Iron Production Center Found in the Jordan Valley
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Arti-Facts

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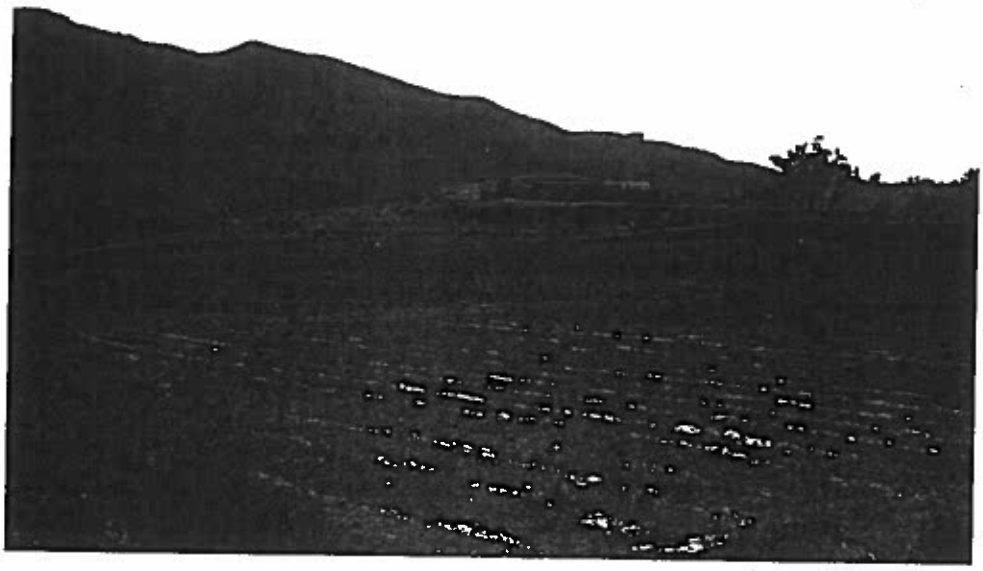
Introduction

In 1996 and 1997, excavations were carried out at Tell Hammeh az-Zarqa in Jordan, a small site on the north bank of the river Zarqa. These excavations, supervised by Eveline van der Steen, form part of the Deir ʿAlla Regional Project, a joint investigation of Yarmouk University of Jordan and Leiden University. Dr. G.J. van der Kooij and Dr. Zeidan Kafafi served as co-directors. During the excavations large amounts of slag, ash, charcoal, molten clay and remnants of furnace structures, clearly the remains of some form of metal production, were discovered. Most of the research on these materials was carried out at the Archaeometry Laboratory of Yarmouk University, headed by Dr. Ziad al-Saad.

Tell Hammeh az-Zarqa is a small artificial hill located near the point where the Wadi Zarqa opens into the Jordan Valley. The Arabic word 'hammeh' means hot spring, a name that must derive from the thermal springs close to the tell (Merrill 1881:93; Blanckenhorn 1912:320). Nearby water is a necessity for the production of iron, both in the construction of furnaces (mixing clay) and treatment of the metal during smithing (annealing).

Another necessity is ore. Approximately 2.5 kms to the north-east of Tell Hammeh is the iron ore deposit of Mugharet al-Warda (Cave of the Roses), the only iron ore deposit in Jordan. This deposit is a lenticular body of massive haematite iron ore. Survey and excavation near the ore-body have found traces of iron smelting activities that may date back to Roman times (Coughenour 1976).

In addition to water and iron-ore, the local environment includes hot eastern winds ('*Sharqiya*') that blow throughout the greater part of the year. These could have provided or augmented a natural draft to the smelting furnaces, although the temperatures necessary to smelt iron seem to make a forced draft more likely.



View of Tell Hammeh az-Zarqa from the North East.

History of the Excavations at Tell Hammeh

The 1996 season

A trial excavation was conducted at Tell Hammeh in November and December, 1996. The objective was to investigate the change in settlement pattern in the Central East Jordan Valley during the transition from the Late Bronze to the Early Iron Age, and the reasons for this change.

A few months before the excavation, a large segment at the eastern side of Tell Hammeh was cut off by a bulldozer for agricultural purposes. This created a large section that only needed to be cleaned to gain a first impression of the occupational history of the site. The cut created Main Sections A and B in the central part of the tell, spanning a total width of about 10 m. The pottery collected indicated that Tell Hammeh had been occupied during the Chalcolithic, Middle Bronze Age, Late Bronze Age, Early Iron Age, and Late Iron Age. Two trenches were cut into the section, one 3 m wide (Square I, section B), the other 4 m wide (Square II, section A). The persistent winds severely hampered excavation, and only the Late Iron layers could be exposed. A mudbrick wall running through both squares was found in these deposits. Partly lying against the wall was a layer mixed of slag, ash and charcoal (locus I–14), indicating some sort of metal industry.

