positive trail into the Ghassulian–Beersheba enigma.

Bar-ingots from the Negev

The lead isotope mapping of all of the bar-ingots so far investigated clearly points to the Timna region for their origin. Only one EB IV smelter, Site 149, was discovered in the Timna Valley, which had produced copper on an industrial scale, and also contained evidence for crucible refining, and probably casting of copper.We may therefore, albeit still tentatively, assume that the bar-ingots of the Negev were actually produced in this workshop.

The distribution of the EB IV settlements where bar-ingots have been found, clearly indicates a wide spread of this merchandise, and the line Hebron Hills – Har Jeruham – Ein Ziq perhaps represents the actual copper route from the far south to the hills of Jerusalem.

The tentative conclusion above has its reason in the fact that the geology of the Feinan region is very similar to that of the Timna region and we may find that the lead isotope ratios are also very similar. This would require a more detailed study of the extractive parameters, especially the trace element distribution between the ores and fluxes and the detailed local geology of the mineralized zones and their lead isotope ratios.

The EB IV phenomena is still enigmatic in its basic parameters, as described in the previous *IAMS Newsletters* issues, and the finger-printing of the bar-ingots to a source in the Arabah is of considerable significance. The archaeological evidence in Timna – and incidentally also at the metallurgical sites of southern Sinai – tends to emphasize their indigenous character, as it is obvious that in this area we do not have the solid 'intrusive' presence of the more northern EB IV sites. At this stage of our knowledge it would appear that the bar-ingots are a local product of somewhat limited distribution – still pure, unalloyed copper as are most of the local metal objects of this region. For the next step of isotope study we intend to use an arsenical copper-type object as well as a proper tin-bronze as path-finders to trace the 'intrusive' elements of the EB IV enigma.

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