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New thoughts about Iron Age metallurgy in Faynan:
A discussion

ABSTRACT: *In Faynan area the copper production took place on real industrial scale in two major phases during the 12th–11th and the 10th–9th centuries BC, with smaller activities at Khirbet Faynan in the 9th and 8th century BC. Because of iron tools, single and twin shafts were dug in the underground. Analogous to the mining techniques, a new furnace construction with special refractories and multiple composed tuyères was invented. The contribution will give a survey of the Iron Age mining and mining technology and tries to perform, on the basis of old and new archaeological features and finds, a reinterpretation of the Iron Age furnace technology.*

KEYWORDS: IRON AGE, MINING, COPPER METALLURGY, SMELTING TECHNIQUE

Introduction

This article will present a short overview of technological innovations of mineral exploitation through the Iron Age by mining activities as well as the production and reconstruction of copper smelting in the Faynan copper district in Jordan, located halfway between the Dead Sea and the Red Sea (Fig. 1).

The main mineralization in the Faynan mining district, and the ancient mines and smelting sites, spreads over an area of ca. 20 x 25 km, from the sand dunes at Barqa al-Hetiye in the southwest to Wadi al-Jariya in the north, and from Umm el-Amad to the wadis Dana, Khalid and Abiad (Fig. 1).

As already pointed out by Hauptmann (2007, pp.73-83, pp.145-152), during the Iron Age intensive mining activities were developed in the mineralization in the Burj limestone or dolomite-limestone-shale.

Mining and Smelting sites

The Iron Age copper mining and smelting sites are mainly concentrated at a few places: Ore (Weisgerber, 2003, pp.84-85; 2006, pp.13-17) from the mines in the wadis Khalid, Dana, Ghuweibe, Jariye as well as from Umm es-Zuhur was brought to Faynan, Khirbet en-Nahas (KeN) and Khirbet el-Jariye (KeJ), where it was smelted to metal (Fig. 1).

Additional exploited formations probably exist in the Wadi Ratiye “Talkopf” area and a new discovered area with densely clustered, innumerable circular depressions covering several square kilometres, was found west and northwest of KeJ. This huge depression field or “mining field” was recently investigated. The authors were not really sure concerning the dating. Due to its immediate vicinity to the mining and smelting site of KeJ, they assume that these flat round pits mainly date to the Iron Age (Ben-Yosef, Levy and Najjar, 2009, p.99).

New data sets of ^{14}C-dates from Levy et al. (2005; 2008), Ben-Yosef, Levy and Najjar (2009) and recalibrated ^{14}C-dates from Hauptmann (2000; 2007) obviously indicate phases of metal production in the Faynan area during the 12th–11th and especially during the 10th–9th centuries BC, with lower production until the 5th century BC, which super-imposed and reworked the earlier period(s) of the Bronze Age. Recycling of EBA slag (Hauptmann and Löffler, 2013, p.80) was performed at KeN, KeJ and at Faynan 5. Recycling of EBA slag is also reported from the smaller Iron Age smelting sites of Ras en-Naqab (Hauptmann, 2000; 2007, pp.123-126) and Khirbet Hamra Ifdan (Levy et al., 2002).

At the largest smelting sites KeN – “The ruins of copper” – and KeJ (Fig. 1), metal production took place on an industrial scale during the 10th and 9th century BC (Hauptmann and Löffler, 2013, pp.77). Other places of metal production (Hauptmann 2000; 2007) are the area of Faynan 5 (Fig. 2, western slag heap), during the 10th– 5th century BC, and the smelting sites in the Wadi Dana around the Khirbe of Faynan itself, which is presently being excavated by T. Levy.

Close to Khirbet al-Ghuwebe (KaG) was another, seemingly smaller smelting site (Glueck, 1935, pp.22-23; Weisgerber, 2006, p.15) without any evidence of large tap

