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# Periods of Ore Exploitation and Metal Production in the Area of Feinan, Wadi 'Arabah, Jordan

## I. Introduction

Even before the discoveries of the oldest metallurgical sites in Turkey, the mountains of Anatolia were suggested to have been the cradle of metallurgy in the ancient world. This hypothesis was confirmed by numerous excavations, e.g. at Çatal Hüyük (Mellaart 1967) where the first lead and copper-smelting operations were dated to the sixth millennium BC. The excavations at Çayönü Tepesi (Braidwood and Cambel 1981) revealed that native copper was worked there in the eighth/seventh millennium to produce artifacts.

The spread of metallurgy was mostly stimulated by the urbanization in Mesopotamia and seems to have already been fully developed in the fourth millennium BC.

Evidence of copper metallurgy in Transjordan and Palestine is not known before the Chalcolithic period, during the second half of the fourth millennium BC. At the moment, the reasons for this chronological gap are not fully understood, neither from the geological point of view nor by archaeology. Copper ores are abundant in Wadi 'Arabah and numerous urban settlements are known from earlier periods. Except for the famous hoard of Naḥal Mishmar where more than one hundred kilograms of metal artifacts were found, metal artifacts have been found in the area only in small quantities, e.g. at Tell Abu Ḥamid (Dollfus and Kafafi 1988), Tuleilat al-Ghasul, Jericho, Tell Abu Maṭar and Shiqmim (Shalev and Northover 1987).

In order to investigate the beginning and development of metallurgy at the local sources in Wadi 'Arabah, the copper ore district at the eastern part of Wadi 'Arabah in the area of Feinan is presently studied in a joint archaeometallurgical project between the Department of Antiquities of Jordan and the Deutsches Bergbau-Museum, Bochum. To understand the complexity of the problems and questions connected with mining, smelting and trading of ore and metal, the scientific approach was necessarily set up in a multidisciplinary scale. Archaeometallurgy is the result of interaction between archaeology, natural sciences and engineering. Therefore, the project is not purely archaeological as it was unfortunately misunderstood in the past (Knauf 1987; Knauf and Lenzen 1987). The work in Feinan involves the collaboration of scientists and scholars of geoscience, metallurgy, chemistry, physics and botany in addition to archaeology. The aim of the project may be summarized by three questions representing the basis of archaeometallurgy in general: When, how and where. Details of these questions are explained in FIG. 1.

The area of Feinan is located some 60km south of the Dead Sea at the foothills of the Rift Valley. It was discovered in 1904 by Alois Musil who noted mainly the Roman and Byzantine ruins of the ancient town. Thirty years later Fritz Frank visited the site again. Some years later Nelson Glueck continued the work in Feinan. He concentrated especially on the pre-Roman periods and found both Iron Age and Bronze Age pottery, and also described some of the slag heaps and mines in the area. A geological survey for economic purposes was carried out in the late fifties by the Natural Resources Authority of Jordan and the Bundesanstalt für Geowissenschaften und Rohstoffe, Germany. The geologist H.D. Kind published the first short, but for the time very comprehensive, study on early mining and metallurgy (Kind 1965).

## II. Geology of the Ore Deposit

Due to its geological situation at the eastern margin of the Wadi 'Arabah rift valley, the type and origin of the sedimentary copper ore deposit at Feinan is similar to the western counterpart at Timna. Therefore, both ore districts have a comparable mineralogical and geochemical pattern. Whereas the identification of ores from Feinan and Timna in most cases seems to be possible (Hauptmann 1989), it is rather difficult to distinguish between copper produced at both deposits. Trace elements and lead isotope abundance ratios are very similar (Hauptmann *et al.*, in prep.).

