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Significance of Gold Exploitation in the Early Islamic Period, Israel

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An archaeological site in southern Israel contains the remains of industrial settlements and implements. The comminuted product of millstones is a powdery material consisting mainly of quartz, and containing up to 20 ppm gold. It appears that the gold was mined within proximity of the site, and that the ore contained microscopic gold. This is the first indication of gold operations in the ancient or modern Levant and it sheds new light on the importance of the Elat area during the Early Islamic period.

Keywords: GOLD, MILLSTONE, EARLY ISLAMIC PERIOD, SOUTHERN ISRAEL.

Introduction

The "Wadi Tawahin" ("The Millstone Wadi" in Arabic) archaeological site in southern Israel (Figure 1) is characterized by the presence of some 30 millstones. They are unique for the region in their relatively large size (up to 80 cm diameter), shape and composition (quartz-diorite). The site was first noted by Frank (1934), who suggested that the millstones were used for crushing "schwerspar" (=barite), and has recently been partially excavated (Avner & Nahlieli, 1991).

A geochemical survey (ephemeral stream sediments) of the Precambrian terrain in southern Israel (Bogoch *et al.*, 1990) led to the discovery of a gold anomaly in the Nahal Roded area (see Figure 1). The archaeological site occurs within the area of this anomaly. For the present study, sediments in and around the archaeological sites were systematically sampled and analysed in an attempt to determine the nature of the milled raw material.

Geography and Geology of the Wadi Tawahin Area

The area is part of an arid, rocky desert, with an average annual rainfall of ~30 mm. All river beds are ephemeral, the drainage being controlled by intense flash floods which occur irregularly from year to year, but which may be absent over a span of several years. Maximum winter and summer temperatures are in the range of 15–25° and 35–45°C, respectively. Climatic conditions ~1000 years ago were apparently similar (Issar, 1990). The topography is rugged with steep slopes incised by numerous immature wadis; the highest point in the area is 432 m above sea level.

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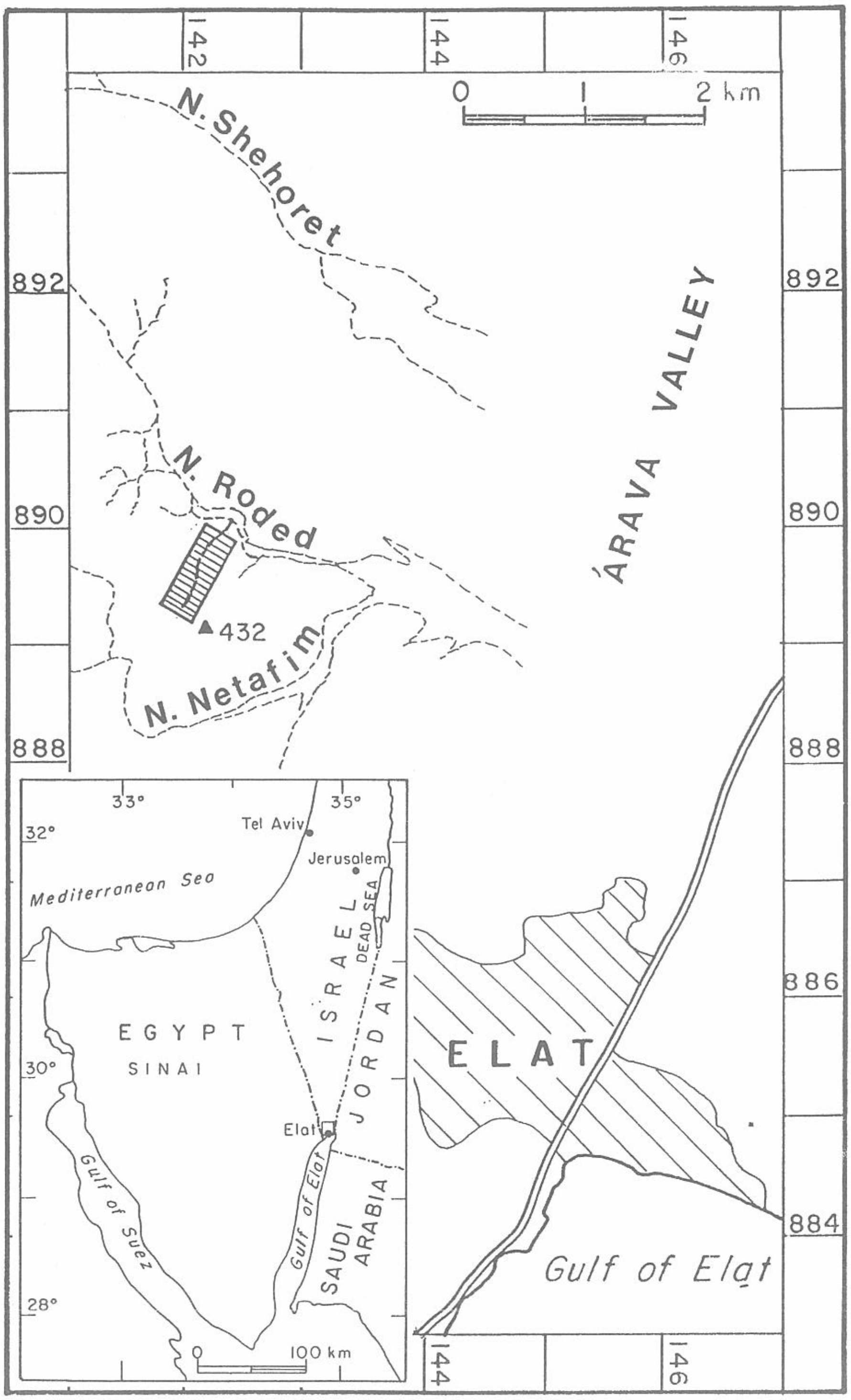

