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IAMS Returns to the Arabah

Important current fieldwork by several IAMS groups in the Arabah convinced the Editor of the IAMS Newsletter to delay the appearance of No. 15 in order to immediately publish this work. Because of the extent of the new discoveries, IAMS Newsletter No. 15 is being published as a special, enlarged issue and combined with No. 16.

Volume Three of *Researches in the Arabah*, the final, definitive report on the archaeo-metallurgical Arabah Project 1959–84, will be the unique story of almost 5000 years of copper mining, from the fifth millennium B.C. to the seventh century A.D. Since the first publication of the Timna mines in 1981, several new discoveries of mine workings and smelters of additional historical periods and different technologies were made by our IAMS group and we decided to return to the Arabah and include these new discoveries in the forthcoming volume.

In the preparation of the definitive report on the excavations of copper smelting sites in the Timna Valley (1964–84), Site 39, the Chalcolithic smelting workshop, was re-investigated. This confirmed the previously proposed interpretation and date of the site, which are discussed in the following pages.

October–November 1989 and December–January 1990 saw several IAMS teams at work in the Timna Valley as well as in Nahal (wadi) Amram, south of Timna, directed by the authors of the reports published in this issue of the IAMS Newsletter.

The Editor

The Discovery of a Copper Mine and Smelter from the End of the Early Bronze Age (EB IV) in the Timna Valley –

More to one of the most intriguing problems in the history of the Ancient Near East

I THE EB IV ENIGMA

The final phase of the Early Bronze Age, EB IV (also called MB I and EB–MB), about 2200–2000 B.C., is still a rather enigmatic chapter in the early history of the southern Levant. It is agreed by most archaeologists that in contrast to the northern region, where large urban sites dominated the scene, the south (Palestine, Trans-Jordan, the Negev, and Sinai, and, at least, part of North-west Arabia), was inhabited by semi-nomadic pastoral tribes who left behind simple dry-built habitations, burial tumuli and rock-cut tombs.

However, archaeologists and historians, summing up the evidence from excavations and surveys, reached quite different, often conflicting, historical conclusions as to the development of this semi-nomadic lifestyle in the south. Kathleen Kenyon (1979, chapt. 6), who used the term 'intermediate EB–MB', advanced the theory of an Amorite invasion from the semi-arid northern fringes of the Fertile Crescent, which overran the Levant, blotting out the preceeding Early Bronze Age urban civilization. Y. Aharoni (1966, 125–31), after first agreeing with Kenyon regarding the Amorite wave, later opposed her idea for this phase of the historical development (1982) and discussed the possibility that these people were of 'Kurgan' origin, following P. Lapp (1966, 94–116) who first proposed the idea of an influx of Proto-European 'Kurgan' people from the Caucasus all the way down to the southern Levant.

A totally different idea for the solution of the EB IV Enigma, was subsequently proposed by R. Cohen (1983, 16–29; he uses the term 'MB I'). Cohen, who himself has extensively excavated sites of this period all over the Negev, stated, 'who are these people? We really don't know'. Yet, he proposes to see their appearance as the slow immigration of people from the south, or south-west into the Negev of Palestine and reaches the rather suprising conclusion, 'these MB I people may be the Israelites whose famous journey from Egypt to Canaan is called the Exodus'.

The rather astonishing discrepency between the various historical interpretations of the archaeological evidence has its explanation in the fact that each side of the argument is right – up to a point – for part of the EB IV phenomena. For it must be emphasized that the EB IV Enigma reflects intricate, complex historical and culteral processes, which can only be properly comprehended in a strictly regional context and not as one overall historical event or development.

Considering our region (from the Nile Delta to the Negev Mountains, the Arabah and North-west Arabia) we see during EB IV (we prefer in this region to call it 'Sinai-Arabah Copper Age – Late Phase'; Rothenberg 1988, Introduction) a strong southward movement of ideas and technology. There were possibly perhaps also people who carried their tools and pottery into an old-established, indigenous, local culture and technological tradition, at the southern arid fringe of the Fertile Crescent, an area deeply entrenched in an age-old heritage of tribal cultural, economic and social coherence – still much in appearance to this day.

As a result of extensive surveys and excavations in the Negev, the Arabah and Sinai, as well as the scientific investigation of the archaeological and archaeo-metallurgical finds, one of the present authors (B.R.) concluded (Rothenberg 1979; 1989, 13–15) that a fundamental revision of previous ethnical and chronological concepts concerning the region had become necessary. This also relates to the EB IV enigma. Since early Chalcolithic times (radiocarbon-dated to the fifth millennium B.C., at the latest) and at least up to the end of the Early Bronze Age (including EB IV), most of the Nile Delta (Maadi, etc.), Sinai and the Negev, and also large parts of North-west Arabia, were inhabited by indigenous population groups which developed their own style of architecture, distinct flint and ceramic industries, and mined and smelted copper wherever suitable ores were available.

Although intruding cultural elements from adjacent, more fertile Pre- and Proto-Dynastic Egypt, Canaan and Palestine, could be identified amongst the finds in these settlements and burials – important for the establishment of a comparative chronology for Sinai, the Arabah, the southern Levant and Egypt (Rothenberg 1988, 14) – the autochthonous development of the local cultures were only occasionally and marginally effected by these intruders, with the exception of the EB IV developments in the southern Levant.

One of the basic facts, established by the extensive petrographic studies of Y. Glass (in Rothenberg 1988, 96–113), which led to this new historical concept, is the continued existence of distinctive ceramic industries in south and central Sinai, which supplied most of the pottery used by the local inhabitants of the region from the early Chalcolithic to, at least, EB IV. This dominant local pottery tradition is recognizable at the habitation sites also during the periods when 'imported' wares made their appearance at many sites in Sinai and the Arabah. The latter must be understood as evidence for foreign peoples who traded with the local inhabitants, like the Canaanite EB II trading posts in southern Sinai, or gradually integrated into the local indigenous population groups, producing a symbiosis of the newly arrived with the locally developed technology. We therefore find in the region sites with very few or even without any of the typical imported ceramic types, but with the typical local EB IV pottery after it had integrated the 'foreign' technological elements. We suggest that the latter sites belong to the latest phase of EB IV, when the newcomers had already been fully absorbed by the dominant local culture.

Characteristically, the 'composite' EB IV population groups, mainly as a result of the influx of the more advanced newcomers from the metal-rich north, now made extensive use of copper-based alloys for its weapons – distinctive types of daggers and javelins (see Merkel, J. E. and Dever, W. G., *IAMS Newsletter*, No. 14, 1989) and, sometimes, fenestrated axes, the latter generally made of tin-bronze by a sophisticated casting process.

One of the present authors (B.R.), in an ongoing systematic study of EB IV metal objects from the Levant, was able to establish the co-existance in this region of two distinct contemporary metalworking technologies. One is a rather simple casting technology of unalloyed copper (and re-used imported arsenical copper), with cold working for final shape and hardening of the cutting edges – found generally in inland Palestine, the Negev and central Sinai and going back to early Chalcolithic times. The second has more sophisticated use of copper-based alloys – arsenical copper and tin-bronze – often showing the use of lost wax casting techniques. These sophisticated objects, mostly weapons, were mainly found to the north of the more primitive, southern region, where only unalloyed copper was used, though occasionally there was an 'infiltration' of tin-bronze objects also into the south. Whilst arsenical copper and tin-bronze found in the south were obvious 'imports' from the north, the origin of the local copper working tradition, and especially of the copper itself, until recently posed a very intriguing problem: Where were the local copper mines and smelters which produced the raw unalloyed material for the local coppersmith of the EB IV period?

II THE DISCOVERY OF AN EB IV COPPER SMELTER AND ITS MINE

We had actually discovered an EB IV (our Sinai-Arabah Copper Age – Late Phase) smelter and mine in Timna as far back as 1967, in the course of our surface exploration of the entire Western Arabah, but we did not realize that these were EB IV sites because we had found only very few and rather atypical sherds among the debris which were undatable at the time.

The smelting site, Site 149 on our survey map, was located on a small, solitary hillock in the middle of the wide estuary of Nahal (wadi) Timna (Fig. 1). On its low, flat western slope a number of cup-marked stones stuck

Fig. 1. The hillock of Site 149, in the middle of Nahal (wadi) Timna. The workshop is located on the low slope to the right of the hill.

out of the sandy ground, and bits of blue ore and small slag lumps were dispersed everywhere, indicating a metallurgical workshop. The actual smelting location was found to be the flat top of the hill, where we found several heaps of heavily charred and partly slagged, mostly brick-shaped rocks, obviously dismantled stone-built smelting furnaces, and quite a mass of small slag lumps (0.5–3cm.).

