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Evidence of Copper Metallurgical Activities at Tall Ḥujayrat al-Ghuzlān, ʻAqaba During the Chalcolithic Period

Introduction

Tall Ḥujayrat al-Ghuzlān is located on the alluvial fan of Wādī al-Yutum, four kilometers north of the coast at ʻAqaba. The site was mentioned, albeit not by name, by Frank when he visited the area (Frank 1934: 245). Archaeological investigations were carried out at the site in 1985 and 1990 (Khalil 1987: 481-483, 1988: 71-117, 1995: 65-79). In 1998, an archaeological survey and excavation project was established in Wādī al-Yutum and the al-Magaṣṣ area as a joint venture between the Institute of Archaeology, University of Jordan and German Archaeological Institute at Berlin, in co-operation with the Department of Antiquities of Jordan. Nine seasons of survey and excavation took place between 1998 and 2010. Some of the results have been published in *Prehistoric Aqaba I*, edited by Lutfi Khalil and Klaus Schmidt (2009).

During the various excavation seasons numerous stone, mud-brick and mud walls were discovered, forming rooms, storage pits and other installations; four building complexes were reported (Eichmann *et al.* 2009: 22-26). In the western part of the site, four groups of wall-decoration were discovered. These consisted of finger-tip impressions pressed into the still soft mud-plaster of the walls of Building D and represent ibex and human figures, all in the manner of line drawings. In addition, several hand impressions were observed. These impressions might be interpreted as part of a ritual presentation (Schmidt 2009: 99-112).

In the south-western part of the site, more than 50 meters of the city wall was exposed during the 2010 season.

A rich inventory of artifacts was recovered during the excavations, *viz.* pottery vessels, flint implements, stone tools and ornaments, including bracelets, beads and shell pendants. In addition, a variety of metallurgical remains were exposed.

On the basis of radiocarbon determinations, Tall Ḥujayrat al-Ghuzlān can be dated to between 4000 and 3200BC (Klimscha 2009: 263-367).

Metallurgical Finds

Copper production involves a number of individual metallurgical stages: mining, ore processing, smelting, melting, casting and, finally, shaping by cold or hot hammering.

Most of the above-mentioned stages are evidenced by metallurgical finds found at the site, e.g. rich nodules of copper ore, grinding slabs for ore preparation, ceramic crucibles for smelting and / or melting, and ceramic moulds. In addition, metallic prills, lumps, ingots and artifacts were recovered during the excavations (Eichmann *et al.* 2009: 26-33).

Ores

Nodules rich in copper ore were found in various squares. They vary in size from *ca.* 0.5 to 5cm, are mostly of sedimentary origin and consist of massive secondary green copper minerals, often mixed with brown iron oxides.

Two samples of copper ore from Tall Ḥujayrat al-Ghuzlān were chemically investigated and proved to be paratacamite (Cu2 (OH) 3Cl) (Khalil and Riederer 1998: 4). Sixteen ore samples from Tall Ḥujayrat al-Ghuzlān and Tall al-Magaṣṣ were also analysed. The latter is located approximately two kilometers west of Tall Ḥujayrat al-Ghuzlān and is contemporary with it. These samples contain mainly copper minerals of malachite (Cu4 (OH) 6 (SO4)), cuprite (Cu2O) and various copper silicates (Hauptmann *et al.* 2009: 295-304).

There is no evidence for the presence of copper ore deposits in the vicinity of ʻAqaba. Timna, where copper ore occurs as concretion nodules dis-

seminated in Upper Palaeozoic / Mesozoic Nubian sandstone is located some 15 kilometers north-west of Tall Ḥujayrat al-Ghuzlān. The Faynān area, located about 140 kilometers north of 'Aqaba, is also rich in copper ores.

A question which frequently arises is whether or not it is possible to differentiate between Faynān and Timna ores. When an attempt was made to identify the provenance of the copper ores used to manufacture metal artifacts from Tall al-Magaṣṣ, it was concluded that they most like came from Wādī 'Arabah. Petrographic analyses indicate that the origin of these ores is probably Timna (Hauptmann *et al.* 2009: 295-304).

Grinding and Hammer Stones

Ore-processing, during which the ores are mechanically separated from the rock, is an important step in the manufacturing process; rich ores need to be crushed or ground to a power before smelting. Different stone tools, e.g. hammers, would have been used to grind ores on the grinding slabs.

During the 1998 survey at Tall Ḥujayrat al-Ghuzlān, a large number of grinding and hammer stones were found on the surface of the site (Khalil and Eichmann 1999: 513). These were studied and classified into different forms and types. It has been suggested that concave / convex slabs were most likely used in the preparation of copper ores; two grinding stones still have traces of ore adhering to their working surfaces (Kerner 2002: 270-271). The hammers used to crush the ores are mostly made of basalt, with only a few on crystalline stone.