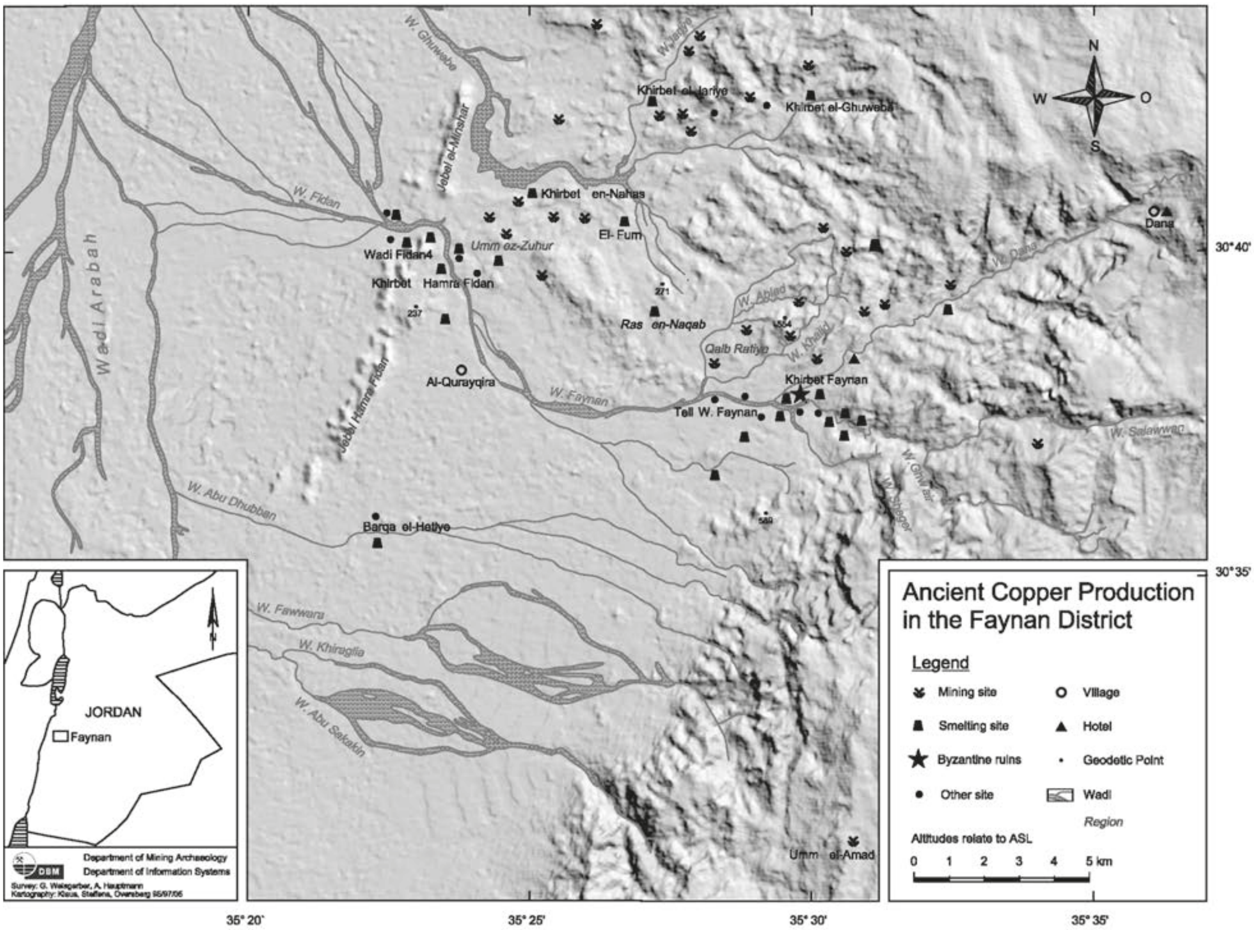

Fig. 1. Geographical overview of the Faynan mining district at the foot of the Jordanian Plateau. Ancient mining and smelting sites and some other important archaeological find spots. Each mining symbol represents a site where up to 50 or more mines (underground) have been explored (Hauptmann, 2007, fig. 6.1).

slag like at KeN. The associated ceramic indicates early Iron Age (I) occupation. The accumulation shows similarities to the pottery from KeJ (Ben-Yosef, 2010, pp.447-448).

The Iron Age mining and smelting sites like KeJ are connected with larger centralized building structures. The mining and smelting sites were controlled and supplied by the large building structures (Weisgerber, 2006, pp.15-16). Larger sites, like KeN, were fortified and at KaG two hill forts (7th/6th century BCE) were built (Ben-Yosef, 2010, pp.418) at the edge of the mining district (Weisgerber, 2006, p.15), in order to protect the copper production and trade. These structures are the basement for the necessary infrastructure that is needed for smelting the ores — a supply of experts, manpower, water, food and fuel.

Mining Technology

Through the application of new technologies, the Iron Age miners were able to get access to parts of the deposits which were not available for EBA miners (Weisgerber, 2006, p.13).

By well understanding the geological features and the knowledge of the need for ventilation new shafts were opened. The new invention of special single ventilation shafts (Weisgerber, 2003, pp.84-85; 2006, pp.13-17) like in the Wadi Khalid mine 17 (Fig. 3) can reach a depth of 40 m or more. The use of iron tools probably enabled such work and made the exploitation close to and beneath the foothills of the nearby cliff possible. The installation of the shafts directly to geological faults allows an effective reduction of the already loosened side of the rock.

The most fascinating feature of Iron Age deep mining are the double or twin shafts. In the Faynan Area, normally round twin shafts were applied. Mostly, they are sunken, only separated by 0,5 m thick rock walls in order to optimize the extraction of ore and the ventilation of the underground mines (Fig.4). Today, they are open to a depth of about 10 m, once, they reached to the ore stratum at depths of 40 m or more (Weisgerber, 2003, pp.84-85; 2006, pp.13-17). The dating of the twin shafts is often unclear, because of the absence of archaeological excavations.