In spite of our very intensive search, we were unable to find more than a handful of sherds – obviously early, handmade pottery – and these could not be dated. This was rather frustrating because the site was very different from all the other smelting sites we had investigated in the region. First of all the blue ore, believed at the time to be azurite (but since identified by the Geological Survey of Israel, Jerusalem, as the copper silicate bisbeeite), had not been found in such dominant quantities in any of the copper smelters of Timna. The stone-built furnaces of Site 149 did not really fit with our ideas about prehistoric copper smelting furnaces, up till then of the primitive hole-in-the-ground type. The relatively large quantity of slag also indicated a hitherto unknown scale of prehistoric copper production. Furthermore, the slag appeared to be much more homogeneous and solid than the Chalcolithic slag so far encountered in the Arabah (Rothenberg *et al.* 1978, 9.)

Continuing the survey, we looked for the source of the blue copper ore (bisbeeite) found on hillock 149 and, after a systematic search in the vicinity, we located a group of workings, Sites 250, 250A and 250B, which showed clear traces of blue mineralisation in the rock faces. These workings could actually have been seen from the smelter's hill. Looking north-west, there is a colourful low range of hills (Fig. 2) with one steep mountain, Givat Sasgon, at its end. Right in the upper slope of the lower ridge are two low and long rock shelter-like caves in each of which we found a thick vein of mineralisation, mainly the blue ore bisbeeite.

There were actually three different places of special interest on this mountain. In one of the two 'caves' (Site 250), in a shallow, ashy habitation midden, we found a number of sherds and many very fine flint drills, together with tiny bits of platy blue ore. It was obviously a bead manufacturing workshop – and the pottery could be dated to the Chalcolithic period of the region (our 'Sinai-Arabah Copper Age – Early Phase').

The second 'cave', Site 250A (Fig. 3), looked more like mine workings but because of a huge rockfall it could not be properly investigated at the time. There was a thick vein of mineralisation in its rockface, mainly of bisbeeite. There were no finds here other than quite a lot of ore and a large mineralised boulder on some flat ground in front of the 'cave' with some roughly spherical flint hammerstones. From here a clear path could be seen running down the hill in the direction of our hill smelter, Site 149.

Climbing up towards the cliffs of Givat Sasgon we noticed some slag which had apparently slipped down from another site higher up the slope. Right at the top of the saddle, close to Givat Sasgon, we found the actual smelting site, Site 250B, and a shallow heap of very rough and viscious-looking slag. This slag was quite different and far more primitive than the slag observed previously at Site 149. Luckily, with the slag, there were quite a few pottery sherds which could be dated to the

Fig. 2. Givat Sasgon: Site 250. The entrance to the mining 'caves' are clearly visible on the hill to the right.

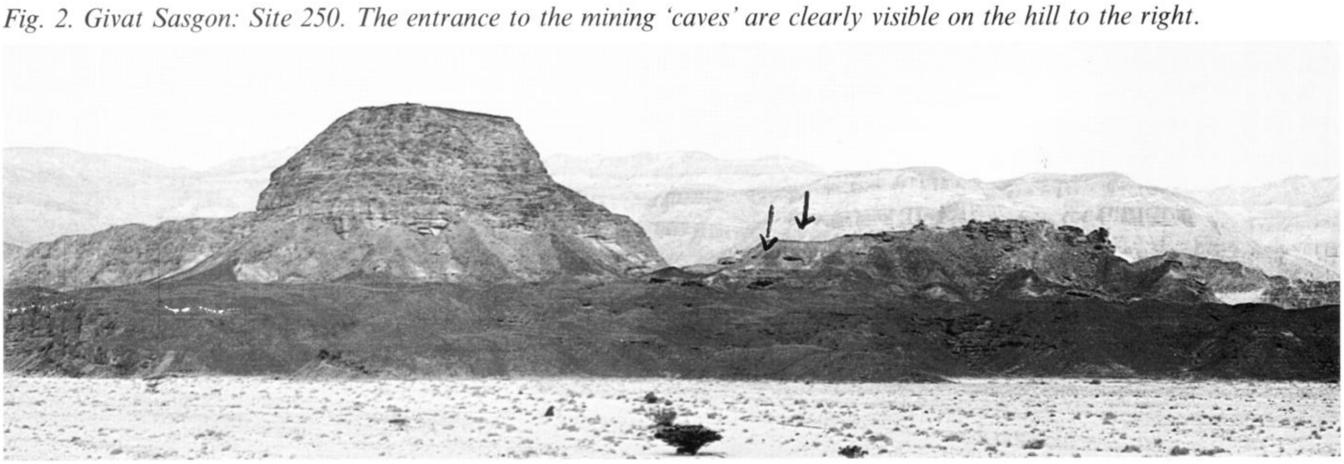


Fig. 3. Entrance to mining 'cave', Site 250A. To the right, the ore dressing platform, partly covered by rock fall, with a large mineralised boulder.

Chalcolithic period of the region. Obviously, in this period there was mining, smelting and bead-making on this mountain, based on the use of the blue bisbeeite ore.

III EXCAVATIONS IN 1984, AND AGAIN IN 1990

The circumstances of the particular type of copper ore, the location of the mine, Site 250–250A, quite close to the smelter, Site 149, and the fact that no other mine of this type of ore has been found in the area, evidently connected the mine and the smelter. However, the very obvious technological difference between the Chalcolithic smelter, Site 250B, and the smelting debris at Site 149, plus the necessity to secure the relation of the smelter, Site 149, to the bisbeeite mine on the opposite hill and the importance of a reliable date for such a unique and obviously advanced smelting technology, demanded systematic excavations.

We were able to solve the immediate dating problems of Site 149 in 1982, even before we were able to excavate the sites. This was in the course of the systematic petrographic investigations of the pottery of Sinai and the Arabah (by Jonathan Glass), which became instrumental in creating the new regional Chronology: The Sinai-Arabah Copper Age – Early, Middle and Late Phase (Rothenberg 1988, 14). The sherds from Site 149 produced a secure date for this site: The Sinai-Arabah Copper Age – Late Phase, approximately equivalent to Early Bronze Age IV of the Levant. This identification and dating naturally emphasized the great importance of this site because it was the first ever discovered smelter of this enigmatic period.

Excavating in the copper mines of Givat Sasgon (Sites 250 and 250A)

The mine workings on Givat Sasgon were investigated in detail and partly excavated in October 1989 and January 1990. Michael Beyt and Amit Segev of the Geological Institute of Israel, Jerusalem, have recently concluded a thorough geological re-investigation of the Timna Valley (to be published, together with the report on the mines of the Arabah, in Vol. 3 of *Researches of the Arabah*). According to their up-to-date geological information about this part of the Tinma Valley all the mine workings so far, extracting mainly copper carbonate malachite and some chalcocite, had been found in the cretaceous Amir-Hatira Formations, also called the Middle White Nubian Sandstone. Givat Sasgon, now identified as an ancient mining site, contains mainly hydrated copper silicates – chrysocholla and bisbeeite – located in the shaly facies of the Timna formation of the Cambrian (Fig. 4), which was also the main target of the modern mining operations in Timna.

Excavating Mining Site 250A

This shaly facies is rather distorted and the sandstones above it are rather shattered and brecciated on contact. This means that both the rock types encountered in the mine were very highly jointed and, therefore, easily mineralised by hydrothermal solutions. The jointing also means that they could easily have been mined using