At Feinan, two main mineralizations occur which are exposed to the surface and reveal ample evidence of ancient mining (Hauptmann *et al.* 1985; Weisgerber and Hauptmann 1988). The stratigraphically higher mineralization is concentrated along fractures in Cambrian sandstone. Here, the ores consist mainly of malachite, chalcocite and

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| TERRITORIAL ARCHAEOLOGY<br>Extent and Periods of Settlements | HISTORY OF TECHNOLOGY<br>From Ore to Metal<br>Mining, Smelting | ENVIRONMENT<br>Vegetation<br>Fuel Supply |
| ECONOMIC POSITION<br>Amount of Metal Produced | BEGINNING/ DEVELOPMENT OF METALLURGY | TRADING<br>Export of Ore & Metal |

1. Scientific concept of archaeometallurgical work at Feinan.

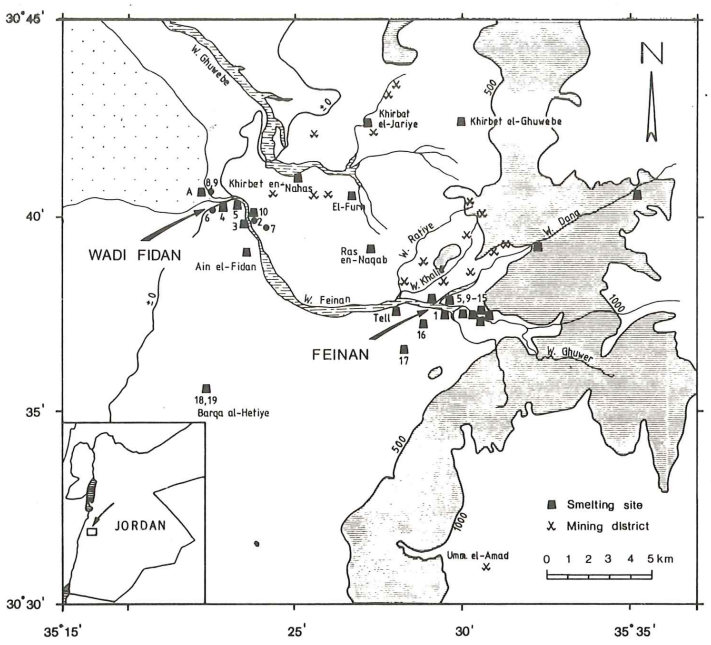
"tile ore". Underlying this formation, the main ore body is connected with the manganese-bearing Dolomite-Limestone-Shale Unit (DLS) of the Lower Cambrian. The ores of the DLS generally form pockets and intensive impregnations in the shales consisting of emerald green copper silicates (chrysocolla) and malachite. A more detailed describtion of the ores is given by Heitkemper (1988).

## III. Copper Ores and Metal Through the Ages

### *The Pre-Pottery Neolithic*

The first proof for the use of copper ores in the Feinan area dates to the eighth/seventh millennium BC. Pieces of beautiful coloured copper ores were found together with the flint tools at the site of Wadi Fidan 6 (FIG. 2), a settlement which was discovered and preliminarly dated by Raikes (1980) to the Neolithic period. The first new $^{14}C$ date determined so far from the samples we took revealed an age of 9185+/−120 bp[1] (uncalibrated). Most interesting are numerous finds of 2-3cm long flint drills apparently used for manufacturing beads: Similar drills are well known from Shar-i Sokhta in Iran for making lapis-lazuli beads. In fact, the seventh millennium is the period when "greenstone" beads and green powder for cosmetic purposes became popular all over Transjordan and Palestine, as well as in Anatolia and the Balkan peninsula[2]. This apparently represents a shift from the use of red ochre to a new colour, green. In Jericho nearly one hundred beads and pendants were found mostly in PPNA levels (Wheeler 1983). "Greenstones" were also found at many other sites dated to the seventh/sixth millennium (cf. Garfinkel 1987). Of special interest are the finds from 'Ain Ghazal (Rollefson and Simmons 1986). A number of "greenstones" from 'Ain Ghazal, Jericho and Beiḍa have been identified as consisting of copper silicates traded from Feinan (own investigations)[3]. Most likely the powdered dioptase used to make up the eyes of some plaster figurines from 'Ain Ghazal (Tubb 1985) is also made of this material.