The hauling of persons, ore, waste, tools and food became more complicated with the increasing depth, and thus, ropes and winches had to be utilized. In addition, the

Fig. 2. The satellite image (Ikonos-satellite data) shows the archaeological remains around the Khirbe of Faynan (KF). In the western and to the northern areas are slag heaps from the Iron Age (EZ), in parts surrounded from heaps dated from the Early Bronze Age. Straight south of the Wadi Faynan, near the mouth of the Wadi Ashegher the Roman-Byzantine smelting (RB) site is situated. The remains of the aqueduct (A) are connected with a rectangular water reservoir (Z), which itself runs a Roman mill. At this point the wide irrigation system reaches to the west (Courtesy of European Space Imaging / © European Space Imaging GmbH).

ventilation, lighting and stabilization of the underground room-and-pillar-constructions had to be ensured. Post-holes (Fig. 4) for windlasses (Weisgerber, 2003, pp.84-85; 2006, pp.13-17) have been identified several times beside the mouth of shafts, mainly of twin shafts. The axle for the winch has been constructed directly over the central region of the shafts. This is quite different from the Egyptian shaft windlasses at Timna, where the machine was situated in front of the shafts.

The windlasses at Faynan were probably operated by levers starting at the axle positioned in a cross form in the beam. No crank was used (Weisgerber, 2006, p.14). Additional step holes were dug into the faces of the shafts (Fig. 5). At Timna (Weisgerber, 2006, p.15) on the other side of the Wadi Araba, steps or step holes in the shaft walls exist, too.

As the faces of the shafts have traces of steps, lifting and lowering of persons was a combination of climbing and the use of windlasses.

The construction of deep vertical shafts raises the question how to find technical solutions for air supply during the sinking of a single shaft, like the shaft 17/1 in Wadi Khalid (Fig.3), and the mining of ore.

Morin et al. (2013, p.13) investigations showed that in winter time, the atmospheric air is colder than the shaft walls and flows slowly downwards like a “waterfall”. Due to its current thermal exchange with the walls, the air in the shaft is warmer. The warmer air concentrates in the center of the shaft and moves upwards. Fresh air runs down from the surface to the base of the shaft as a result of an irregular convective flow.

In summer time (Weisgerber, 2006, p.15), the air filling of the shaft reaches the wall temperature. Due to this, the air in the shaft remains colder and heavier than atmospheric air above. During the day, the shaft works as a cold air trap and natural air convection could still exist but would remain extremely slight. Atmospheric air temperature during the night or heat released by miners at work in the shaft and by oil lamps can also engender a kind of air convection. In contrast to the winter time, the terms in the shaft are obviously worse for respiration during summer days. A driving during the summer night is conceivable. The use of bellows and pipe systems is more likely. Based on this technology driving is throughout the year possible.

After finishing a ventilation shaft, the mine can be operated the whole year long. The reason for this is the air