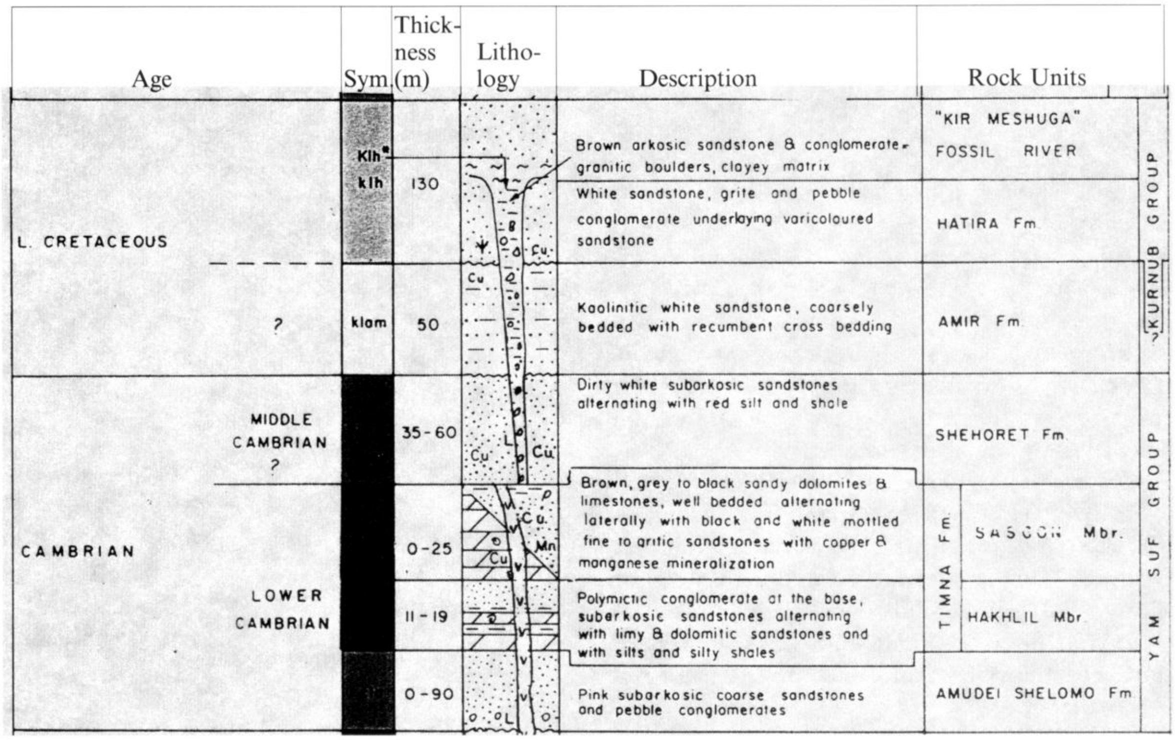


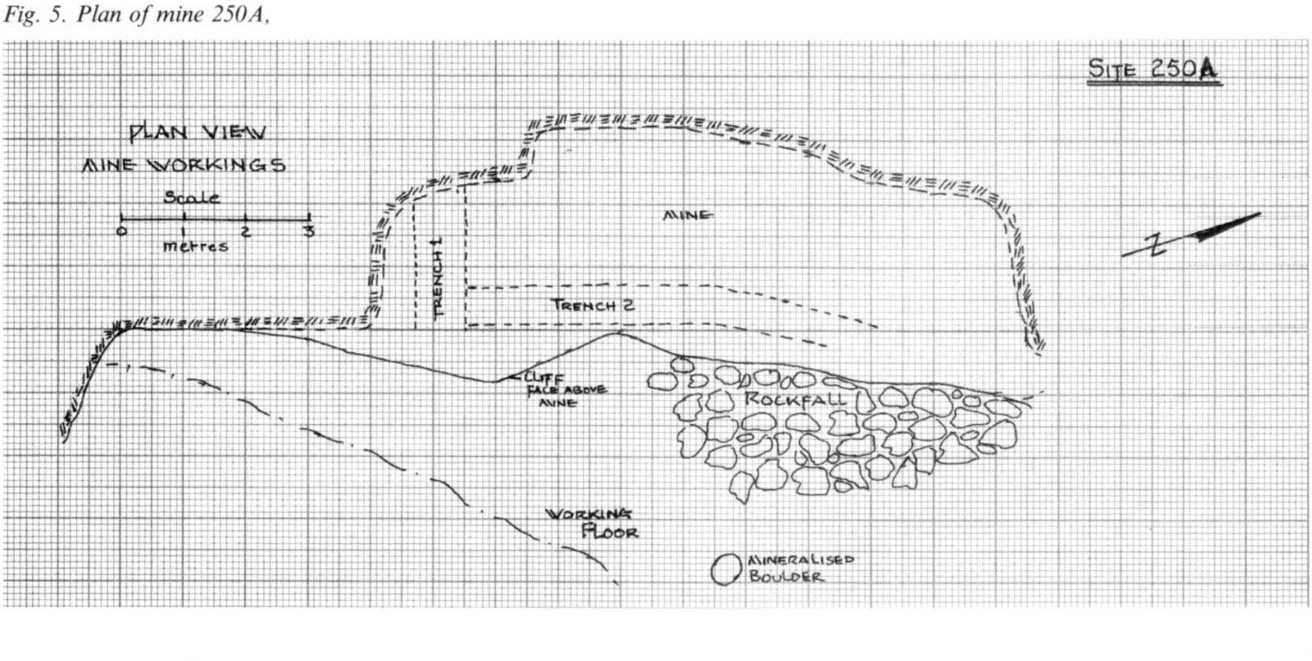
Fig. 4. Schematic geological section of the Timna region.

nothing but hammers or hammer and gad (or pick). Due to their friability it is unlikely that tool marks would be preserved.

Fig. 3 shows the mine entrance as it exists today, under a low cliff face, which runs roughly SW–NE. The eastern end of the workings have been destroyed by a rock fall. At the western end of the workings the shales and brecciated sandstones are cut back to a depth of about half a metre under the brow of the more competent overlying sandstones, and this very probably indicates the full extent of the natural weathering of this horizon. The fact that no mineralisation was noted in the shales at this end of the occurrence supports the view that this slight undercut was formed naturally. The shales also fold down and thin out rather sharply at this western end of the outcrop. The shale horizon then flattens out towards the east, and reaches a width of about 70–80cm., the flattening giving an almost horizontal dip where the mining has taken place.

About four metres from the position where the shales fold down at the western end of the shale exposure, they are cut back another metre into the cliff and this cut deepens rapidly to reach four metres, a further four metres to the west (Fig. 3). This sudden deepening marks the beginning of actual mining activity. In the side walls and in the roof of this excavation some mineralisation can be seen, and this adds credence to the supposition that the material removed from this excavation was ore and that the sudden deepening of the undercut under the sandstone brow is the start of the ancient mine workings. The workings were, at this point, filled with sand to about 20cm. from the roof and excavation was required

Fig. 5. Plan of mine 250A,



to establish the height of the ancient mine workings. Fig. 5 is a diagram of the mine as measured during the excavation. The sand filling had clearly been introduced largely by water.

In January 1990 the mine was investigated by trenching. Unfortunately no working tools were found during this excavation. It seems probable that it was simply a hammer operation, all that would be needed in this friable rock. The miners probably followed the best mineralisation in and stopped working when the quality of the ore dropped. The size of the workings must relate to the amount of pre-existing mineralisation. No tunnels were seen, nor was there any evidence of exploration probe holes in the walls of the excavation.

Our first excavation trench, a cross section of the mine, was cut at the western end of the workings from the lip of the cliff face into the face of the mine working left by the ancient miners. The height of the mine proved to be about 80cm. at this point and it stayed roughly constant on the face. The floor of this trench showed traces of mineralisation, confirming that there had been mineral to mine at this point.

A second trench, cut parallel to the cliff face, stayed at the roughly 80cm. height for about three metres, then there was a lip and thereafter the mining height was only about half a metre. Again there was evidence of mineralisation, confirming the nature of the rock removed. The cutting of this trench enabled the extent of the remaining workings to be measured. An unknown amount of working was destroyed when the cliff face collapsed at some time after mining had ceased.

To the south-east of the mine opening on a level area of the hillside there was a well mineralised boulder of the brecciated sandstone (Fig. 3). This showed where the boulder lay in relation to the mine – it was unlikely to have been moved to its present site by natural forces and must rather have been moved by human intervention. This gives further proof that this excavation in the cliff face was indeed a mine.

No waste dump has been identified but there is a drainage channel running away from the site and any waste there has probably long since been washed away. In any event, this is not a large excavation and the amount of debris would not have been very extensive. In addition, debris from the mine would not, in this area, look very different from the natural rock scree after several thousand years of weathering.

Excavating Site 250 – the mine and bead workshop
Under the overhanging rock ledge, the cavity was about nine metres long, orientated SW–NE, and gradually deepened to about four metres. Inside, behind the washed-in sand fill, close to the inner wall were the remains of a fireplace and near it a small storage pit for broken blue ore. Under the sand were more flint drills and also larger flint debitage, plus several handmade sherds of the kind found during the survey, and many more blue ore lumps. There were two small lumps of slag, though there were no signs of any metallurgical activity.

Outside the 'cave', on the slope below, there was a quantity of finds which must have gradually slipped down from above: flint tools, including drills, more sherds, a hammer stone and also a lot of blue ore.

At the inner rock face was a vein of mineralisation several centimetres thick containing blue bisbeeite ore *in situ*. Obviously this 'cave' had been created by mining the mineralized rock face to extract the blue ore. The ore was of a high-grade blue tint and glittered in the light – a very attractive material for jewellery.

Besides the actual mining 'caves' blue mineralisation outcropping can be seen dispersed at several other locations on the mountain, which could have led to surface mining and exploration all over the site, following the outcropping mineralized vein.

Excavating the EB IV workshop and smelter Site 149.
Site 149 was excavated in 1984 and recently re-investigated in January 1990. The workshop area on the lower slope (149A) had a low wall running right through it (N–W), probably acting as a shield against the strong north wind. About 15 crushing anvils and mortars and many small round stone hammers were found in small groups as if workers had just left for a short break (Fig. 6). Inside some of the mortars were chunks of still uncrushed blue ore and finely crushed bisbeeite ore was found dispersed all over the site. Obviously the smelting charge for the furnaces on top of the hill above was prepared here.

There were also numerous tiny fragments of slag on the floor and it seems that slag lumps containing numerous visible copper prills were also crushed here.