The use and trade of copper ores from Feinan for




2. Topographical map of the area of Feinan and its surroundings showing mining areas, smelting sites and settlements mentioned in the text.

cosmetic purposes does not yet represent the beginning of metallurgical processes to produce metal by smelting ores. The close association of "greenstones", however, to finds of lime plaster as shown at 'Ain Ghazal, Nahal Hemar and Jericho suggest a possible technological link to metallurgical processes, because lime plaster is produced under conditions suitable also for reducing copper ores. We are therefore conceding the possibility of the first metallurgical step in this period with a high degree of probability, considering as well the chronological relation to Anatolia and Mesopotamia discussed above.

### *The Pottery Neolithic*

Some 2km west of the ruins of Feinan a tell with a height of 2.50m was discovered. The tell is half eroded by Wadi Feinan, thus presenting a profile through the layers. The tell is under excavation by the Department of Antiquities (Najjar *et al.* 1990). $^{14}C$-data, pottery and a clay figurine date the tell to the Pottery Neolithic A, from the second half of the sixth to the late fifth millennia. Also a number of copper ore pieces were found which evidently show the use of the ores but no metallurgical treatment.

### *The Chalcolithic*

Corresponding to other Chalcolithic settlements in Trans-

[1]Sample no. HD-12333-11988. The $^{14}C$ dating was carried out at the Institute for Environmental Physics, University of Heidelberg.

[2]From the scientific point of view, the *terminus technicus* "greenstone" used in archaeology is not correct. It comprises a number of green minerals such as malachite, chrysocolla, dioptase, turquoise, amazonite, serpentinite and, in the case of Jordan, also green apatite.

[3]A collection of the green beads, pendants and unworked pieces of ore from 'Ain Ghazal were given to us by Dr. Rollefson for scientific investigation. The material from Beiḍa was offered for investigation courtesy of Mrs. Diana Kirdbride and Dr. Brian Byrd. The material is under study.

jordan and Palestine, the first clear evidence of metallurgical activities appears in the area of Feinan in the second half of the fourth millennium. At the moment, three smelting sites dating to this period are known, one of which was already discovered by Raikes (1980) (Wadi Fidan 4= site "C"). The other sites are Feinan 17 and 19. The sites were dated archaeologically by pottery, flint tools and basalt vessels typical for the Chalcolithic period in this region (Hauptmann *et al.* 1985). Furthermore, it was possible to date mining and smelting activities by numerous archaeometallurgical finds from Tell Abu Maṭar, Safadi, Shiqmim and Wadi Ghazzah, where copper ores from the Feinan area and slags technologically comparable to those found at the sites mentioned could be identified by scientific investigations (Hauptmann 1989).

Next to pieces of slag and copper prills which only point to small scale metallurgical operations carried out in this area during the Chalcolithic, the most important finds from Wadi Fidan 4 included a number of stone mining tools (Hauptmann and Weisgerber 1987). This collection represents a remarkable sequence of the variety in the raw material itself (basaltic rocks). Blanks, semi-finished, broken or discarded examples of mining tools are present in large numbers. Such tools also came to light scattered around the adits of mines, on waste dumps, and in wadi beds in the Qalb Ratiyeh area, an indication of extensive Chalcolithic mining. On the strenght of field evidence Chalcolithic mining obviously was concentrated on malachite and tile ore in the Cambrian sandstone, and was not capable of exploiting the deeper lying copper silicates in the DLS. Typically, the ancient mines in this area prefigure later Roman mining activities, as clearly indicated by the re-opening of the shafts and galleries. The mineralogical and chemical examination of copper ores from the settlements mentioned gives evidence for extensive export of Feinan ores in this period (Hauptmann 1989). We know from investigations of metal, slags and furnace fragments that they were smelted in these settlements to produce a very pure metal with a low level of impurities. This metal was used for manufacturing flat axes and toggle pins. On the other hand, copper based arsenic-/antimony-/lead-alloyed artifacts such as scepters and maceheads found at Tell Abu Maṭar, Shiqmim (Shalev and Northover 1987) and Nahal Mishmar (Key 1980) suggest the import of metal from other sources, perhaps from Anatolia. By the comparison of ores and metal we can exclude a production from local sources. Furthermore, as we have no evidence so far for local smelting of such alloys, we have to even assume an import of the finished artifacts as well.