Figure 1. Location of the archaeological site in southern Israel (hatched rectangle, see Figure 2 for details).

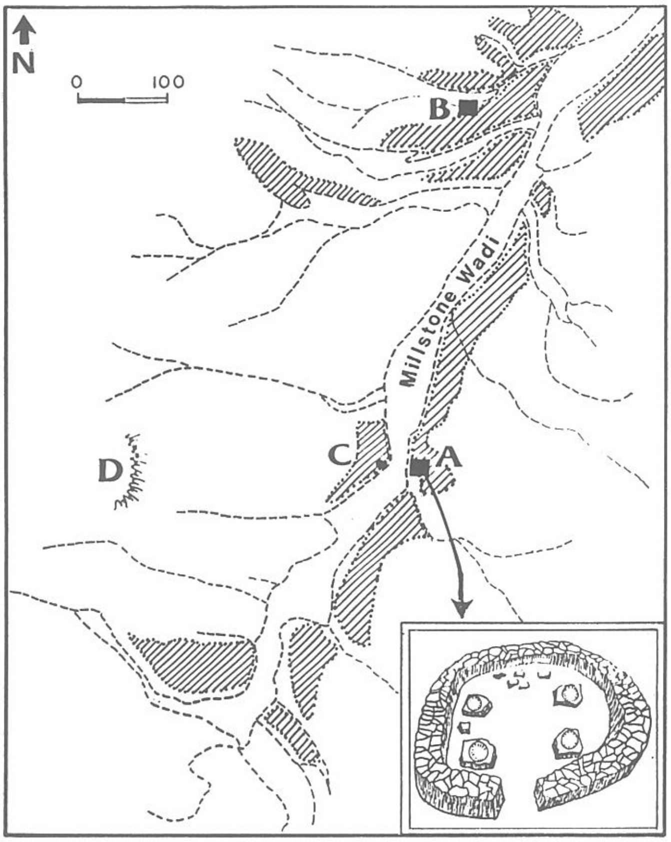

Figure 2. Outline of Wadi Tawahin (Millstone Wadi) showing main features noted in text: A, "main building"; B, unexcavated building with apparent *in situ* millstone bases; C, bell-shaped storage pit (see Figure 4); D, probable site of quartz-diorite quarry for the implements. Cross-hatchings are ancient alluvial terraces.