Samples of the material were analyzed at the Archaeometry Laboratory of Yarmouk University. Of eleven different lab-samples analyzed, at least one, HA7, was positively identified as a slag from the smelting of iron, based on its outer appearance and the results of microscopic analyses. The other samples turned out to be ore in various stages of reduction and fragments of molten clay.

The 1997 season

The possibility that evidence of iron production had been discovered justified another season of excavation in early 1997. This was made possible thanks to the generosity of the Department of Antiquities of Jordan, which funded part of this second season. Work on the bulldozer-cut was continued,

and sections were created at the south (C and D) and north (E and F) end of the cut. Sections E and F revealed remains of what may be iron smelting furnaces. Excavation was continued in squares I and II from 1996. Some stone walls were found from the Early Iron Age period, but the excavated area was too small to draw conclusions as to the nature of the occupation. The layer of slag and ash from the iron industry uncovered in square I in 1996, was found to extend into square II.

In square I, locus I–14 was excavated further. Large amounts of slag, ash, charcoal, and molten clay were encountered as in 1966. This layer appears to be a dump of two collapsed furnaces. The first furnace is located in and under the southern section of the square, and has therefore not been excavated completely. It appears to have been a round structure constructed of mudbrick; it was filled with ash, charcoal, various slag and molten clay. Many pieces of square clay tubes, possibly tuyères, were found with the scattered remains of an iron-smelting furnace. All that was left of the second furnace at the northern end of the square, was a high concentration of fragments of molten clay and mudbrick associated with slag. This debris layer might be related to the layer of slag and molten clay that became visible in sections E and F.

The industrial layer was covered by a wash layer that also contained slag, charcoal, tuyères, fragments of molten clay and one iron arrowhead; the layers extended into square II. Both layers were sampled extensively. These samples were classified and analyzed at Yarmouk University in late1997 and form the main part of the range of sampled material.

Finally, in order to collect more information on the iron industry a new trench was opened, square IV, to excavate the furnace that was found in section E (IV–13). This furnace was made of heavily burnt mudbrick and filled with ash, slag and burnt brick fragments. The analyses at Yarmouk University indicate that these are completely similar to the slag from I–14. An ashy layer surrounds the furnace structure, which itself is standing on a layer of heavily burnt material. This layer possibly incorporates remains from an older furnace that was leveled. More charcoal, ash and burnt mudbrick were found in the loci below the furnace structure(s). Therefore, there seems to be a sequence of at least two furnaces here.

Unfortunately, the bulldozer had removed the larger part of this furnace, and what was left collapsed almost as soon as it was cleaned. As a result, all that could be sampled from within the furnace were small amounts of slag, ash or charcoal. Only through the archaeometrical analyses of these samples can a connection be made between the iron-smelting remains of Square I / II and Square IV.

No top-plan of the structure could be drawn but the furnace seems to be circular. From the section, the outside measurements of the furnace seem to be 2 to 2.5 m across and 60 to 80 cm high. These dimensions represent only the preserved size; while the furnace may have been wider, it was almost certainly higher.

Two more possible furnace structures, each resembling IV-13 were found in Main section F, to the north of section E. They measure 1.5 m across and 40 cm high, again the minimal (outside) size. These also contained slag, ash, and burnt mudbrick. Additionally, lumps of haematite iron-ore were found in the most northern furnace.

Dating the Evidence of Iron Production at Tell Hammeh

At present, the only method to date the remains of the iron production is by the associated pottery, which place them in Iron Age II period, between 800 and 700 BCE. In all squares, the smelting remains are found close to the surface. They all seem to belong to the same phase, and no remains of the industry prior to Iron II have been found. However, since only a very small area of the site has been excavated, it is possible that iron was produced in the area prior to this time (Pigott and McGovern 1982). Further excavation may reveal that the site was long a center of iron production.

Laboratory Analyses

Method

During 1996 and 1997, the Tell Hammeh iron production remains were studied, inventoried and analyzed at the Archaeometry Laboratory of Yarmouk University in Jordan by Xander Veldhuijzen. The sampling was supplemented with high-grade haematite (Fe_2O_3) ore from Mugharet al-Warda, which has been analyzed in the 1960's (Van den Boom and Lahloub 1962:39–46; Bender 1968:149–151). All material was studied, described and, if necessary, drawn and/or photographed. A working classification was made, based on the outer appearance of the samples and the various expected technological steps in iron production and their related material remains. Most of the slag showed a 'tapped' structure, indicating the practice of the running of liquid slag from the furnace during the smelt.