*The Bronze Age*

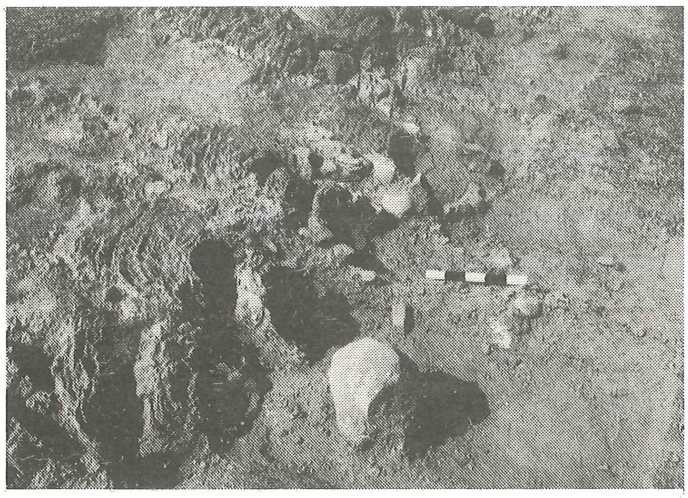
The first peak of extensive mining and metallurgical activities is dated by $^{14}C$ data and pottery found inside the mines and on several of the 15 slag heaps to the EB II-III, in the middle of the third millennium (Hauptmann 1989; Hauptmann and Roden, in press). From this period onward until the Late Iron Age very rich copper-manganese ores from the Dolomite-Limestone-Shale Unit were exploited. The use of mixed ores lead to the revolutionary discovery of the fluxing agent of manganese: the formation of a liquid slag now became possible and by this the smelting of ores intensively intergrown with the host rock. This caused an opening of numerous mines e.g. in Wadi Khaled and Wadi Ḍana. The volume of the slag heaps suggest a production of metal in the scale of 100-300 tons. Compared with the Chalcolithic mining and pyrotechnology the slag now reveal a considerable structual change and improvement. Unique in the archaeometallurgy of the Middle East is the excavation of 31 smelting furnaces at Feinan 9 and 11. These furnaces are partly preserved and show a construction not known before: contrary to other reconstructions which always show a tendency to shaft-like furnaces, we are faced here with very shallow, open bowls which do not point to any use of tuyeres, but rather suggest natural draft (Hauptmann and Roden, in press) (FIG. 3).

In view of the large number of smelting sites in EB II-III, the situation of settlements from this period remains puzzling. There is obviously a concentration of smelting sites around the ruins of Feinan itself but except of some scattered Early Bronze Age pottery from the survey we have no evidence of an occupation there. Despite the enormous increase of copper production in this period, the demand for this metal in Palestine and Transjordan was not fully covered by local sources. Like in the Chalcolithic several sorts of copper based metals were in use, the provenance of which may point to extensive trade with Anatolia, Mesopotamia or Iran. The trace-, element- and lead-isotope analyses of numerous artifacts on the other hand point to the use of copper from Feinan, e.g. at Jericho, Numeira and Umm al-Beghal (Hauptmann *et al.*, in prep.). A number of artifacts investigated from Bab adh-Dhra', however, were not made of this metal as would be expected. These are made of arsenical copper and in one case we could identify a tin bronze dagger (Karak Museum inv.-no. 1257) from the EB III/IV, which is one of the earliest known from Transjordan. It is surprising that people of the Early Bronze Age town which is situated only some 80km north of Feinan apparently prefered metals and alloys imported from abroad.