The area of the archaeological sites is within the Precambrian terrain of southern Israel, the northern extension of the Arabo-Nubian Shield. It is dominated by quartz-diorite which is crossed by numerous NE–SW trending quartz-feldspar porphyry dykes of rhyolitic composition, and younger andesitic to dacitic dykes at various trends. Leucocratic granite, intrusive into the quartz-diorite, occurs sporadically. In most exposures of the area, the quartz-diorite is friable to a depth of at least 2–3 m. Numerous small quartz veins and lens-like segregations (up to $2 \times 0{\cdot}6$ m) are present. Most of the latter are barren, white quartz. However, one relatively large body ($\sim 15\ m^2$), 200 m downstream from the northern extension of the site, is slightly ferruginous, and contains up to 9 ppm gold (Au-grains 1–20 μm in diameter).

The composition of the bed sediment in Wadi Tawahin is representative of all rock types present in the watershed and is extremely heterogeneous in fragment size, varying from boulders to silt. Ancient river alluvial terraces discontinuously line both banks of Wadi Tawahin (Figure 2). The alluvial terrace sediment is well-bedded, weakly indurated, and similar in composition and fragment-size distribution to the present wadi bed sediments.

Figure 3. "Main building" viewed towards the north.

Description of the Archaeological Site

The archaeological remains are scattered on both banks of Wadi Tawahin over a length of some 500 m, and largely occur on the surface of the ancient alluvial terraces (Figure 2). They include different constructions, work implements and excavations. The remnants of 12 single-room buildings (round and square-shaped, 3–5 m diameters), 23 tents (represented by near-circular arrangement of stones), a group of 5 graves, 14 work stations or work rooms, and a storage pit are present. The implements include a total of 31 whole, and numerous broken, millstone bases; 3 millstone tops; 44 anvils; many stone hammers, and the base of a single saddle quern.

The best-preserved feature is the remnant of an approximately square shaped building ("main building") 4 × 4 m in size, with one opening on the south side (Figures 2 & 3). The walls have been reconstructed to a height of ~1·2 m from its pristine state of 0·2–0·8 m. A similar site (not excavated) is present some 400 m to the north (Figure 2, site B). One partially excavated work-station ~20 m south of the "main building" consists of a 2 m long, low wall, with partial perpendicular extensions at both ends. Two anvils, four hammers and one millstone were found close to the wall. Opposite the "main building", on the western side of the wadi, a bell-shaped storage pit (2 m high, 1·55 m wide at the bottom) is present within the ancient terrace (Figure 4). Similar bell-shaped storage pits are well known in many cultures and from many periods.

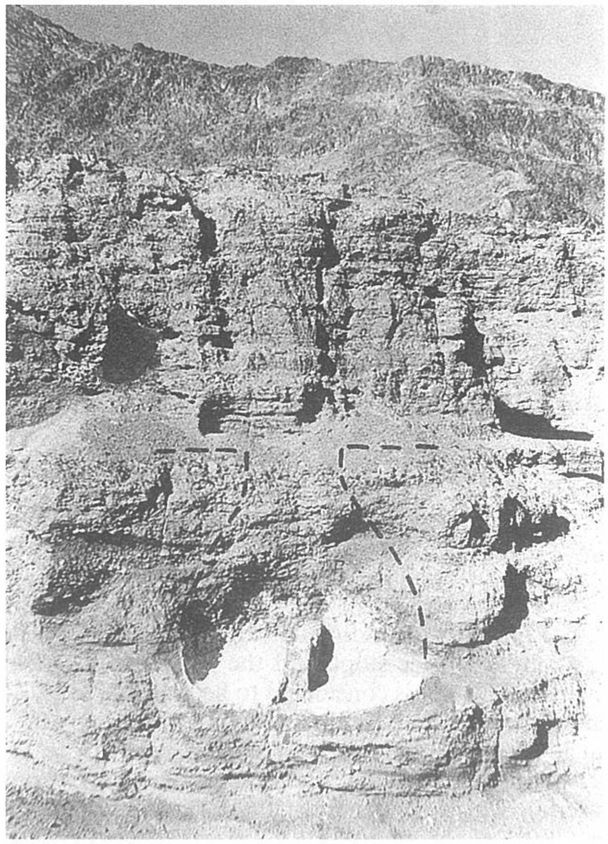

Figure 4. View towards west of bell-shaped storage pit. White covering on base and sides is the comminuted product (powder) of the millstones; dashed lines are schematic "reconstruction' of storage pit.

