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Original article

MINING AND THE ARCHAEOLOGY OF ENERGY IN GRECO-ROMAN EGYPT

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Abstract:
This research discusses mining and its relation with the science of energy archaeology; as well as the role of the tools used in the metal industry; during the Greco-Roman era in Ancient Egypt. It reviews the millstones and mills used in this era; as well as the role of humans and animals in energy production and the importance of wood and coal in biological energy production, in order to demonstrate the importance of the archaeology of energy in interpreting many businesses and industries of this era.

1. Introduction

The interest of the ancient Egyptian in mining and obtaining various minerals; for their several uses in his daily life; is evident on the walls of ancient Egyptian tombs, on which he engraved his mining processes, as well as the expeditions to extract minerals. These depictions appear in the form of inscriptions which were discovered on the roofs of mountain caves and the areas surrounding archaeological mining sites [1]. Among the most famous ancient mining locations are the caves at Serabit El-Khadim region, to which King Senefru sent his mining expeditions. [2]. Gold mining processes began; in a narrow sense; during the pre-dynastic times of ancient Egypt, by simply digging the ground to obtain quartz pieces; which were then crushed and fragmented using huge stone hammers to obtain the gold within, fig. (1-a) [3]. Thus; ancient Egyptians are considered the first nation to acquaint the archeology of energy, which they applied in the operations of their metal industry, using special tools such as manual mills, fig. (1-b & c) and manual gold laundries. Fig. (1-d) shows manual gold laundries which consisted of a washing table covered with sheep skin; in which the quartz powder was placed in a deep hole; then water was lifted by a "Shadof" onto the slopped washing table to flow downwards until it fell into a shallower hole which allowed the water to return back to the deeper hole, this process was repeated one step after another until gold flakes were revealed [4].

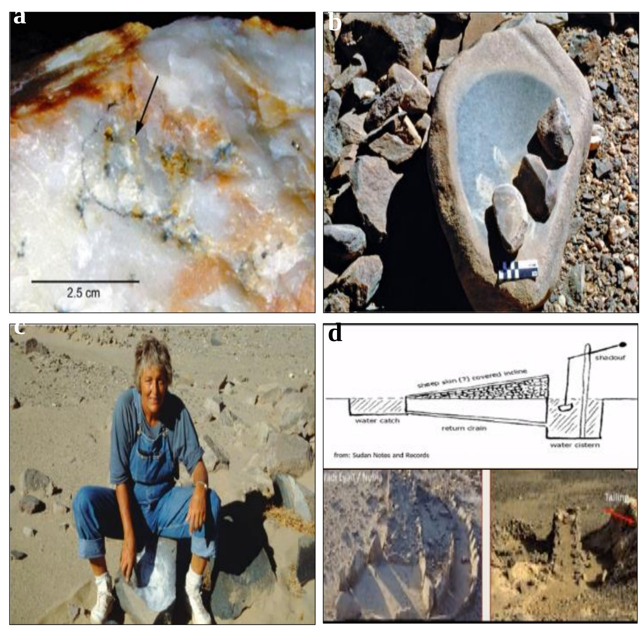

Figure (1) **a.** a gold fragment (marked by the arrow) within a quartz nugget, **b.** a flat mill used to crush quartz, **c.** a grinding mill with an integrated seat; dates back to the new kingdom; by which white quartz powder was produced using a small runner stone; southeast of El-Hisinat (Rose-Marie Klemm who discovered the site, **d.** manual gold laundries (*After: Klemm & Klemm, 2013*)

2. Archaeology of Energy During the Greco-Roman Period

2.1. *Mining and archaeology of energy*

Hydraulic power was used in the Greco-Roman times to compress gold and tin ore, to move huge masses of barren land and to cut through mountains; it was also used to crush ore, which is one of the hardest mining processes, therefore; the mechanization method was a significant advance for productivity in these times. In some ancient mines of the Iberian Peninsula and Brittany, large stone blocks bear the marks of repeated pestle striking in the same place; these are anvils struck by pestles lifted by a camshaft [5].