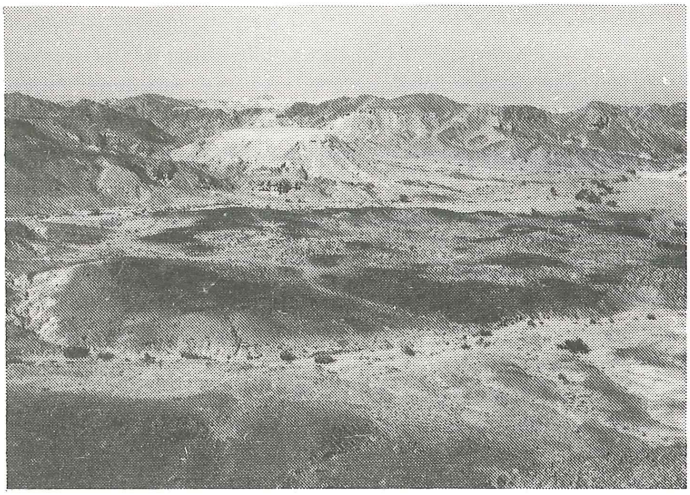
Archaeometallurgical activities ceased during the Middle Bronze Age. Based upon the results of our surveys, there is no proof for metal production during the second millennium. This is quite remarkable in view of the fact that copper production during the Late Bronze Age reached a peak at Timna. The production there was heavily stimulated by the Egyptian mining expeditions which obviously did not reach the area of Feinan.

*The Iron Age*

The second main period of copper production in the Feinan



3. View of six smelting furnaces from Feinan 9. The furnaces are part of a battery with 27 furnaces located on top of a hill from where slag was thrown down. The battery is dated by $^{14}C$ to the middle of the third millennium.



4. The Iron Age II smelting site of Khirbet an-Nuḥas. With slag amounts of 60,000-80,000 tons this represents the largest known smelting site next to Cyprus in the Middle East from this period.

area is dated to the Iron Age IIB and IIC (Hauptmann *et al.* 1985; Knauf and Lenzen 1987). Two well known smelting sites at Feinan and Khirbet an-Nuḥas (FIG. 4) are the best (but not the only) examples to demonstrate metallurgical activities in an industrial scale. It should be stressed that in this periods besides Cyprus, the largest copper production of the entire Near East is concentrated in the Feinan area. Enormous slag heaps of more than 100,000 tons reveal a metal production in the order of 5000-10,000 tons. It seems that this period, all over the Middle East, saw a boom in copper before iron finally dominated as the new metal of daily life. Also in Oman where copper was produced abundantly over the ages, enormous quantities of this metal were produced during the Iron Age.

At Feinan, mining and smelting was carried out at a large, very well organized scale with a sophisticated technical know how. EBA mines constructed in the rich mineralizations of the DLS were re-opend and enlarged to a considerable extent. Through a better geological understanding additional new ore deposits were presumed, found by prospection shafts and exploited in Wadi al-Abiaḍ, the lower Wadi Khaled and at Umm adh-Dhur. Due to new methods and facilities of engineering and a better understanding of geological features, deeper parts of the ore deposits were exploited sinking shafts down to a depth of 50-60m. The ore worked in more than 100 mines was transported to a few central smelting sites like Feinan, Khirbet an-Nuḥas and Khirbet aj-Jariyeh, where the metal itself was produced. Faced with slag heaps of volumes like at Khirbet an-Nuḥas, the question of fuel supply arises. Stimulated by smelting experiments which suggest double the amount of fuel to produce one unit of slag, botanists[4] investigated charcoal inclusions in slags from different periods and compared the results with the recent vegetation. Most interestingly it turned out that the kind of fuel (charcoal) supply for the smelting sites and its provenance varied from one period to another (Baierie *et al.* 1989). For mining and smelting during the Iron Age II (the activities are dated to a period of nearly 500 years) we calculate a comsumption of at least 200,000-250,000 tons of charcoal. To which extent this deforestation lead to a man-made desertification in the area is a subject of present and future studies in our research project.