The millstones consist of rough-hewn rectangular to square-shaped quartz-diorite blocks, most measuring between 60 and 80 cm across on the upper surface, and between 30 and 50 cm in height (Figure 5). The underside is frequently not worked beyond the quarrying stage. The grinding areas are circular recessions measuring between 40 and 60 cm in diameter and up to 11 cm in depth, with steep edges (~80°); at their centre is an upraised projection (3–5 cm above the base) in the middle of which is a recessed hole for a spindle. No grooves are present. The tops are the inverse of the circular recessions, up to 10 cm thick, with a central through hole for the spindle, and an ~5 cm deep hole near the edge to support a turning handle. Millstones were probably located, apparently *in situ*, in each of the corners of the "main building" (Figure 3).

The anvils are rectangular-shaped blocks, up to 40 cm long, 30 cm wide, and 20 cm in height (Figure 5). Irregular-shaped depressions are present near the centres of the upper surfaces. The hammers are of two types: relatively large sizes (up to 20 cm in maximum diameter), roughly ellipsoidal or squarish in shape; and smaller sizes for use with one hand. Unlike the other implements which are composed of quartz-diorite, the saddle quern base is a leucocratic granite of the variety found nearby.

The only location in the Wadi Tawahin area containing fresh quartz-diorite is at the top of the steep slope above the western bank of the wadi, at the southern part of the

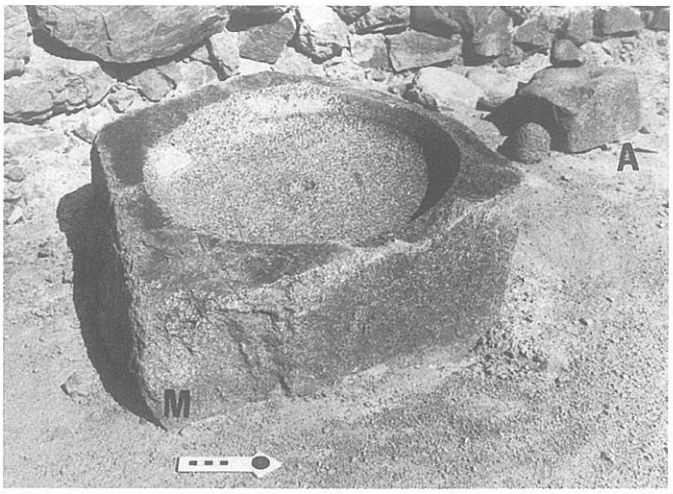

Figure 5. Millstone base (M), and anvil (A) and adjacent small hammer, in the "main building"; scale bar in cm.

site (Figure 2, site D). Possible indications of quarrying are present in the large angular blocks which cover the lower slope and the flat surface of the terrace, a feature not observed elsewhere. This site is considered to be the most likely source for the millstones and other quartz-diorite implements.

At different locations in the site, and in particular, close to *in situ* millstones and within the bell-shaped storage pit, are concentrations of very fine-grained, powdery, light-grey material, which differs from the terrace sediment in its homogeneity and fine-grain size (100% of the material is <150 μm and 50% is <62 μm). This material is considered to represent the comminuted product and, at least in part, was stored in the bell-shaped pit. The powder is composed mainly of quartz (~80% vol.) and contains particulate gold (up to 10 μm in diameter) or "dust" on quartz fragments (Figure 6).

Pottery fragments of different types indicate an apparent age of the site between the 8th and 10th centuries AD (Early Islamic period).* A single ^{14}C measurement on a sample consisting of small charcoal fragments taken 10–30 cm below the surface at one of the work stations ~70 m south of the "main building" yielded 1074 ± 47 years BP (970 AD calibrated).