Slag

After the rich copper ores had been crushed, the ore would have been converted to metal by means of heat during the smelting process. This requires high temperatures of around 800°C and the presence of oxygen; the process yields pure metallic copper and slag.

The excavations at Tall Ḥujayrat al-Ghuzlān uncovered a small amount of furnace-smelting slag, but a large number of ceramic crucible fragments, often with traces of copper still adhering, were discovered (Khalil and Riederer 1998: 4-5; Khalil *et al.* 2003: 169).

There seems to have been experimentation with crucible-smelting of ores (Tylecote 1974: 54), perhaps using charcoal, crushed rich ore and a blowpipe (Khalil and Bachmann 1981: 105-106).

Ceramic Vessels Used for Metallurgical Activities

Various specialised ceramic vessels used in metallurgical activities were recovered during the excavations at Tall Ḥujayrat al-Ghuzlān, including pale or light reddish clay crucibles and casting moulds. These are hand-made and have large voids, probably resulting from the use of organic temper which was incinerated during firing. Sherds and complete vessels still bear the remains of corroded metallic copper products, including traces of prills.

Crucibles

As noted above, smelting is a chemical reduction process completed through the agency of heat. It is known that a single smelting process in a small furnace will produce a large amount of slag (Bachmann 1982: 5), yet only a small amount of furnace-slag was found at Tall Ḥujayrat al-Ghuzlān. No smelting furnaces or furnace-linings were uncovered at the site, suggesting that furnace-smelting was not practiced at Tall Ḥujayrat al-Ghuzlān. However, a large variety of smelting crucible sherds was discovered during the excavations.

Crucibles are rounded vessels, with curved sides, rims and (sometimes) spouts. No complete crucible was discovered at Tall Ḥujayrat al-Ghuzlān, but a variety of diagnostic sherds, e.g. rims, spouts, bases and socketed handles, were found. In general, sherd thickness varies between 1 and 4cm. Sherds are either thin and of fine-tempered clay or, more commonly, are thick and straw-tempered. Rim sherds suggest that the crucibles typically had an opening of between 13 and 20cm in diameter (Pfeiffer 2009: 308-311).

A typological study of Late Bronze Age and Iron Age crucibles from the British Isles, Russia and the Levant has been published. They consist of various shapes, e.g. triangular, circular, globular, oval, necked, pinched, lidded and socketed (Tylecote 1979: 19-20). When diagnostic crucible sherds from Tall Ḥujayrat al-Ghuzlān are compared with the above study, they fall into the following main groups:

1. Curved rims with widely to moderately rounded lips.
2. Straight rims with pointed or flat lips.
3. Socketed handles with various socket shapes, e.g. rectangular, rounded, ellipsoid and bow-shaped. A wooden shaft would have been fitted into the socket to manoeuvre the heavy crucible

in or out the fire. This type of socketed crucible been has been designated the 'Magass type' (Pfeiffer 2009: 310).

In an attempt to differentiate between ceramic sherds from smelting as opposed to melting crucibles, two basic sherd-types were identified: (1) thick sherds, most likely from smelting crucibles, with vitreous and slaggy materials adhering and (2) thin-walled, highly burned sherds, most likely from melting crucibles, with metallic prills still adhering. However, further typological, chemical and petrographical analyses are still needed to clarify the difference between smelting and melting crucibles.

Crucible fragments have been found at a number of archaeological sites contemporary with Tall Ḥujayrat al-Ghuzlān, e.g. Abu Matar (Perrot 1957: pl. 1.1), Arad Stratum I (Amiran 1978: pl. 67: 9, 12) and Faynān 100 (Wright *et al.* 1998: 56).

Moulds

Four complete and many fragmentary pottery moulds were found during the excavations at Tall Ḥujayrat al-Ghuzlān. These are handmade; fingerprints are often still visible as a result of attempts to smooth the slipped surface during manufacture.

The moulds are made of fine and tempered clay; their inner surfaces often have green strains derived from corroded metallic copper. These stains are below the mould rims and illustrate the level of the molten metal when the vessels were in use.

The moulds can be categorised into two main types: rectangular and oval. Their shape indicates that they were used to cast ingots (rather than tools) which could either be traded as stock-metal or hammered, whether cold or hot, into the shapes required.

The rectangular moulds were designed to produce a tabular ingot. They measure *ca.* 13 by 10.5cm, with plain bases varying in thickness between 0.7 and 2.5cm. The walls vary in height between 0.9 and 2.4cm, with a thickness of between 0.6 and 1.5cm. The estimated volume of this type of mould is between 60 and 120cm^3 (Pfeiffer 2009: 307).