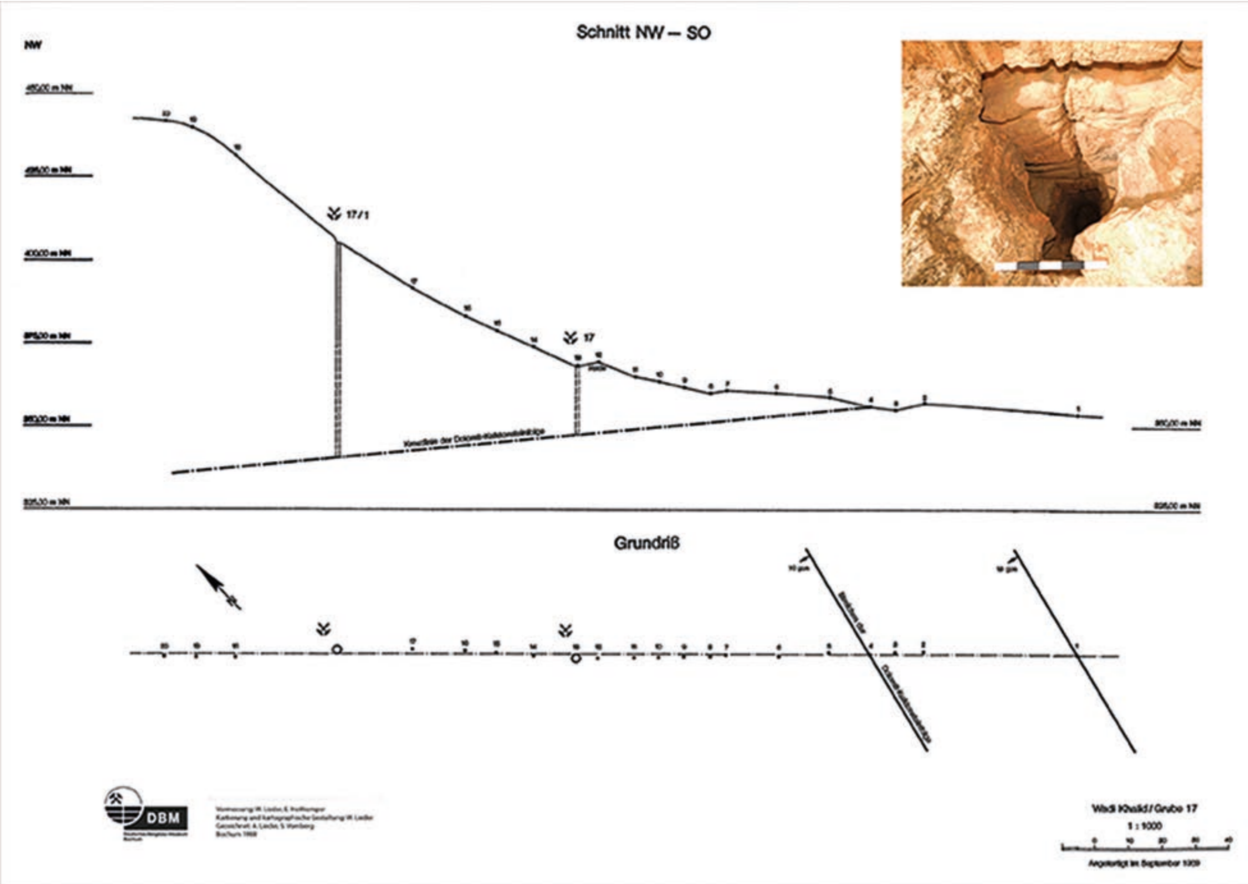

Fig. 3. Wadi Khalid mine 17. Deposit, mine and ventilation shaft (map). Ventilation shaft 17/1 (photo: Deutsches Bergbau-Museum Bochum, I. Löffler; map: W. Lieder, S. Vomberg).

Fig. 4. Wadi Ghuwebe. Iron Age twin-shaft construction, dated by pottery from the tailings. The three diagonally positioned post holes indicate the kind of winch in operation with a thin, central positioned axle (photo: G. Weisgerber, Deutsches Bergbau-Museum Bochum).

Fig. 5. Wadi Khalid, mine 2, "Triple Shaft". The shaft is located at the bottom of the steeply arising Ras Gebel Khalid formation in order to explore at this point the copper ore deposit of the DLS-zone below. The double shaft construction is dated by pottery from the tailings to the Iron Age. Step holes were dug into the face of one Iron Age shaft (photo: I. Löffler, Deutsches Bergbau-Museum Bochum).

circulation in the ventilation system between shafts and mine, such as the mine 17 in Wadi Khalid (Fig. 3).

The depth of the single and double shafts raises the question of the construction time. The diameters of the twin shafts of mine 5 at Wadi Abiad and Gebel Ghuwebe (Fig. 4) are about 1 m and correspond to an area of approximately 0,78 m^2. With a calculated driving of 5,76 m^3 per month (Conophagos, 1980, pp.195-196) this results in a theoretical shaft driving of 7,38 m per month and 88,56 m per year. If the shaft is constructed close to a fault the driving will be faster (Fig. 3, shaft 17/1).

Overall, about 50 Iron Age shafts and/or mines were opened in the Faynan mining district (Hauptmann and Löffler, 2013). These sophisticated mining installations, where the preparations alone took approximately a year or more before the ore could be extracted, could not have been organized by a small group of people (Weisgerber, 2006, p.15). According to Hauptmann and Löffler (2013), mining and smelting activities to such a large extent and of such a degree of resources investment and sophistication were probably undertaken by large enterprises and by a number of experienced experts.

In general, no typical Iron Age mine in the Faynan mining area has completely been excavated. There is only one entrance at the smaller mine 18 at Umm ez-Zuhur, opened by erosion, but which does not really help us to understand the procedures of Iron Age mining (Weisgerber, 2006, p.14).

Metallurgy

The copper production in the Faynan mining district achieved an industrial scale during the Iron Age, dated back to the 12^{th}–11^{th} century BC and especially the 10^{th}–9^{th} century BC (Hauptmann and Löffler, 2013, p.84). Comparable to the development of mining techniques, the copper smelting technology in this period (Hauptmann, 2000, pp.155-161; 2007, pp.242-254) was using new furnace constructions with special refractory and multiply composed *tuyères*. The new kind of slag tapping arrangements and the fabrication of large tapped slags characterize the outstanding result of these technical innovations. According to the calculations made by Hauptmann (2007, p.147), between 6,500 and 13,000 tons could have been produced during the Iron Age in the Faynan mining district.

Iron Age furnace technology

In contrast to the Early Bronze Age copper smelting installations, Iron Age furnaces were constructed of slag-tempered (Tite, et al., 1990; Hauptmann, 2000, 2007; Al-Shorman, 2009) clay. Corresponding to the archaeological field evidence in the Faynan district, the features of the furnaces are comparable to those from the contemporary smelting sites at Timna 30 Locus 10 (Hauptmann, 2000, p.73; 2007, p.102).

The reconstruction of the Iron Age smelting furnace by Bachmann and Rothenberg

In the absence of comparable furnace remains, a reconstruction of possible Iron Age smelting (from Timna)