One of the surprise finds of the excavation was a quantity of drop-like, nodular slag, some looking like dross, which had the typical appearance of crucible melting-refining slag. Furthermore, on the floor of the workshop were found fragments of clay vessels, slagged on their concave inside and obviously connected with this crucible melting slag. Evidently at Site 149 there was

Fig. 6. Ore and slag crushing workshop at Site 149

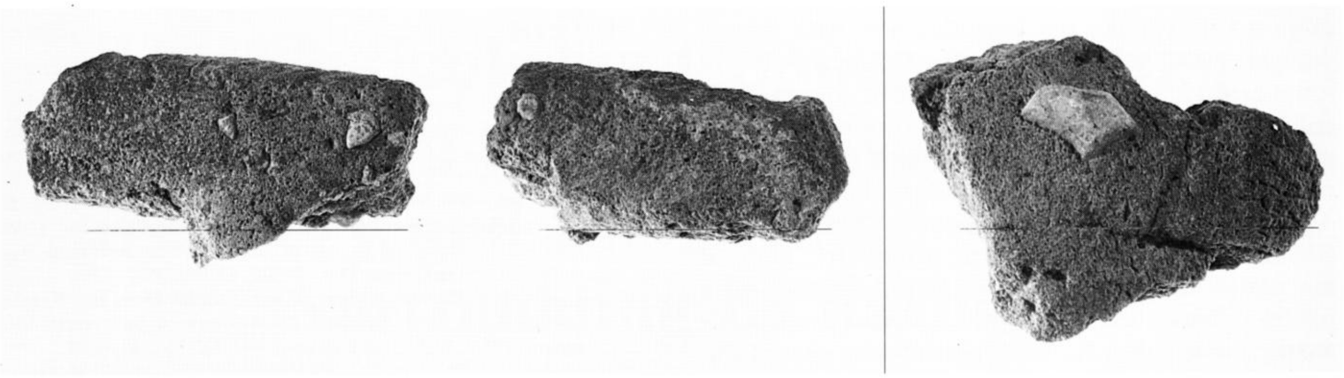


Fig. 7. Typical sample of the clay 'rods', some with fragments of the crucible-like vessel still adhering. 1:1.

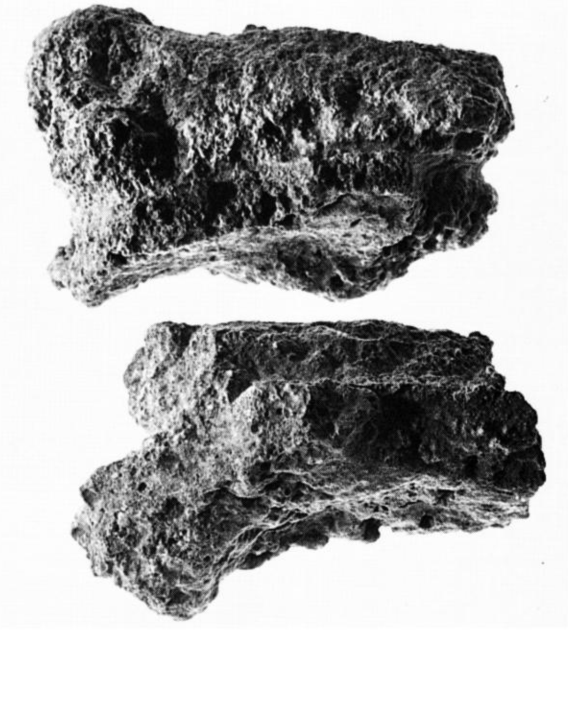
also secondary extractive refining metallurgy, perhaps also casting of copper ingots (for a similar situation at the Hathor Mining Temple at Timna see Rothenberg 1988, 192–7).

The clay vessels or crucibles had a peculiar, thickened, clay coil-like rim (about 1–1.5cm. diameter), attached from the outside to the edge of the straight wall of the handmade vessel (Fig. 7). Many such fragments were also found among the slag on top of the hill. Site 149 produced several hundred of these round clay fragments, looking like broken rods, sometimes with a slight slagging on one side, but never showing any signs of high temperature firing. Judging from the light buff colour, the 'rods' were fired under oxidizing conditions – not smelting! Whenever a 'rod' was found still sticking to a piece of the vessel's wall, the inside of the vessel showed a crust of slag, typical of the encrustation often found in used crucibles (Fig. 8). The slight curvature of the slagged fragments indicated that the diameter of these vessels must have been quite large – pointing to a secondary refining and concentration process by re-melting the metal-rich slag in a fairly large crucible-like vessel. This would also explain why the small 'rods' often showed no obvious curvature. Some of the straight 'rods' give the impression of not having been fired and were apparently never used, these were probably pre-prepared coils and not actually applied.

It is of considerable interest that this peculiar ceramic technology (manufacturing the vessel rim separately and attaching it at the finishing stage of the vessel's production), is well known as a typical technique of the EB IV potter (Amiran, R. 1969, 80) and can be observed on many types of vessels of this period. Site 149, the only EB IV smelting site found so far in the southern Arabah and Sinai, is the only smelter where such peculiar 'clay rods' have been found and there can be little doubt that they are characteristic of the technology of this period only. However, in the copper smelting sites of the Feinan region, in the north-east Arabah, many similar clay 'rods' were reported (Bachmann and Hauptmann, 1984, 115–17) and repeatedly discussed in recent literature (Hauptmann *et al.* 1985, 171–2), being interpreted as implements for removing slag from the furnace wall or from inside a blocked tuyére. Alternatively, in his latest publication on Feinan, Hauptmann now relates the clay 'rods' to a totally new type of smelting furnace model, dated to Early Bronze II and III (Hauptmann 1989, 129–30): 'shallow, widely opened natural draught furnaces without a shaft . . . bowl-shaped back- and side-walls nearly 60cm. in diameter and up to 40cm. high. The bottom is semicircular'. Hauptmann discusses 'a front constructed of vertical orientated claysticks like a pipe-grating'. The photographs of the furnace remains in Feinan show 'multiple renewed backwalls of the furnaces' after excavation (Hauptmann 1989). A photograph of the same 'furnaces', before excavation, was previously published by Bachmann and Hauptman (1984, Abb. 11) who noted that macroscopic examination showed almost no effect of heat. On both photos there were no discernable signs of the characteristic charred ground usually found around a smelting furnace – or of the heavy slagging of the wall of a furnace which produces tapped slag (cf. the smelting furnaces of Site 2 at Timna, Rothenberg 1985).

The extensive experimental and theoretical research of the last few years (Merkel 1983; Bamberger *et al.* 1986 and 1988), and our own field experience in the excavation of almost complete copper smelting furnaces from the Chalcolithic Period to Early Islamic times in the Arabah (see Rothenberg 1985), make it almost impossible to envisage a pyrotechnological smelting process in a large and shallow bowl under partial oxidising conditions as

Fig. 8. Detail of 'rods' with slagged, curved inside of the original rim of a crucible-type vessel. 2:1.



proposed by Hauptmann (and this only with natural draught), which could exist without a chimney effect of some kind. It is also extremely difficult to imagine a reducing atmosphere in a wide-open bowl standing in the wind achieving the high temperatures ('1200–1250°') required for several hours to produce the tapped slag described by Hauptmann as related to these 'furnaces' (1989, 129–30). Simply because no tuyères were found at the related slag heaps at Feinan is not evidence for a totally different technology which thermodynamically seems unacceptable. At numerous smelting sites of different periods in the southern Arabah, Sinai and the huge smelting sites in Andalusia (Rothenberg and Blanco 1981), no proper tuyères were found and it is obvious that a different kind of heat protection was used for the bellows. Surely, the mathematical model of the smelting of oxide ores, developed by Bamberger and his colleagues (Bamberger *et al.* 1988), and based on the almost complete furnaces excavated in the southern Arabah, cannot be totally ignored in the reconstruction of smelting furnaces of very similar periods (?) at Feinan, in the adjacent northern Arabah.

Although the detailed process technology of Site 149 has yet to be investigated – hence no reconstruction of the production chain is posited here – preliminary chemical investigation of some of the slags has shown them to be of the fayalite type, as common in Timna, indicating fluxing with iron oxide. Most of the slag is broken into small pieces, but much of it shows clear flow patterns on their top surface. There is also larger, platy slag pieces with the same pattern on top and sand baked into the bottom surface. There can be little doubt that at the end of the smelting process most of the slag was tapped out onto the sandy floor in front of the furnace and most of it was broken up to extract any entrapped copper prills.

Quite a number of EB IV sherds were found on the floor but no other traces of habitation. It seems that the workers lived somewhere else and, nearby in the Arabah, several habitation sites of this period have been identified and dated recently.

Site 149 exhibits pyrotechnical process details not yet encountered elsewhere in the Arabah or Sinai and these seem to indicate a 'foreign' origin of the smelter – people and technology – or at least a strong influence from outside the area. The remains of Site 149 bear witness to a major step forward in the history of extractive metallurgy, the advance from the primitive, indigenous, prehistoric hole-in-the-ground plus bellows technology to, at least, partly stone-built furnaces and a smelting process that already had a quite large-scale proper production of low-viscosity, tapped slag. The archaeological evidence points to subsequent crucible extraction and refining of crude copper prills – and suggests even the casting of ingots.