The oval moulds were intended to cast an oval ingot. They measure *ca.* 11 by 6cm, with either flat or round bases varying in thickness between 1 and 2.5cm. The volume of this type of mould is estimated at between 40 and 50cm^3 (Pfeiffer 2009: 307).

Similar rectangular and oval moulds were found at Tall ash-Shūna in northern Jordan. These date to the Late Chalcolithic and Early Bronze Age I (Rehren *et al.* 1997: 625-640; Philip 2001: 163-233). Ceramic mould fragments were also discovered at Faynān 100 (Wright *et al.* 1998: 56).

A study showing the ratio of metal finds to ceramic vessels used for metallurgical activities, as recovered from Tall Ḥujayrat al-Ghuzlān during 2000 - 2006 seasons (excepting 2002), gives a useful indication of the large scale of copper production at the site (Pfeiffer 2009: 311).

Metal Artifacts

Various copper objects were recovered during the Tall Ḥujayrat al-Ghuzlān excavations, including prills, lumps, ingots and tools.

Prills and Lumps

Prills or pellets are globular in shape, varying between 0.5 and 2cm in diameter, and are usually the first product to be recovered from the smelting process. These can be gathered up and re-smelted or melted in a crucible to produce a lump or ingot of copper. Similar metal prills were found at Tall ash-Shūna (Rehren *et al.* 1997: 629).

The lumps vary in size and weight. A number of lumps from Tall al-Magaṣṣ were chemically analyzed, indicating that they consist mostly of pure copper with few impurities, except in a small number of cases where the proportion of iron reaches 3.2 % (Khalil and Riederer 1998: 7; Hauptman *et al.* 2009: 301).

Ingots

During the 2003 season, an oval-shaped ingot was discovered in Square I6, Locus 10 in the southern part of Tall Ḥujayrat al-Ghuzlān. It is complete, with one face convex and the other plain; its weight is 1.1kg and its size is *ca.* 13.8 by 8cm. Its size and shape suggest that it came from an oval mould of the type recovered at the same site (Khalil *et al.* 2003: 172, fig. 149).

Similar oval-shaped copper ingots were discovered at Maadi in Lower Egypt; these date to the Late Chalcolithic period (Rizkana and Seeher 1989: pls 4, 9-11).

Tools

A number of simple tools were recovered during the Tall Ḥujayrat al-Ghuzlān excavations, including

rods, pins and trapezoidal axes and adzes. Such artifacts can easily be shaped by cold or hot hammering.

An awl, a trapezoidal block and a chisel fragment discovered at Tall al-Magaṣṣ were analysed. Their chemical composition showed that they were relatively pure copper with a low proportion of trace elements (Khalil 1992:146; Hauptmann 2009: 301).

Trapezoidal axes and / or adzes have been discovered at many Chalcolithic sites in Jordan and Palestine, including Tulaylāt al-Ghasūl, Shiqmim, Abu Matar, Bir as-Safadi (Shalve and Northover 1987: 361). In addition, three fragmented copper trapezoidal axes / adzes were reported from Maadi in Egypt (Rizkana and Seeher 1989: 15, pls 4: 3-4 and 11: 20-22).

Conclusion

It would appear that the metallurgical remains discovered at Tall Ḥujayrat al-Ghuzlān belong to a Late Chalcolithic metal workshop. Evidence for the extent and skill of copper production at the site indicates that there was at least some well-organised craftsmanship. The copper metallurgical activities were not on the scale of a small village community, but rather larger.

Rich copper ores were carefully selected and transported from Timna, or perhaps Faynān. The ores were prepared and smelted at the site in ceramic crucibles to produce metallic prills, which could be re-smelted or melted and cast into ingots, which could in turn have been exported or shaped by cold or hot hammering.

The total quantity of artifacts discovered is relatively small, especially compared to the extent of the smelting and melting operations evidently undertaken at the site. Therefore, metal production seems to have exceeded site needs and therefore hints at the existence of a trade in metals, especially when the large number of ceramic moulds – which indicate that production was focused on ingots rather than artifacts – is taken in consideration.

Complete and fragmentary ceramic moulds were recovered. These are both oval and rectangular in shape. An oval copper ingot was discovered at Tall Ḥujayrat al-Ghuzlān during the 2003 season.

Oval and rectangular copper ingots were discovered at Maadi in Lower Egypt. These are of similar shape and size to the moulds from Tall Ḥujayrat al-Ghuzlān, which is suggestive of the existence of trade relations between ʻAqaba and Predynastic Egypt. Tall Ḥujayrat al-Ghuzlān has yielded other evidence to support this supposition, including a basalt vessel fragment (the so-called 'Libyan Vase') and flint tools and shells similar to material known from the Buto-Maadi culture. It seems therefore seems clear that there was some sort of trade and / or exchange between Lower Egypt and the ʻAqaba region during the fourth millennium BC.

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