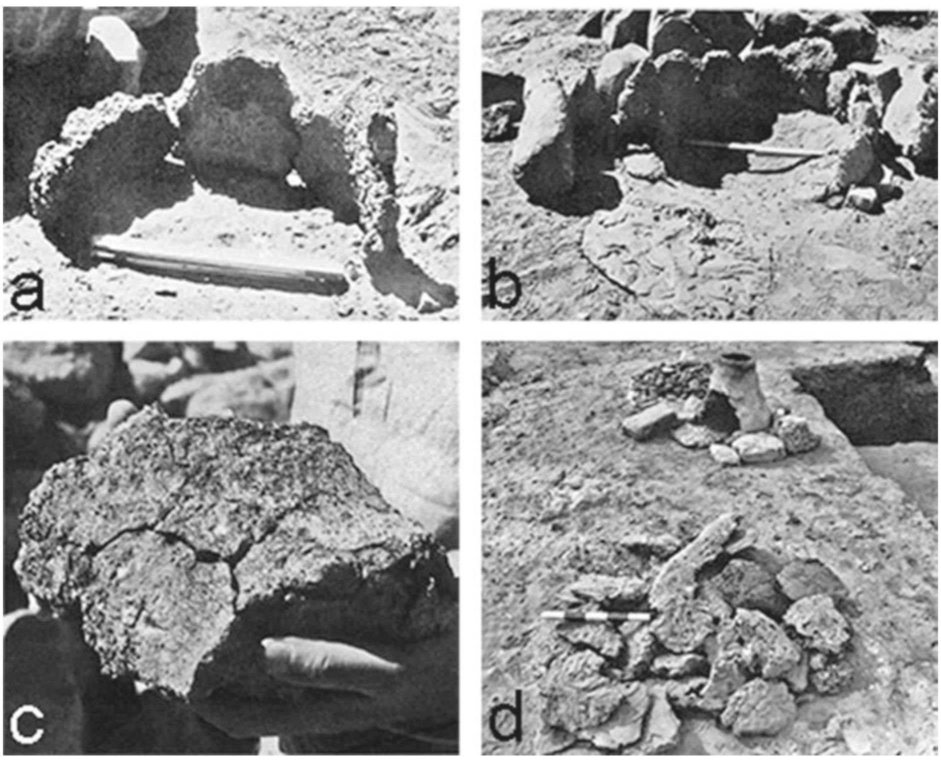

Fig. 6. Site 30, Layer I: Fragments of furnace wall, added to a small (a) and a large semicircle (b) (Bachmann, Rothenberg, 1980, figs. 234, 235). Double-curved furnace lining fragment (c) (photo: G. Weisgerber, Deutsches Bergbau-Museum Bochum). Furnace reconstruction (d) with original fragments and plaster in the rear area. In the front area are fragments of taped slag. Furnace opening intentionally left open (Bachmann, Rothenberg, 1980, fig. 242).

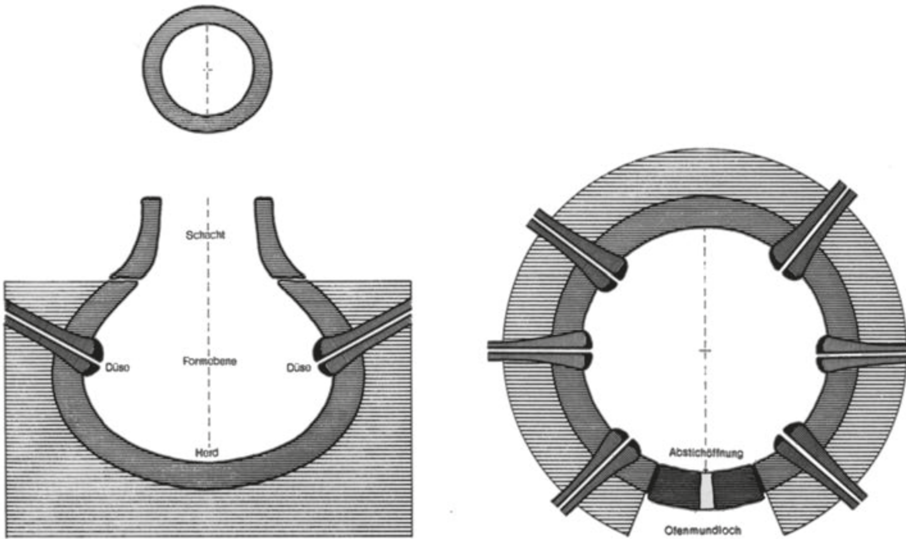

Fig. 7. Iron Age furnace reconstruction based on finds from Timna Site 30, Stratum I dump E4 (Bachmann, Rothenberg, 1980, fig. 239).

Fig. 8. Timna 30 Locus 10, set stones around the furnace, wall and working platform. Slag sand inside the structure. Stone foundation of smaller stones below the furnace (photo: G. Weisgerber, Deutsches Bergbau-Museum Bochum).

was suggested by Bachmann and Rothenberg (1980, pp.218-223, figs. 232-235.; Rothenberg, 1990, pp.44-54), only based on the features of Timna, Site 30. For the rebuilding of the smelting furnace, Bachmann and Rothenberg did not use the furnace finds and features of Locus 10 but only took the furnace remains from the waste dump of E 4.

They found two semi-circular furnace fragments (Bachmann and Rothenberg, 1980, pp.218-219) and reconstructed two diameters about 0, 23 and about 0, 54 cm (Figs. 6, a and b), but they do not know their purpose and their position in the furnace construction. In addition, a convex-concave shaped furnace fragment (Fig. 6, c) was documented where slag had stuck on the convex side. They assumed that these fragments were a part of the transition zone (Fig. 7) of a pear-shaped reaction chamber and recognized that they must have been positioned very close to the actual reaction space.