Five samples were subjected to various analyses. The non-slag samples, such as the burned clay and tuyères, were analyzed for chemical composition. All other samples were cut, hand-polished and cast in epoxy-resin. The mounted samples were then machine-polished to one quarter of a μ and studied microscopically to determine their mineralogical composition and phases. A phase is defined as a macroscopically homogeneous body of matter. All matter can exist in three different phases: solid, liquid or gaseous. Certain metals, such as iron and tin, are polymorphic (allotropic) and crystallize in several structures, each stage in a different temperature range. Each crystal structure defines a separate phase. During the smelting of iron ore, several iron (oxide) phases occur, at specific temperatures. The presence of certain iron (oxide) phases in a slag may thus lead to the reconstruction of the temperature ranges of the ancient smelting furnace. Microphotographs were made of all samples. Some of the samples were also examined and photographed with a scanning electron microscope (SEM). Chemical elements of certain phases were defined by electron probe microanalysis, to bridge the results from phase-specific microscopic and bulk chemical analysis.

Various areas of all samples, related to the microscopically studied surface, were pulverized, dissolved in various acids and tested for their chemical (main and trace) elements with Atomic Absorption Spectrometry (A.A.S.). Two samples were later retested using X-ray fluorescence analysis (XRF).

Results

The macroscopic analysis divided the samples into five main categories: slag (magnetic and non-magnetic), furnace remains

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The 1997 Samples

	SiO_2	Al_2O_3	FeO/ Fe_2O_3	CaO	MgO	K_2O	TiO_2	Cu	SnO_2	Ag_2O	Zn	Na_2O	P_2O_5	MnO	F	L.O.I.	Total
HA97 21	33.0	5.6	39.7	15.9	1.9	1.08	0.49	n.d.	<0.002	<0.002	<0.002	0.1	1.16	1.09	0.2	-2.0	98.226
HA97 65	7.8	0.35	75.5	7.6	0.14	0.03	0.06	n.d.	<0.002	<0.002	0.006	<0.01	0.19	0.05	<0.05	8.1	99.89

and the trace elements of all samples. The main elements verify the origin of the samples as a result of iron production, whereas the trace elements serve as 'fingerprints' for comparison between slag, ore and artifact. Traces of titanium (Ti /TiO_2) and silver (Ag) and, less clear, traces of sodium dioxide (Na_2O) and zinc (Zn), are found in all slag, vitrified furnace wall and ore samples. This strongly suggests a connection between the iron production at Tell Hammeh and the ore deposit of Mugharet al-Warda. The chemical composition of the vitrified end of one of the clay tubes (extremely similar to that of most slag) clearly showed that it had been in contact with the slag. This positively identifies it as a tuyère used for air supply to the furnace.

Conclusion

Combining the results summarized above leads to a tentative reconstruction of the Tell Hammeh iron smelting process. Apparently the smelters used large furnaces, charged with Mugharet al-Warda ore and (most likely) charcoal, fired to high temperatures. Air was supplied through square unbaked (prior to the smelt) tuyères, 5 by 5 cm in section. Whether bellows were used is not known, but it seems likely, considering the small opening in the tuyères (1 cm in section) and the apparent temperature in the furnace. It is not impossible, however that air supply was caused by natural draft, or that this draft was augmented by the strong local wind.

The iron production debris (slag, ash, charcoal, ore, tuyères, furnace remains and various fragments of burnt and vitrified clay), that were found at Tell Hammeh constitute quite a complete range of iron-smelting remains. This indicates some form of iron production center, using the ore from nearby Mugharet al-Warda. Archaeologically, there is no indication of any activity other than smelting. Indicators of forging such as hammer-scale, hammering stones or anvils have not been identified.

Besides being of considerable importance for the reconstruction of very early iron smelting techniques, the finds at Tell Hammeh constitute the oldest example of iron production found in the region, if not worldwide, to date. By comparision, the only other find of comparable age, from Tell Afis, Syria, supposedly dates to approximately 700 BCE and consists of a few slag found on the floor of a room (Matthiae 1979:2–4; Ingo et al. 1992:273–275). The next oldest finds were found in Agadez, Niger (approx. 500 BCE) (Posnansky and McIntosh 1976:184; Calvocoressi and David 1979:10; Childs and Killick 1993; Miller and van der Merwe 1994). The first instance of slag together with furnace structures in the entire Mediterranean region is known from Baratti Beach, Italy and is dated to 170 BCE ±70) (Craddock and Hughes 1995:265).

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