2.2. *Archaeology of hydraulic*

2.2.1. Millstones "Ptolemaic period"

The process of crushing quartz blocks; after extracting them from the mine; was an indispensable step before the washing and melting processes required to extract gold from the quartz ore could be performed. It is evident that the hydraulic power was used to crush ore; as hand millstones were found at Samut North in the Eastern Desert they date back to the "Ptolemaic period" and were used to crush blocks of quartz [6]. Men over thirty years of age were responsible for this process; "Those over thirty years of age take this stone and with iron pestles pound a specified amount of it until it reaches a small size, fig. (2-a & b)." [7]. There are two mills that were discovered at Samut North, fig. (2-c) and they are almost unparalleled. The two rotundas are about 10 m in diameter; their floor is entirely paved with large stone slabs, although the eastern structure suffered depredations that occurred either in medieval times (an Umayyad jug was found last year in its filling), or early in the 20th century. They are both surrounded by a peripheral wall of 50 to 80 cm in height, made of large blocks and small stones bound with clay; its inner face is slightly sloping into the interior of the structure. Inside, the floor consists of large slabs near the wall, and smaller slabs in the central space. The stones are filled-in with clay, forming an extremely smooth horizontal surface. In the center of the west rotunda (the eastern counterpart is destroyed), there is a cavity delimited by large stone slabs, probably a posthole, fig. (2-d) [8]. A few centimeters of the peripheral wall, a clear trace of wear is visible on the pavement of the two rotundas (more perceptible in the western one), 10-15 cm wide and perfectly circular in shape, fig. (2-e); certainly, caused by the frequent passage of a wheel; it explains the special layout of the floor slabs: the biggest and most resistant slabs were placed where the mill ran, to support its weight. The grinding mills of Samut North were most probably used to reduce the ground ore into powder, after the first stage of crushing the quartz blocks just extracted from the mine. This was a necessary step before the washing and melting processes to extract gold from the quartz ore. During the excavations, quartz powder was indeed discovered between the slabs of the western structure, along with two modern nails [8]. At present; it is difficult to propose a reconstruction of the operation of the two mills discovered in Samut North, since they are almost unparalleled. The field observations led to restore a wooden arm, stuck in a central axis and fitted with a stone wheel (or two a central axis and fitted with a stone wheel (or two diametrically opposite wheels) at its extremity. It was probably moved by men or animals, almost certainly walking inside the two rotundas, between the central post and the grinding wheel. Other examples which share some similarities with the Samut North mills; do exist; in particular in the nearby Eastern desert site of Compasi, Barramiya[(a)], figs. (2-f & g) [9]. Immediately below a masoned well from the Ptolemaic period are the clearly re-constructible ruins of a water-driven, heavy mineral processing plant measuring about 8 m in diameter; such devices are well-known from Laurion/Attica, fig. (2-h) [10].

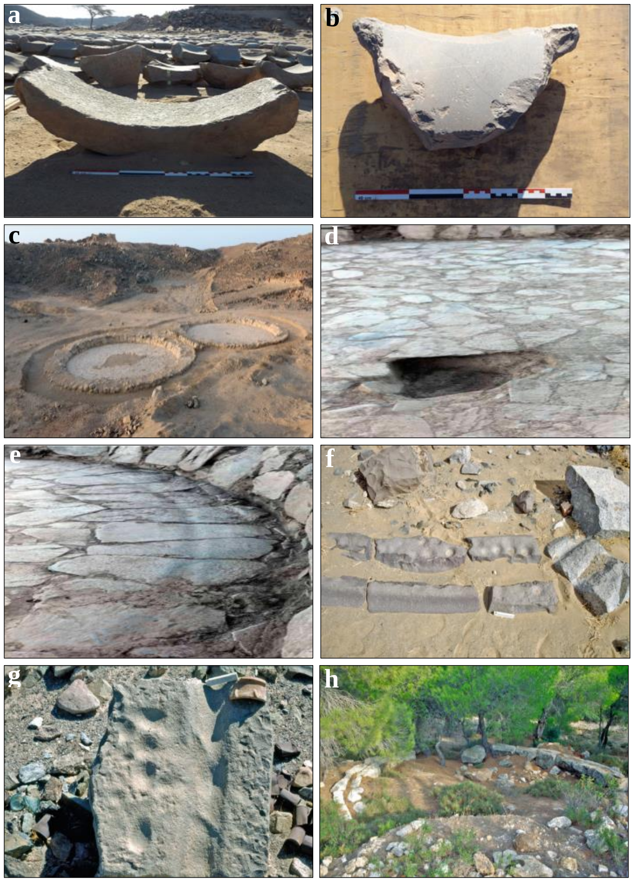

Figure (2) **a.** & **b.** millstones and millstones "with ears" (*After: Faucher, 2018*), **c.** a general view of the Samut North mills, from north-east (*After: Redon & Faucher, 2016*), **d.** the cavity in the center of the western rotunda (*After: Redon & Faucher, 2016*), **e.** trace of the wear on the pavement of the western rotunda (*After: Redon & Faucher, 2016*), **f.** parts of a circular installation for gravity separation of heavy minerals at Daghbag IV, Ptolemaic period (*After: Klemm, 1997*), **g.** a segment of a circular installation for gravity separation of heavy minerals in the debris from Ptolemaic Period gold processing at Barramiya (*After: Klemm & Klemm, 2013*), **h.** a circular installation for gravity separation of heavy minerals in Laurion/Attica, ~400 BC (*After: Klemm & Klemm, 2013*).