From other fragments (Fig. 6, d; Fig. 7) they constructed a chimney-like shaft (Bachmann and Rothenberg, 1980, p.219, p.221, fig. 239) . The authors neither explain how the S-shaped furnace wall is connected to the open area of the shaft or chimney nor how these areas may have been touched by slag (see Figs. 6, a-c).

Bachmann and Rothenberg propose a pear-shaped furnace (Fig. 7), nestling between stones and soil for heat isolation, with a volume of about 0, 04–0, 06 m^3. Furthermore, the authors propose without any evicence (Rothenberg, 1990, p.47) that 4–6 *tuyères* were inserted into the surrounding furnace lining to ensure artificial air supply. After the complete excavation (Fig. 8), Rothenberg (1990, p.47) reconstructed a rather smaller furnace which had been repaired after repeated use and thereby deformed. A secondary use as a storage pit (Fig. 8, b) for slag sand is described, too.

The new reconstruction of an Iron Age smelting furnace

During the processing of the archaeological findings and features of the site Faynan 5 (dating: Hauptmann, 2007, Table 5.1), new insights into the Iron Age furnace technology could be won. Along with new archaeological

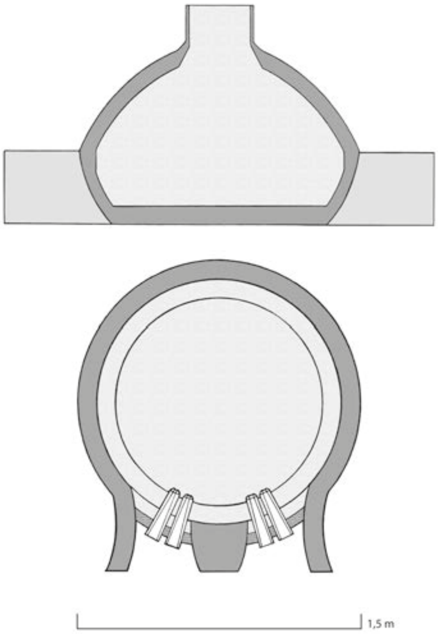

Fig. 9. Reconstruction of an Iron Age smelting furnace based on the finds and features of Faynan 5, Timna Site 30, Stratum I and KeN, Area R Locus 145. The position of the tuyères based on the reconstruction of the smelting furnace from Africa and the features of the Excavations in Faynan and Timna. No tuyères were found in situ. They were positioned in the furnace front area and were quarried out after each run to remove the remains of copper containing slag.

Fig. 10. Timna 30, Locus 10 (a), multi-phase furnace with working platforms (set stone slabs), remnants of the multi layered furnace wall and S-shaped opening of the furnace behind the scale (photo: G. Weisgerber, 1974, Deutsches Bergbau-Museum). (b), multi-phase cupola furnace. Slag sand- / clay mixture eroded and multi layered furnace wall in the rear region of the furnace (right). Thinly tapering repair layers in the direction of the furnace opening. Round smeared mouth of the furnace opening in the lower left area of the slightly S-shaped outgoing part adjacent to the working platform (left) (photo: A. Hauptmann, Deutsches Bergbau-Museum Bochum) containing slag.

finds and features from KeN, Area A, Locus 145, (Ben-Yosef, 2010) and the old features of Timna 30, a new reconstruction was aimed:

The furnace was embedded in the soil on stones for heat isolation and was stabilised with a working platform of stones and/or plate-shaped slag – Faynan: Locus 5.2 and Locus 5.4; Timna: Site 30, Layer I, Locus 10: (Rothenberg, 1980, pp.98-203; 1990, pp.46-48), KeN: (Ben-Yosef, 2010, pp.658-664). The furnace linings were made of clay and crushed slag and could withstand temperatures up to 1100 °C – Timna: Tite et al. (1990, pp.173-174); Faynan: furnace lining, Loc. 5. 2 (sample: JD 1/48 = 5507/55071, 55072), 1100°C; furnace bottom: Loc. 5. 1 (sample: JD 1/42 = 5501), 1100°C (Schneider, 1987).The outer diameter of the furnace is approximately 1, 2 to 1, 5 m and the inner diameter up to one meter. The height of the dome-

Fig. 11. Cupola furnace from Faynan 5.2. Surrounding stone foundation and obtained dome construction of the furnace made of slag tempered clay. The remains of the reaction chamber adjacent to the remnants of the previous working platform made of plate-like taped slags (photo: A. Hauptmann, Deutsches Bergbau-Museum Bochum).

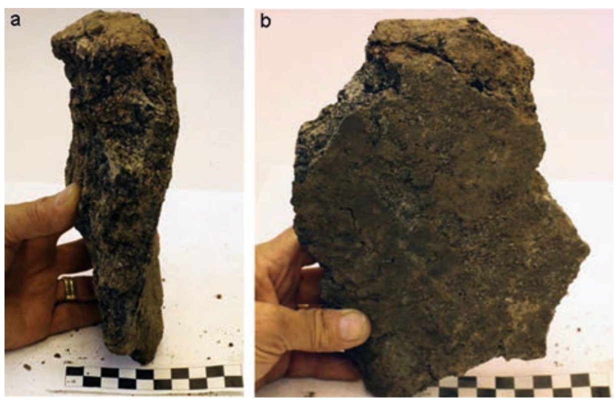

Fig. 12. KeN Area M, Locus 745. Shaft fragment with approach and edge (height 15-18 cm). Profile view (a) side view (b) (Ben-Yosef, 2010 fig. 7.29, with permission to reproduce by the author and the Levantine Archaeology Laboratory, UCSD).