Beno Rothenberg and C. T. Shaw

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It is with deep regret that we announce the death in June of Professor R. F. Tylecote, one of our founder Trustees. An appreciation of his work will appear in our next issue.

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The Chalcolithic Copper Smelting Furnace in the Timna Valley – its discovery and the strange argument surrounding its dating

Early in 1960, during our first exploration of the Timna Valley, Moshe Preis, the geologist of the modern Timna Copper Mines Company handed me a handful of early flint tools (see photos in Rothenberg 1962, Pl. XV), which he had found together with some small pieces of copper slag on top of a hill at the fringe of the Arabah, near the entrance to the modern mine. This 'gift' was rather exciting because until then we had only seen much later smelting sites, dated (now) to the Egyptian New Kingdom, 14th–12th centuries BC, and the Roman-Early Islamic period, where no flint tools were ever found. These flint implements were the first indication of prehistoric copper smelting in the Timna area.

During the following weeks of fieldwork we therefore investigated the area just *outside* the Timna Valley and located, besides the site seen by the geologists (later excavated and called Site 39 – see below), a large cluster of prehistoric settlements, many of them with remains of copper smelting, e.g. pieces of slag dispersed over a small working area (several square metres) near the houses or on a low hillock nearby. Amongst the slag and the houses we found flint tools as well as sherds of handmade early pottery (quite different from the handmade Iron Age pottery of the Negeb).

During a later survey we also discovered evidence of prehistoric mining and copper smelting *inside* the Timna Valley, although it became obvious that the prehistoric, rather small scale, 'cottage industry' type of copper production which was generally attached to settlements, took place mainly in the Arabah, outside Timna, and near the sources of drinking water and firewood.

The most significant result of our extensive surveys during the years 1959–84 was the conclusion that in prehistoric times the Arabah, part of the large, semi-arid region comprising the Sinai Peninsula from the borders of Egypt to the Mountains of Arabia and the Southern Negeb, was inhabited by indigenous pastoral nomads, copper (and turquoise) miners and smelters (for first reviews see Rothenberg 1979;1979a). We located several hundred prehistoric sites in the Arabah and adjacent Sinai, many of which could be dated by flint industries and pottery and recently also by radiocarbon measurements (Dr H. Haas, S.M.U. Radiocarbon Laboratory, Dallas, Texas – see Rothenberg, B. ed. *New Researches in Sinai*, Vol. 1, in press) to the era from the 6th millennium BC (Pottery Neolithic), through the 5th–4th (Chalcolithic) to the beginning of the 3rd (Early Bronze Age).

Typological as well as petrographic investigations of the flint industries and pottery of this indigenous prehistoric population established the existence in Sinai, the Arabah and adjacent areas, of a well-defined autochthonous prehistoric culture which could be traced through three phases of cultural development – accompanied by three, parallel developing, distinct phases of copper smelting technologies: from the primitive 'hole-in-the-ground' smelting hearth of the Chalcolithic Periods, through the first stone-built bowl-furnace and first slag tapping of the Early Bronze Age, to the sophisticated, well-ventilated, clay-lined shaft-furnace with perfect tapping facilities of the Late Bronze Age and later (Rothenberg, 1985). The scale of production at the individual smelting sites of these technological, and chronological, phases is also highly significant. A Chalcolithic 'cottage industry' produced only a few kilograms of copper whilst during the Early Bronze Age production increased to hundreds of kilograms, and the major smelting camps of the New Kingdom (Late Bronze Age) produced many hundred tons of copper, i.e. they achieved copper production on a really industrial scale. It is against the background of these basic facts that we have to try and understand the appearance of prehistoric

Fig. 1. Site 39.

copper mining and smelting in the Arabah – and the significance of the Chalcolithic smelting furnace at Site 39, the first prehistoric copper smelting installation ever found anywhere.

Site 39 : Chalcolithic Copper Smelting

Site 39 is located in the Nahal (wadi) Nehustan (one of the four main wadis of the Timna Valley), alongside the modern road to the Timna Mines Co. (Fig. 1). It consisted (after its excavation in 1965) of a circular enclosure, Site 39A, used for habitation and as a workshop for the preparation of the smelting charge, at the bottom of the hill on top of which the geologists had found the flint tools and peculiar small slag (Site 39B). The slag looked rather rough and viscous and showed numerous inclusions of copper pellets, quite different from the solid slag lumps we had previously seen at the New Kingdom smelting camps of Timna. During our subsequent survey we found more flint tools and also a few sherds among the slag on top of the hill and these appeared to be the same as found around and (during its excavation) within the circular enclosure below. The archaeological finds at Site 39 were studied at the time by Professor M. Stekelis, Director of the Department of Prehistory, Hebrew University, Jerusalem, and dated to the Chalcolithic Period (Rothenberg 1962, 8 and Chapter III).

In 1965 we excavated Site 39 (Rothenberg, B. 1966; 1972, 26–51). In the centre of the slag dispersal on top of the hill we found a hole-in-the-ground smelting hearth. It was originally dug into the ground to bedrock and had a low substructure of small stones (Fig. 2). The excavation proved that, at the conclusion of the smelting operation the content of the hearth was raked out in order to mechanically extract the metallic copper pellets entrapped in the very viscous slag. Obviously, the Chalcolithic smelter in his primitive hole-in-the-ground 'furnace' did not achieve the separation of the metallic copper from the viscous slag. Many of the slag pieces found scattered around the furnace had sandy furnace wall material still sticking to them, and most contained quite a lot of copper prills (Fig. 3).

Excavating the furnace site, 39B, in 1965 (Rothenberg 1966, 86–93; 1978, 4–11, Plan and section Fig. 12), we found a hard-trodden working floor underneath the shallow Present Surface and this was stratigraphically the surface into which the hearth had been dug. On this floor we found some handmade early potsherds and a good number of flint tools (Rothenburg 1978, Fig. 17–9). The prehistorian A. Bercovici, Tel Aviv University, studied these flint tools and wrote: 'Other implements, especially the axes family, are almost exclusively of Chalcolithic type and, therefore, important for the determination of the latest possible date of this group'. Bercovici compared the flint implements and the potsherds of Site 39 with the similar Chalcolithic finds from below the Egyptian Mining Temple of Timna (Rothenberg 1988) and reached the conclusion that this group of flint objects and potsherds indicates 'a Chalcolithic culture which existed towards the end of the Chalcolithic Period ... the late 4th millennium BC' (Bercovici, A. 1978, 16–20).

During the excavation in 1965 we collected several bags of soil containing traces of charcoal for radiocarbon dating but, to our great disappointment, there was not enough carbon in the samples for the C14 dating techniques available at the time. However, the archaeological evidence found at Site 39, especially as seen in the context of the extensive Chalcolithic occupation of the region and documented at hundreds of sites all over Sinai and the Arabah, made up for this lack of radiocarbon dates for Site 39.

The discovery and excavation of the first Chalcolithic smelting site and furnace was received with considerable

Fig. 2. Chalcolithic copper smelting furnace, Site 39A.

Fig. 3. Typical Chalcolithic slag (actual size) from Site 39A.

interest by archaeo-metallurgists and archaeologists alike and many of our colleagues came to see the site, taking metallurgical samples and archaeological finds for further studies. Site 39 quickly became the key site for the study of *Chalcolithic Copper Smelting* (Tylecote, R. F. and Boydell, P. J. (1978) and, indeed, appears in the archaeological and archaeo-metallurgical literature as the model-site for Chalcolithic archaeo-metallurgy. Site 39 with its distinct primitive copper smelting technology (and because of its location near many Late Bronze Age to Early Islamic smelting sites, the archaeological evidence and sophisticated archaeo-metallurgical installations as products of which could be easily compared *in situ*) became the obvious type-site for the early beginnings of copper smelting (for lack of space we quote here only some of the most important references: Tylecote, R. F. 1976, 7; 1986, 19).

Strange arguments surrounding the dating of Site 39

There was, however, one odd exception: James David Muhly. Already in the Supplement (1976) to the publication of his doctoral dissertation of 1973, he wrote: 'While little of the early material has been published thus far, it seems doubtful that anything at Timna is really earlier that EB II' (Early Bronze II = 2850–2650 BC – P.C.). Since I have always found it difficult to argue with people possessing supernatural powers like clairvoyance, which enables them to know things hidden from ordinary man (like unpublished archaeological finds or archaeological sites never seen), it seemed at the time of little use to react to Muhly's 'views'.