From the technical point of view, we know that mining and smelting at such an extent and under difficult conditions like at Feinan could only be realized by a very tight organization which is controlling and supplying a large number of workers at the sites. This is demonstrated for example by the fortification at the smelting site of Khirbet an-Nuḥas. Like in the Late Bronze Age, there is no evidence for Egyptian activities as proven at Timna by Rothenberg (1988). We therefore may assume that the mining and smelting in this area was controlled and organized by the Edomites from the Jordanian plateau to strengthen their economical and political power. The Iron Age copper production ended about 400 BC.

*The Roman Period*

It is certainly connected with a far-reaching exploitation of the rich copper mineralizations in the Dolomite-Limestone-Shale Unit in earlier periods that the Romans, after a break of several hundred years, exclusivly mined the low grade copper ore in the Cambrian sandstone. These

[4]Botanical investigations are carried out by Prof. Frey and his coworkers from the FU Berlin.

ores crop out in the area of Jabal Ratiyeh and further south of Feinan at Umm al-'Amad. Due to their specific mineralogical composition (main ore is malachite instead of coppersilicate in the DLS which is rather difficult to smelt without adding flux) these mineralizations were already mined in Chalcolithic times. The mines now were re-opened and enlarged showing partly the excellent and unique mining engineering which is characteristic of the Roman period. One of the most impressive technical monuments in this respect is the chamber-pillar construction of Umm al-'Amad, a mine located south of Feinan high up in the mountains. With a lateral extent of 120 × 55m, this is the only and best preseved mine known in the Roman Empire.

Most of the Roman mines, however, which were worked between the second and fifth centuries AD (in the Jabal Ratiyeh district we registered more than 120 mines) are sad witnesses of crude robbing of copper ores in mines where the basic rules of underground safety were ignored. This observation coincides with textual evidence from the church fathers Eusebius and Hieronymus who vividly described the cruelties of the "damnatio ad metalla" (Geerlings 1985).

Similar to the organization of smelting during the Iron Age II, the Romans transported the ores to one central site near the ruins of Feinan. Nearly 50,000-70,000 tons of slag demonstrate the large amounts of copper produced here which are roughly estimated at several thousand tons. The local infrastructure of the town with an aquaeduct, water reservoir and some square kilometres of irrigated farmland indicates the economic power and importance of this metal district in the desert.

*The Islamic Periods*

After 500 AD the role of Feinan as a major copper supplier in the southern Levant ended. But it is shown by textual evidence and the relics of churches that the town still had a certain importance during the early Byzantine period. During the Mamluk period some minor activities were proven to produce copper or even iron, as suggested by slag and metal investigations. They were connected with a renovation of the water channel leading along Wadi al-Ghuweir to Feinan, the aquaeduct crossing Wadi Asheqer and the water pool opposite the town of Feinan. Three smelting sites were discovered at Feinan itself and close to Khirbet an-Nuḥas, where the relics of a small settlement consisting of 15 buildings and a mosque exist.

**Aspects of Future Investigations**

The present state of knowledge of the early copper metallurgy in the area of Feinan is based upon survey and limited sounding. An exception is the excavation of the Neolithic Tell Wadi Feinan carried out by the Department of Antiquities which will provide new information on the prehistory of Wadi 'Arabah.

It was possible so far, due to the understanding of the German Mining Museum, to set up a first chronological sequence and to determine the extent of the copper production in space and time. Archaeometallurgical material available from the surface was studied in laboratories and the comparison with ores and artifacts from other excavations resulted in statements and facts important not only for the beginning and development of metallurgy but also for the reconstruction of trade routes in this region, which can correct and modify present hypotheses. A good part of questions concerning the economic and technological background of copper production, the basis for discussing the interaction between metal and man, is going to be solved in this way. Without doubt the cultural impact of metallurgy upon early society is a very important problem which may not be answered without extensive excavation in the Feinan area and which needs the cooperation of more archaeologists who are ready to work on problems far away from the centres of cultural and artistic life.

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