Sampling and Analytical Methods

The surface material on the ancient alluvial terraces near the archaeological site was sampled. Approximately 1 kg samples (sieved to <1 mm) were taken to a depth of 10–15 cm, after scraping away the upper few centimetres of sediment. Other similar samples were taken randomly throughout the site to determine background values. In addition, the powdery material was sampled near and below several millstones, and from within the bell-shaped storage pit. It should be noted that the powder in most places is heterogeneously mixed with the upper layer of the terrace sediment.

For the determination of Au, 20 g of sample were roasted for 1 h at 600°C in a muffle furnace to remove sulphur. After cooling, the samples were digested in 50 ml aqua regia on a hot plate for 1 h. The mixture was then evaporated to a moist state, 20 ml of HCl

*Analysis of the pottery has been carried out by Dr J. Magnes, based on a large number of parallels.

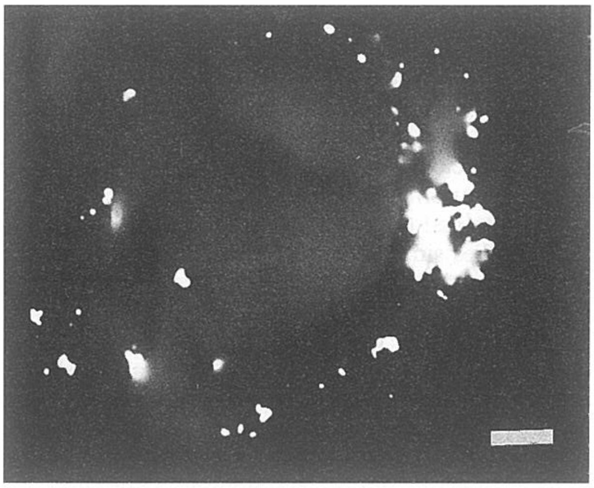

Figure 6. SEM backscatter image of gold particles (white) on quartz grain (pale grey) in powder from bell-shaped storage pit (scanning electron microscope—JEOL 840 with attached LINK 10,000 energy dispersive system).

Table 1. Summary of gold analyses from the Wadi Tawahin archaeological site (all values in ppm)

	Location	Description	No. of samples	Min.	Max.	Avg.
Site A*	Background	Terrace sed.	12	<0·01	0·1	0·02
	Inside "main build."	Powder+sed.	13	0·2	5·0	1·3
	S of "main build."	Powder+sed.	9	6·1	17·0	8·9
	Near/under mill.	Powder+sed.	12	0·2	8·0	5·0
	<5 m S of build.	Powder+sed.	6	0·2	3·42	0·8
	Bell-shaped pit	Powder	4	8·6	20·0	12·8
	S of "main build."	Quartz fragment	2	2·7	10·0	6·3
Site B	Background	Terrace sed.	8	0·02	0·2	0·06
	Near/under mill.	Powder+sed.	7	0·8	9·4	5·0

*Location of sites A and B are shown in Figure 2.
mill.—Millstone.
"main build."—"Main building".
sed.—Alluvial terrace sediment.
powder—Comminuted product of milling.

(1+4) added, and the sample filtered. The solution was transferred to a 100 ml volumetric flask and 5 ml of Aliquat 336+MIBK solution (saturated with 1+1 HCl) was added and the flask shaken. The concentration of Au in the organic phase was measured using atomic absorption (AA) techniques. The limit of detection in the sample is 0·01 ppm Au. International standards yielded results within ± 10% of the published values. Analytical data are presented in Table 1.

Discussion

The relatively high gold content of the powder points to its origin as a gold ore. Although in all its occurrences the powder contains mineral contaminants derived from the alluvial sediment, X-ray diffraction and SEM data suggest that gold was hosted in a quartz-rich gangue. Since the maximum size of particulate gold found in the powder or in quartz veins is in the order of 20 μm (mainly up to 5 μm), it is suggested that even at this early period, methods were available which permitted locating ore with non-visible gold.