Muhly, however, did not let go. In 1984 he published in *Bibliotheca Orientalis* (XLI, No. 3–4) a very extensive review of our work in Timna. Concerning Site 39 he stated: 'I know of nothing found at any of the mining or smelting sites at Timna that need to be dated earlier than the latter part of the Egyptian New Kingdom'. Although Muhly is a well-established expert on ancient history, but he is not a metallurgist nor an archaeologist, and neither has he ever seen any of the archaeological evidence nor the sites themselves, yet he took it upon himself to evaluate and criticise the results of many years of systematic and very large-scale professional investigations by a group of well-known metallurgists and prehistorians. Here is a typical argument: 'Rothenberg has never published any hard evidence in support of the Chalcolithic dating of Site 39'. I wonder what could possibly be such hard evidence in the eyes of an ancient historian – obviously not the detailed comparative study of the flint implements (Bercovici, A. above; Ronen, A. 1970; Kozloff, B. 1974) from Site 39, nor the hundreds of similar settlements and smelting sites in Sinai and the Arabah (Rothenberg, B. 1968; 1970; 1972; 1974, see survey map in 1988) where only prehistoric flint and pottery finds were ever recorded – now C14 dated to prehistoric times.

As his only 'factual' argument against the Chalcolithic date of Site 39, Muhly signed up two rather extraordinary Late Bronze C14 dates published some time ago in *Radiocarbon* (Muhly 1984, 288). Regarding these C14 samples and their implication, I have already pointed out in *IAMS Newsletter* No. 12 (1987) the damage to scientific research by the publication of C14 results of stratigraphically unreliable samples, sent to Radiocarbon Laboratories without confirmation of the context by the excavator. In our case, one of the samples was picked out of the soil brought several years after the excavation from a nearby location as fill for the excavated hearth 39B, in order to prevent its collapse. Muhly ignored the warning by the author of this C14 report, that this sample is 'invalidated by misassociation'. The second sample came from an intrusive Late Bronze Age fireplace of another site altogether (Site F2 in Timna) which was cleared long after the original excavation of the prehistoric site itself and has since been recalled as mistaken (Leese, M. N., in Craddock 1986, 117–8).

If such is all the 'hard evidence' Muhly can provide against our Chalcolithic date for Site 39, and of hundreds of similar prehistoric sites in Sinai and the Arabah, it should be difficult for any informed reader to relate to him seriously.

However, the story – and the damage – goes on: From amongst several recent publications following in Muhly's footsteps, we quote here as typical Hanburg-Tenison, J. W. (1986, 160): 'Much discussion has centred on the claim for Chalcolithic mining and smelting at Timna (Rothenberg 1966; 1978; etc.). Very little corroborative evidence has been produced to support the argument, and most scholars now reject any claim for metallurgy at Timna before the Bronze Age (Muhly 1984, 287)'. Perhaps many of the uninformed readers really were convinced by the overwhelming barrage of arguments produced in such an authoritarian fashion in Muhly's giant Timna review (16 double column folio pages), but scholars who actually studied the sites and finds *in situ*, do not seem to share his 'view'. A team from the German Mining Museum, Bochum, who worked in Timna in 1974–6, and are now active in the ancient mining area of Fenan (Jordan), wrote in a recent reply to Muhly's argument: 'The obvious exploitation of the mineral deposits at Timna and smelting of its ores already in the Chalcolithic Period, as repeatedly postulated by B. Rothenberg, has been disputed recently (Muhly 1984). However, we have to accept as certain the existence of [metallurgical] activities in the Timna Valley during the Chalcolithic period' (transl. B.R.).

Oddly enough, and actually amusing, there are 'Muhly waves' even in recent publications by the same Bochum scholars: '. . . in fact, the smelting furnace, site 39 . . . cannot be dated (Muhly 1984), but the immediate proximity of a dwelling ruin (site 39A) where excavations have produced Chalcolithic flint material, ensures at least the presence of humans at the site in the Chalcolithic Period.' (Weisgerber, G. and Hauptmann, A. 1988, 53).

Rather odd. We quote from the original excavation report of Site 39 (Rothenberg, B. 1978, 7–8): 'An area of 4 × 3m. around the furnace was excavated down to a hard surface, which must have been the working floor, connected with the smelting operations. Charcoal, slag fragments, flint tools and some pottery were found on this floor, right up to the kerb of the furnace' . . . 'At 39B, around the smelting furnace, only one working floor was found, close to bedrock, and **on this ancient surface, flint implements and sherds were found** *in situ*, **and dated to the Chalcolithic Period'.** *Beno Rothenberg*

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Exploring the Ancient Copper Mines of the Wadi Amram (South Arabah)

Wadi Amram is one of the southern tributaries of the Wadi Arabah, about 11km. from the shore of the Red Sea. This report describes an archaeological survey of its ancient copper mines (Rothenberg 1962), carried out by a small team from the Peak District Mining Museum, Derbyshire, England, in conjunction with IAMS, in October and December 1989. It compliments earlier archaeo-metallurgical work by Beno Rothenberg and the Bergbau Museum Bochum, at the nearby Timna Valley (Conrad and Rothenberg 1980; Rothenberg 1988).

Geology

The wadi near the mines is very steep-sided, with many near vertical cliffs, and there is no vegetation or natural source of water in the area. The mines are kaolinitic sandstone of probably Lower Cretaceous age, which is so unusually weak in compressive strength that it can be crushed in the hand. It is part of a thick sequence of white, yellowish and red slits and sandstones, which can be seen to overlie basic and ultrabasic rocks, and are unconformably overlain by an Upper Cretaceous (Cenomanian) limestone sequence, which forms a high escarpment.

The mineral seems mainly to be a copper silicate, probably chrysocolla, occurring irregularly in a band some three to five metres thick, though malachite or related copper carbonate mineralisation is also present. The grade of ore was low, perhaps below 1% where it was mined extensively rather than selectively. It occurs occasionally as substantial nodules, but more generally it was in disseminated form as small wheat-sized nodules. The breccia also contains iron/manganese rich clasts which may have been used as flux in smelting.

Two mining Complexes: Sites 33 and 38 (on the Arabah Survey map, Rothenberg 1962, 1972, 1988).

There are two main mining complexes in the Wadi Amram and both were examined by our team. Site 33 is about one kilometre from the head of the Wadi and consists of two main areas, (a) a long scarp foot which slopes up to the skyline, and (b) an area of wadi-floor, beneath the cliff of area (a), where 'plates' were found. These are very shallow depressions, three to five metres across, which stand out from their surroundings because of their finer washed-in material. Similar 'plates' were excavated by an IAMS team in the Timna Valley in 1976 (Rothenberg 1988, Introd.) and turned out to be alluvially infilled mine shafts or pits. Site 33 has a scatter of Chalcolithic and New Kingdom (14th–12th centuries B.C.) pottery sherds and stone tools.

Site 38 is near the head of the wadi, adjacent to a rock formation called the 'Amram Pillars', a much frequented

