

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 pockets 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).

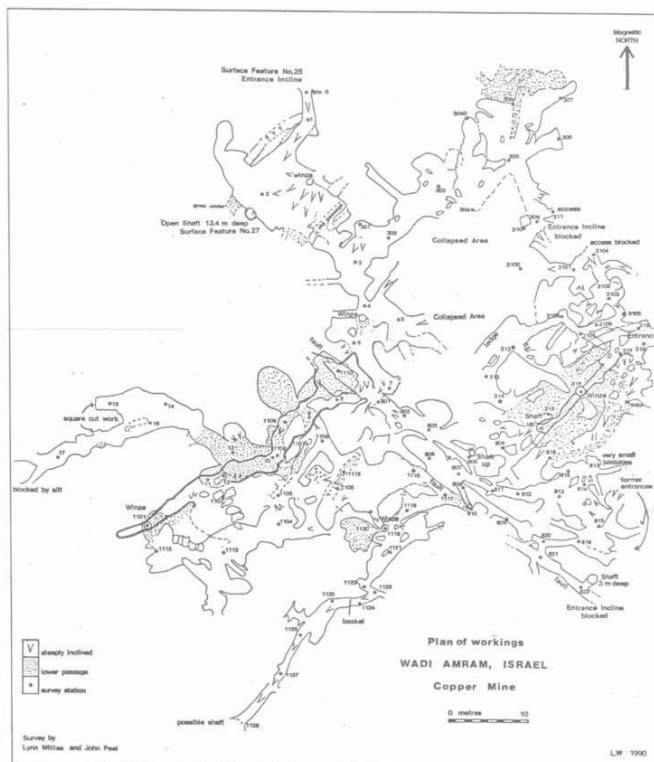


Fig. 4. Underground workings (seen from Stn. 803); the right gallery appears to have been cut by the later, larger workings. At the left pillar working.

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. Byzantine

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 pas-

sages 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.

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 beneficiation

Beneficiation 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 beneficiation 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

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



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