Although the exact location of the ore is not yet known, the presence in the area of the wadi sediment Au-anomaly (bound by N. Roded and N. Netafim, see Figure 1) suggests that ore was mined relatively close to the archaeological site. It is possible that Fe-bearing quartz bodies similar to that in the lower part of Wadi Tawahin may have been exploited. This lens-like body is exposed at the surface and is apparently shallow. Other similar bodies could have been mined-out, leaving little or no trace of the operations after 1000 years of weathering and erosion.

The common method in the processing of vein quartz lodes in ancient mining sites of Arabia involved (1) fragmenting the ore by stone hammers and anvils, and (2) crushing with saddle querns (Berkowitz, 1977; Hester *et al.*, 1984). Millstones were apparently rarely used. However, the type of grinding implement is likely to be a function of the nature of gold occurrence in the quartz gangue. Thus, fine- or very fine-grained gold would require comminution to the grain-size necessary to liberate the gold. Based on the archaeological finds, it is possible to reconstruct the production methods at the Tawahin site as follows: gold-bearing quartz ore was brought to the work station, and first crushed using the anvils and the large, two handed stone hammers. Following this, the material was further crushed with the smaller stone hammers, and finally ground to a fine powder using the hand-turned millstones.

No indications of the processing of the ores beyond the milling stage were found at the site. However, two ancient sources suggest that the separation of fine-grained gold was well established. The Greek writer Agatharchides (181–146 BC), in his work *Periplus Rubri Maris*, quoted in Adams (1954), describes the following method: "In working these deposits the rock is first disintegrated by fires built against it, then mined out and crushed to the size of a fine meal. This is then washed by running water on a slanting table, the operator moving the material about with his hands during the operation. By this process, the rocky material is washed away while the gold dust, being heavier, remains on the table." The terms "fine meal" and "gold dust" suggest a very fine-grained gold ore. According to the 10th-century study on gold and silver by Al Hamdani (in Dunlop, 1957), fine gold dust was produced in a long process, including washing with water on a wood table crossed by thin partitions. This was followed by filtering and further washings, and the concentration of the gold grains using mercury. It is likely that the comminuted ore from the Tawahin site was treated adjacent to a water source, near the coast at "Aila" (ancient Elat, located in the present day Aqaba, Jordan; the name was used from the Helenistic to the Mamluks period).

The significance of gold production at the Tawahin site relates to two historical phenomena from the beginnings of the Islamic period: (1) the importance of gold in Arab economics and culture and (2) the importance of the Elat area. The first gold coins in the Islamic period were produced in 695 AD by the Umayyad Caliph, 'Abd al-Malik, in Damascus. This initiated a new monetary system and represented the start of an enormous economic expansion (Dunlop, 1957). The gold used for this monetary system was at first derived from the "return to circulation of a large part of the accumulated treasures of the east" (Dunlop, 1957), and later, beginning in the 9th century, by the availability of gold from mines in the Sudan. Gold-mining activity was widely dispersed in the Arbo-Nubian Shield of Arabia during (and possibly before) the Islamic period (Kisnawi *et al.*, 1983). There are no references to gold mining in the Elat area, and in fact, no gold mines were known through the entire Levant. The Tawahin site is thus the first to be found from any period.

The Elat area was highly settled in the Early Islamic (Ummayad) period, and many sites extending N–S for over 60 km are present (Rothenburg, 1990; Willies, 1990; Avner & Nahlieli, 1991; Whitcomb, 1976). Thus, in the Early Islamic period, the area enjoyed increased importance and extensive development by virtue of the state's initiative. This activity included agricultural and industrial settlement, and commerce. "Aila" continued to flourish in the 9th and 10th centuries as a commercial centre and gathering station for the Hajj pilgrim caravans from both North Africa and the Levant.

Until recently, the importance of the area was considered to be due to its location between the Levant, the Hijaz in Arabia, and Egypt. The discovery of gold production in Wadi Tawahin now contributes an additional aspect to the importance of the area.

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