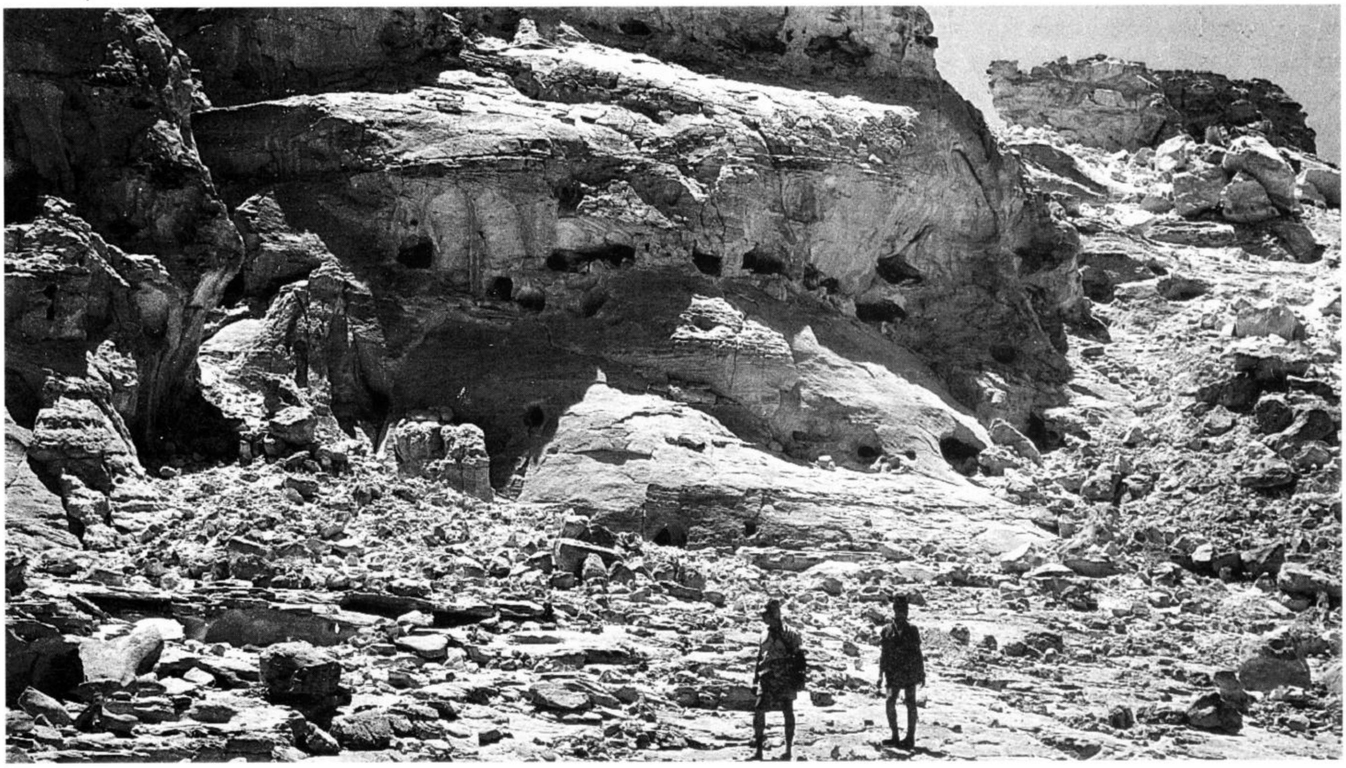


Fig. 1. Wadi Amram Site 33: The Chalcolithic and Late Bronze Age (New Kingdom) mine on top of the cliff. Note the small boreholes next to the larger gallery opening.

tourist attraction. Here quantities of Roman to Early Islamic and later pottery was found. The site was the main objective of our recent fieldwork because no Roman to Early Islamic mine workings had been systematically investigated before in the southern Arabah; in fact, no mines of these periods have so far been surveyed anywhere in the Ancient Near East.

Site 33(a) (Fig. 1) The mines are both galleries and shafts and the tool marks indicate the use of metal tools. The openings are usually just sufficient for crawling – about 80cm. high – but widening out where rich ore pockes were found. The most remarkable features were more or less horizontal boreholes, about 19cm. diameter and up to 10m. long (see the small holes in the rock faces in Fig. 1). These must have been driven in using a long wooden rod, possibly shod with a pointed metal bit, such as were found in the Timna copper mines of the New Kingdom period (Rothenberg 1972, Fig. 29: 1–2, now understood as mining tools). Smaller bores were also seen at the ends of the small workings, usually developed from a conical opening about 50–70cm. deep and 30–40cm. wide at the mouth. Since there were examples of several of these at the end of some tunnels, it is clear that they were for explorations in order to find workable nodules of ore and not for opening out a face. This clearly saved much excavation, at the risk of missing some smaller concentrations of ore, and the boreholes are the oldest evidence of the use of this exploration technique.

Site 33(b) The flat valley below the mining cliff of Site 33(a) has a variety of archaeological remains, including a smelting site, stone-built habitation and workshop structures, and an area of significant scatter of green copper minerals near what appear to be 'plates'. The number of these 'plates', if they were indeed mine shafts (which needs to be established by future excavations) would indicate that they were just not 'wildcat' prospecting holes but a fairly large scale mining enterprise. There is a very substantial thickness of alluvium laid down in the wadi which the ancient miners would have had to penetrate, and there was no obvious outcrop to follow, as so often in Timna.

Site 38 is a very large mining complex which has been worked by inclined galleries and vertical shafts, and later

Fig. 2. Mining waste heap, behind it mineworking, later used as habitation.

by opencast methods. Contrary to the New Kingdom mines at Timna, there are substantial mining waste heaps at Site 38 (Fig. 2), typical for all mining sites in the southern Arabah which were dated by the pottery as Roman to Early Islamic. Waste heaps on higher slopes, though much eroded, are easily recognised by their flat tops and sides close-streaked by gullying and in the absence of large stones, The largest waste heaps, several metres high, are in the wadi bottom. The position of these seem to be just about at the furthest underground workings of the mine (described below) and it is evident that large quantities of the waste has been drawn out from shafts.

There are few shafts open and visible at the surface today as most have been infilled or otherwise covered by debris. Linear waste heaps show some of the outcrops to have been worked opencast, but nowhere for more than a few metres. A number of mine entrances and other cavities were used as habitations. These appear also to be distinguished by hanging-holes cut into narrow projecting spurs, perhaps for storage of food or for hanging lamps. Similar holes were found near the entrance to one of the larger inclines into the mine, near which was found a dump of cloth, food remains, twigs, pottery, and leather.

The underground mine workings of Site 38 (Fig. 3).
The main entrance to the mine is high up on the steep south side of the wadi (see Fig. 3, Feature 25). It is an incline, originally large enough to walk in, which connects with an open vertical shaft to surface after some 15 metres. It leads to a complex of workings which penetrate underground to below the wadi bottom, and to the south-east passes under the ridge, emerging in several

Fig. 3. Map of the underground workings (Site 38).

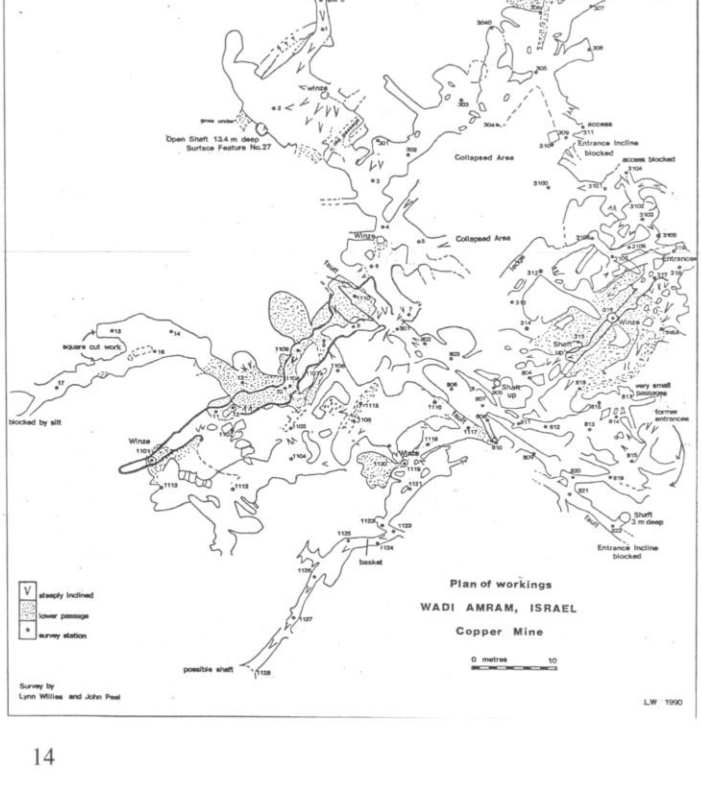


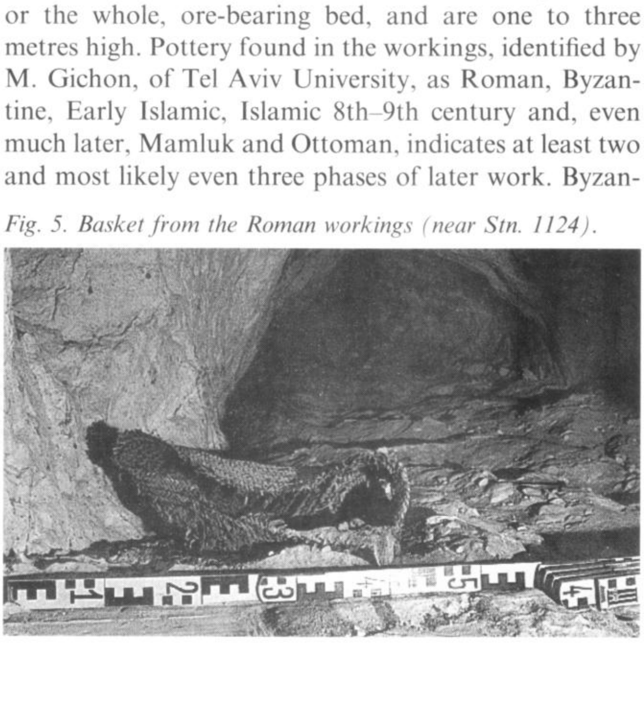
Fig. 4. Underground workings (seen from Stn. 803); the right gallery appears to have been cut by the later, larger workings. At the left pillar working.

places along the outcrop of the beds in the adjacent tributary valley.

The earliest phase of working seems to have been by inclined galleries from the south side of the ridge, following the bearing beds; from these lateral and vertical ramifications followed the richer ore. Some of the galleries seem systematically to follow the dip downwards for considerable distances, with shafts sunk (or raised?) near the furthest extent to link to the surface for air, and perhaps for easier ore or spoil removal. These galleries have a diameter of about 70cm. and are sub-circular (Fig. 4), but where ore was found they were developed into small chambers or wider sections. Shafts associated with the galleries are about a metre in diameter, if to the surface, less if part of the ramifications. As the oldest pottery found underground is Roman, this seems to be the date of these workings. An exciting find which seems to belong to this early phase of the mine is an almost complete basket, used for carrying ore, found near the bottom of the mine (Fig. 5).