2.2.2. Millstones "Roman period"

The ultimate improvement in the effectiveness of the processing of Roman gold is the round mill, measuring 30-45 cm in diameter, from a basal stone with a disc-shaped cavity, where a convex circular overhead stone with a central axial hole and another side of the handle stick, fig. (3). This round mill was made for a more precise power to produce gold in about a third of the time required by the previous method [12]. The archaeology of mills and milling during the Roman period facilitated the mining processes, tab. (1) as well as making bread [13].

Figure (3) Shows a Roman round mill (*After: Trastsaert, 2012*)

Table (1) The stages of the hydraulic millstones development

Energy	Time	Shape
Human	***Early Dynastic Period*** Higalig mine, Egypt; heavy duty two-hand hammers which were used to crush quartz ores during extraction.	
	Old Kingdom Abu Mureiwat, Egypt; fist hammers (on the right) with originally pointed impact-surfaces for chipping off ore fragments.	
	Middle Kingdom Daghbag, Egypt; mortar made of red granite and pounder, which were used to crush quartz ores	
	New Kingdom Marahig, Wadi Allaqi, Egypt; flat grinding mill and fist grinder for quartz powder production.	
Human & Animals	***Ptolemaic Period*** General view of the Samut North mills, taken from north-east side.	
Human	***Roman Period*** Roman round mill	

2.3. *Mining and biological energy*

The first biological energy was wood, which was essential for heating, cooking and producing glassware and bricks; then there was charcoal, which was widely used in mining. It was found that mangrove wood was used as fuel at coastal sites where mangrove tree formations were present, also; the ben oil (Moringa) tree exists at the quarry sites in Mons Claudianus, Porphyrites, Badia and Kainè Latomia; all located in high-altitude areas where this tree grows naturally, fig. (4-a). Moreover; the acacia (ACAC) charcoal found at all the archeological sites, fig. (4-b & c) confirms the major economic role of these trees as lumber and fuel [14], as all these woods were used as fuel for the manufacture and maintenance of the extraction iron tools used at the quarry sites [14].

Figure (4) **a.** mangrove (Avicennia marina) on the Red Sea coast, south of Qusayr al-Qadim (*After: Veen, 2011*) [15], **b.** the gallery forest composed of acacias (Acacia tortilis subsp. raddiana) along Wadi Abu Ouasil, **c.** acacia ehrenbergiana near the site of Xèron Pelagos (*After: Bouchaud, 2018*).

2.4. *Importing fuel from the Nile Valley*

In addition to the extensive exploitation of the desert fuel resources, there are at least two indications that fuel was imported from the Nile Valley. The first is the identification of the Nile acacia, Acacia nilotica (ACNI, sunt) at Myos Hormos, Mons Claudianus and Porphyrites; as this tree has characteristic anatomical stigmas that differentiate it from the other acacias mentioned above. Nile acacia does not grow in the desert and its recurrent presence; in the form of charcoal in archaeological contexts related to different metallurgical activities; probably shows the import of fuel from the Nile Valley [15], The second indication is that there are several ostraca found at Mons Claudianus mention the use and circulation of charcoal imported from the Nile Valley to the sites of the imperial quarries of Mons Claudianus and Porphyrites (including Badia), (*O. Claud.* I 21), fig. (5-a & b).

1 Ἱερώνυμος ἀρχιτέκ(των)[---]
2 Κρονίωνοςgen,) τῷ[......] [πλεῖ]στα
3 χαίρειν. [.........] [εἰς]Κλαυ-
4 διανὸν ἄνθρακοςγόμο\ν/
5 α [16,17]
1 Hieronymuschief-artificer..
2 of Kronion, many greetings to…
3,4 ....the charcoal-maker .... the ship's freight to Claudianus
5 one [18]

Chaff and straw were also indirectly used as fuel, through dung which was an important source of fuel in arid regions and was; in many cases; the route through which chaff and straw entered the deposits, fig. (5-c) [16].