Fig. 13. *Reconstruction of a smelting furnace of Timna 30, Stratum I by the excavation team of 1976. There is no connecting point between the S-shape form and the approach of the shaft (photo: Deutsches Bergbau-Museum Bochum).*

Fig. 14. Experimental iron smelting (a). Reconstruction of an African iron smelting furnace. The large nozzles are located directly in the specially manufactured furnace opening, which can be opened by any trip without destroying large parts of the furnace. Reaction chamber (b) of the upper iron smelting furnace (Source images a and b: http://warehamforgeblog.blogspot.de/2011/03/heat-under-africa.html. Full and complete copyrights: © Darrell Markewitz). The nozzles are directed at different angles to the melt. This feature corresponds to the different angles of the slagging at the nozzles from Tinma and Faynan (Rothenberg, 1990; Hauptmann, 2007; Al-Shorman, 2009; Ben-Yosef, 2010).

shaped/lenticular design is minimum 50-80 cm (Figs. 8-11). The dome has probably a chimney-like opening at the top. Repairs of the furnace wall caused an increase in the wall thickness in the rear region of the furnace and resulted in a reduction of the reaction chamber (Fig. 10). The furnace front lining/area were broken after each run to remove the remains of copper containing slag, and to empty the furnace from unburned and unsmelted material (Hauptmann and Löffler, 2013, p.79).

Based on the furnace wall fragments, round components (Figs. 6; a, b, d) were reconstructed which can be assigned to chimney-like forms (Bachmann and Rothenberg, 1980, p.218; Rothenberg, 1980, p.199).

Almost identical components were found, among other things in KeN Area M (Ben-Yosef, 2010, p.677). The rim fragment (Fig. 12) of a shaft without any slag shows a short shaft with a height of 15-18 cm.

The components with smaller diameter could be used for the chimney, and the larger ones could be used as the furnace opening. It is shown by the roundish formed area on the furnace opening at Faynan 5.4 (Fig. 10, b). The reconstruction of the furnace of Timna excavation team of 1976 (Fig. 13) already shows the shape of the Iron Age smelting furnace. The approach of the chimney is incorrectly positioned, since the furnace is not a shaft furnace, but a cupola furnace, and the chimney is not located on the charging port but on the furnace dome. In addition, the ends of the S-shaped forms do not fit with the approach of the chimney (Figs. 9, 10, 13).

The furnace opening was stabilized by a work platform (Figs. 8, 10, 11) in front of the furnace. The opening area of the furnace front is approximately up to 90 cm (Fig. 10, 11) wide and the sides of the furnace wall going slightly concave to the outside. The S-shaped form of the opening leads to a slightly pear-shaped construction of the furnace. This has already been observed on the feature photos of the furnace Locus 10 (Rothenberg, 1980,

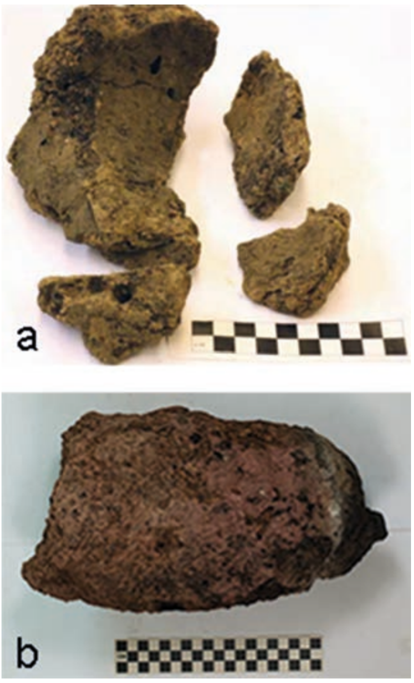

Fig. 15. Furnace lining with nozzle hole (a), KeN Area M, locus 707. Large nozzle (b, side view) from KeN area R, Locus 071. Length 31 cm, diameter 15 cm (Ben-Yosef, 2010, fig. 73.33,3 fig. 7.37, with permission to reproduce by the author and the Levantine Archaeology Laboratory, UCSD).

Fig. 16. Parts of large Iron Age nozzles and nozzle caps from KeN Areas M, R (Ben-Yosef, 2010, fig. 7.41, with permission to reproduce by the author and the Levantine Archaeology Laboratory, UCSD).