Most of the early mine workings were cut through by later work (see Fig. 4), which partly reused old passages. Whereas the older ramifications were small, following, we can presume, richer ore, they later cut through much, or the whole, ore-bearing bed, and are one to three metres high. Pottery found in the workings, identified by M. Gichon, of Tel Aviv University, as Roman, Byzantine, Early Islamic, Islamic 8th–9th century and, even much later, Mamluk and Ottoman, indicates at least two and most likely even three phases of later work. Byzan-

Fig. 5. Basket from the Roman workings (near Stn. 1124).



tine work, sufficiently separated in time from the earlier workings to allow shafts to be infilled, is the most extensive period of post-Roman mining, with its wide and high passages down to the lowest areas. That the bottom, and probably deepest part of the mine was served by shafts, is made clear by large spoil heaps at the surface, and by limestone rubble found below close to the shaft bottoms. Much sand was left in the mine and its crushed state indicates that some sorting took place underground. Large areas of workings have been back-filled and are not easily accessible today.

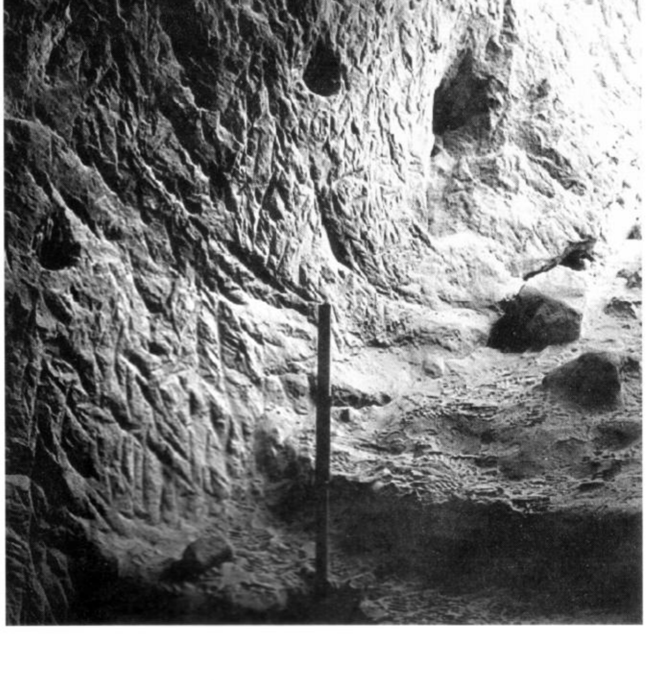
Some areas of the mine close to the surface have a very different type of working, with at least three larger cross section inclines, one with steps (Fig. 6), and the development of large chambers in an irregular pillar and stall system: the pillars or walls of earlier working have been extracted to a high degree and pillar failure is frequently seen. The waste of this working seems to have been dumped at the surface, or lower down the mine, and it is possible that it was intended to be the final working, in effect robbing the pillars on retreat. Frequent finds of Islamic pottery, glass and textiles, may relate to this final phase.

Underground working methods

The softness of the sandstone means that mining, though very dusty, would have presented few problems. Metal or metal-tipped tools seem to have been used throughout. In small spaces, probably of the first phase, the 'pock-marks' suggest the use of a straight-shafted pointed tool, which was hit by a mallet or hammer. Long-handled versions of such tools may have been used for boreholes of up to one metre in depth. In other areas, the tool marks suggest the use of hammer-gad or small picks, and in larger, probably later workings, there was use of both a large pointed pick and a bladed hack.

The combination of shafts and inclines meant that ventilation was good once they were linked. Some passages may have had the specific function of providing air flow, whilst others, larger, linking more frequently into the ramifications, were probably for transport. The number of shafts found, and others suspected from surface and underground indications, suggest their principal function was ventilation, though those at the furthest and lowest workings would have importance for winding.

Fig. 6. Steps and lamp niches in the underground workings. Note the tool marks on the wall.



Haulage in the small passages was obviously difficult, and the many fragments of baskets indicate the main method of underground transport. The baskets were much the same as a modern shopping basket in size, made of reeds and a coarse brown string, and had a leather or string handle. Judging by the size of the complete basket found, they could have held as much as ten kilograms, and would have been half dragged, half carried in the low passages, or possibly passed via a chain of handlers. In the later and larger inclines near the surface a fully upright mode of travel was possible, allowing greater speed and loads. This would have allowed an efficiency improvement of perhaps twentyfold which, with a similar order of increased productivity in workings large enough to swing a large pick or hack, probably enabled economic working also of the lower grade ore.

Most areas of the mine had lamp niches cut in the wall (see Fig. 6), though alternative lighting may have been used as well, indicated by occasional small fragments of charcoal in the galleries.

Ore benefication

Benefication of the ore was begun during mining. In the earliest period this was probably by selective mining, i.e. extracting only the larger ore nodules. Since the ore is relatively hard compared with the sandstone it is easily separated. Much sand was left underground and the ore must have been hand-picked out of the mining debris, perhaps after the latter was 'combed' with large pieces of pottery, with one or more edges rounded by wear, found both in the mine and at the surface. In working heaps, next to mine faces, the green mineral was easily visible, whilst on the surface and underground waste heaps, it was relatively sparse. Two flat areas were found at the surface where the amount of green mineral left was very high; it seems that these were benefication or storage areas.

Much material was brought to the surface where separation by hand-picking would have been much easier and a sufficient technique. It is possible that winnowing and sieving were also used, as shown by experiments undertaken by us at the site. In any case, the waste heaps at the surface today contain very little copper ore.

Lynn Willies

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From the Director's Desk

Thanks to James Gourlay
The Director of IAMS and its Scientific Committee wish to express their sincere gratitude to Mr James Gourlay, London, for his generous support which made it possible to go out once more into the Arabah and complete our unique, 6000 years story of copper mining in this region. Mr Gourlay's support will make Volume 3 of *Researches in the Arabah* a far more comprehensive publication than originally foreseen.

Sir Alistair Frame, Chairman of RTZ and IAMS Trustee, named by the Copper Club, New York, the Copper Man of the Year.
The Copper Club, founded 46 years ago as a meeting ground for the international copper world, initiated in 1962 the annual Copper Man of the Year award – named the Ankh Award, after the graphic symbol for copper of Ancient Egypt – to be given to the outstanding personalities of the copper world. The award to Sir Alistair was announced at the annual festive dinner of the Copper Club at the Waldorf Astoria on February 8th. The Trustees of IAMS and its Scientific Committee congratulate Sir Alistair on this prestigious Copper World award.

Thanks to the initiative of Sir Alistair, the Director of IAMS was invited to give a presentation about IAMS' aims and its research and teaching activities to a group of leading personalities of the copper industry and also a short talk about IAMS at the Copper Club dinner. We are grateful to Sir Alistair for his efforts to help in spreading the gospel of IAMS.

Welcome to our newly elected Canadian Trustee
The Trustees of IAMS and its Director are very pleased to welcome Keith C. Hendrick, President of Noranda Minerals Inc., Toronto, as the first Canadian Trustee of IAMS. Since IAMS was conceived as an international research and teaching programme it is hoped that the involvement of an eminent representative of the Canadian mining industry will be instrumental for the further enlargement of the orbit of IAMS's activities in the Western Hemisphere.

'The Ancient Metallurgy of Copper', soon to appear.
Our next IAMS publication *Researches in the Arabah Vol. 2, The Ancient Metallurgy of Copper*, was due to be published in Autumn 1989. There were five chapters to the volume: The pyrotechnical installations and their products, from the Chalcolithic Period to Early Islam (Beno Rothenberg); The experimental reconstruction and simulation of the smelting process (John Merkel); The theoretical and experimental study of the extractive processes of oxidized copper smelting, including the mathematical modelling of smelting in a Timna-based smelter (Menahem Bamberger and Peter Wincierz); The industrial clays and ceramics at the Timna smelters (Mike Tite *et al.*); The production of metallic iron in the copper smelting furnace (Noel Gale *et al.*).

When all the manuscripts were with the printers and the proofs became available, allowing a convenient overview of the publication, the Editor and his editorial colleagues felt that the copper ingots, the final product of the installations and processes discused in great detail in our volume, had not been studied in the same detail and thouroughness as the other components of the extractive processes. Professor Itzhak Roman, School of Applied Science and Technology, Hebrew University, Jerusalem, agreed to undertake this work, setting aside many other obligations, and to produce an additional chapter, Copper ingots, by early 1990. This chapter, including eight pages of microphotography, represents an important, complementary rounding up of the archaeological, experimental and theoretical investigations of ancient copper smelting, and is now with the printers. *The Ancient Metallurgy of Copper*, is in its final phase of production. The Editorial Committee is very grateful to Professor Roman for his willingness to make this great effort and to write up his results with the minimum of delay.