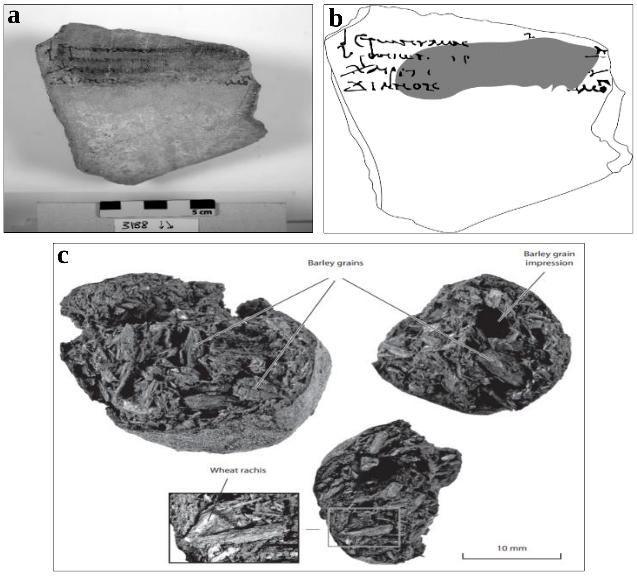

Figure (5) **a.** Qift archaeological storeroom Claud. 3188; Egypt, Mons Claudianus, int. excavations 1987-1990, now in Qift, storeroom EAS Claudianus no. 3188 (*After: Bingen, 1992*), **b.** drawing of Ostraka O.Claud. I 21, **c.** camel droppings; complete barley grains and wheat rachis, which helped in fuel production (*After: Veen & Tabinor, 2007*).

3. Results

The ancient Egyptian was interested in mining and obtainning minerals to be used for various tasks in his daily life; this is evident by the engravings on the walls of ancient Egyptian tombs which demonstrate his mining and mineral extraction processes. The ancient Egyptian is considered the first to recognize the archeology of energy that he applied in the metal industry, by using tools such as manual mills and manual gold laundries. Hydraulic power was used to crush ore; as hand millstones were found at Samut North in Eastern desert “Ptolemaic period" which were used to crush quartz blocks, as well as two rotundas found at Samut North. Biological energy played an important role in mining during the Greco-Roman period. Animal energy was largely utilized in the operation of large mills. Nile acacia does not grow in the desert; and its frequent presence in the form of charcoal in archaeological contexts related to different metallurgical activities, probably confirms the import of fuel from the Nile Valley. It was spread more than the Acacia Local (ACAC), fig. (6) shows the spread of wood in Mons Claudianus and Mons porphyrites.

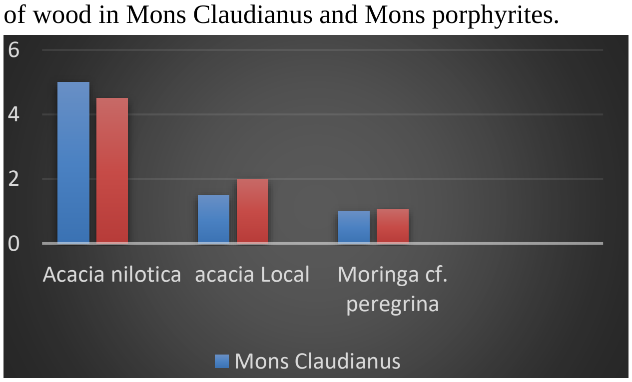

Figure (6) the spread of wood in Mons Claudianus and Mons porphyrites

4. Discussion

Although the two mills were initially interpreted as gold washes when they were first discovered; but after carful studying, it was found that they were mills to crush quartz, also; it is definitely possible that the two mills were powered by people or animals. The available data do not provide a precise description of the qualitative and quantitative evolution of wood resources in the harvesting regions in concern. To take only the case of local resources, the existing corpora are too limited in time and suffer from substantial methodlogical biases (limited number of remains, too targeted sampling) to account for the dynamics of biodiversity within the eastern desert. However, the available corpus is still too small to accurately understand certain aspects; such as the possible presence of local coal mining or the role played by human activities in biodiversity dynamics. The archaeobotanical analyses in progress and their comparison with the data drawn from the papyrological corpora are certainly two avenues of research to be explored in the years to come to complete this first synthesis. The most important question still remains; what were the sources of water in the eastern desert of Egypt? This is an important aspect in linking mining with the archeology of energy.

5. Conclusion

Mining in the Greco-Roman period was associated with the archeology of energy, through energy hydraulic which began with employing the energy of humans. The energy of animals substituted for the human energy whenever it was possible at an acceptable cost. Plants fuel (i.e., wood, charcoal,) were the main source of energy used in mining during the Greco-Roman period.

Endnots

(a) The deposit area of Barramiya is one of the most important ones in the Egyptian Eastern Desert. Apart from some lengthy interruptions it stayed under exploitation from Egypt’s earliest history until the 1950_s. Mining under the British occupation in the early twentieth century has severely damaged and even completely wiped out ancient archaeological traces in the entire district, particularly in the valley plain leading from Wadi Barramiya to the mines.

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