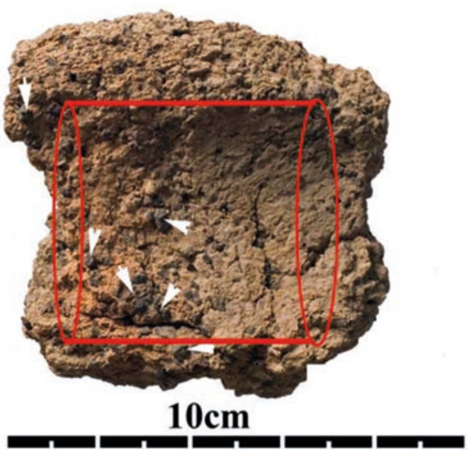

Fig. 17. Portion of a nozzle tube (KeN 136.2) from KeN (Al-Shorman, 2009, Fig. 4.29; photo: Deutsches Bergbau-Museum Bochum).

p.198-200; 1990, pp.46-48, fig. 71). The curved furnace wall transition (Fig. 10) to the streaked feed opening is clearly visible. The furnace opening could contain one or more specially designed openings (Figs. 9, 14) which are separated by a web rib such as at those recent furnaces from Africa (Fig. 14).

However, in the two drawings of the furnace (Rothenberg, 1990, fig. 69) (Fig. 8, a) Locus 10 has got no S-shaped opening and no last building stages of the furnace, in contrast to the feature photo (Fig. 10, a).

S-shaped furnace fragments with slag traces (Fig. 6, c) are proven in Timna 30, Layer I (Rothenberg, 1990, p.46), as well as in KeN, Area M (Ben-Yosef, 2010, p.677, fig. 7.28). The slagging probably occurred in conjunction with the use of nozzles that are situated in the furnace opening.

The unique artefact (Fig. 15, a) of a large piece of furnace wall shows the probable position of the large nozzle in the furnace opening (Ben-Yosef, 2010, p.658-659). The dimensions of the opening correspond to the space requirement of the large nozzle (Fig. 15, b) which has an inclination of about 10° in the direction of the furnace bottom (Ben-Yosef, 2010, p.689). At no find places *tuyères* were found in a furnace *in situ*. They are almost exclusively in fragmented condition and were probably quarried with parts of the furnace opening in order to get access to the melt.

Summary

The detected traces of slag and the S-shape / pear-shaped design of the furnace show that pieces, formerly designated as shaft fragments, are part of the furnace opening which contains the large *tuyères*.

In all well-documented furnaces the front part is destroyed, which is connected with the adjacent working platform (Figs. 10, 11). This platform allows getting access to the interior of the furnace in order to enable, apart from the first charging of fuel and ore and tapping the slag, the removal of the smelting products, as well as the repeated reparation of the furnace[1]. I also assume a charge of the furnace during the smelting process through the chimney. All the features and the result of the reconstruction clearly show that the pear-shaped floor plan in the area is horizontal (Figs. 9-10) and not vertical standing like in the reconstruction of the furnace in 1980 (Fig. 7).

Supplement

Bachmann and Rothenberg (1980, p.221) suggest that the furnaces were working with an artificial air supply and that far larger air intakes and possibly wind tunnels would have been necessary. The large Iron Age *tuyères* (Figs. 16, 17), however, are constructed of two components (Rothenberg, 1990, figs. 73-78). They consist of the nozzle cap, which serves as protection, and the nozzle tube (nozzle head) that leads the air.

The air outlet port has a diameter of about 1-3 cm (Fig. 16). The rear portion of the nozzle tube will vary, with diameters of the air inlet of 8 to 14 cm (Fig. 17) (Rothenberg, 1990, fig. 78; Al-Shorman, 2009, Appendix B.3, KN 136, 2). In the front region of the nozzle, the cross section is reduced to a diameter of about 2 cm. This effect is further enhanced by the attached nozzle cap. Due to the Venturi principle, the air speed is increased in this area.

As for the EBA furnaces from Faynan 9 (Hauptmann, 2007, pp.104-108), the use of a bellow is not required for this type of air supply, as long as the air draughts by a chimney runs and the furnace opening is largely closed as it can be seen in the furnace reconstruction from Africa (Markewitz, 2015, fig. 14). Craddock in contrast sees the evidence of a use of bellows already in the use of clay *tuyères* (Craddock, 1995, p.180). Neither in Timna (Rothenberg, 1990) nor in Faynan (Hauptmann, 2007) direct evidence of some sort of bellows was documented.

However, the use of wind bellows is conceivable. The main question concerns the use of the bellows. What were they used for, smelting or melting?

Possible indirect evidence can be provided by the detection of large distinctive curved leather-stitching needles, used to build or repair the bag bellows. These kind of needles are found in some numbers at metal production sites such as Timna (Craddock, 1995, p.180). For example in the area around the smelting site Timna 30, in Stratum II (Rothenberg, 1980, p.196) the Timna excavation team found a large number of these big curved needles. Most of the excavated material from Timna 30 has not been fully published (Oral information by Craddock, 2014).

In contrast, no information on needles or leather-stitching needles is known from Timna, Stratum I (Rothenberg, 1980, pp.198-201; 1990, pp.44-54), KeN (Ben-Yosef 2010) or the Faynan 5 (Hauptmann, 2007) area. So until now, there is no indirect evidence for the use of bellows in context with these smelting installations.

Notes

1 For example the EBA furnaces from Faynan 9: Hauptmann, 2007, pp.104-108.

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