Gold mining in the Eastern Desert of Egypt (Roman period)

The organisation of the gold-mining industry in the Eastern Desert of Egypt at the time of the Roman occupation is a rather neglected field of research. My aim hereinafter is to theoretically recreate how this was set up through the survey and study of known classical goldmining settlements, and suggest a standard layout of settlements for the gold mines in the Eastern Desert. In support of this reconstruction a study was made of 52 sites, some of which were visited.

The main two sites used here are Wadi Bakariya (Ptolemaic/Roman) and Wadi Daghbag (Compasi, Ptolemaic/Roman); located in the central portion of the Egyptian Eastern Desert. They are very well preserved and are used as basis for the understanding of Roman industrial mining.

1. Mining the ore

Mining a deposit happens in four stages, prospecting, exploration, development and finally exploitation.

1.1. Prospecting

The method of prospecting is to walk the identified area and study at the geology. The most common method is looking for outcrops and decolouration of the host rock, or indigenous rock. Auriferous quartz veins that intrude the host rock affect the colour around its edges and are the primary clues the classical miners were looking for. Or they traced the auriferous sedimentary debris to the source, often an outcrop upstream of a dried-out or active riverbed. This process starts of by "panning" the sediments for nuggets and when this is exhausted the river is followed upstream.

Ancient sites with actual remains of prospection still visible are not widely known as they are not easily identifiable by non-geologists. Some traces have been identified on the wadi slopes at the mine of Wadi Daghbag (Compasi, Ptolemaic/Roman).[1] Here they removed loose-lying debris to examine the rock underneath. This left large vertical "scratch marks" on the hill slopes, with small heaps of rubble at the bottom of the shallow trench (fig. 1).[2]

Figure 1. Wadi Daghbag, prospection "trenches".

[1] Personal comment by geologist Karen Van Opstal.

[2] All photographs, if not specifically marked, are taken by Barbara Tratsaert.

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1.2. Exploration

There is not much information for the period in this entry as there are few physical remains left because of later mining of the same deposits. Pliny the Elder provides a technical description of finding gold; he stated that there are three methods in use during his time. These methods are "*collecting the detritus of rivers*" ["*fluminum ramentis*"], "*sinking shafts*" ["*puteorum scrobibus effoditur*"] or seeking it "*in the fallen debris of mountains*" ["*in ruina montium quaeritur*"] (this refers to open-cast trenches), and sub-surface "galleries" ["*cuniculis*"].[3] Diodorus gives a short description of how auriferous veins were observed by ancient prospectors in Egypt: "*τῆς γὰρ γῆς μελαίνης οὔσης τῇ φύσει καὶ διαφυὰς καὶ φλέβας ἐχούσης μαρμάρου τῇ λευκότητι διαφερούσας καὶ πάσας τὰς περιλαμπομένας φύσεις ὑπερβαλλούσας τῇ λαμπρότητι, οἱ προσεδρεύοντες τοῖς μεταλλικοῖς ἔργοις τῷ πλήθει τῶν ἐργαζομένων κατασκευάζουσι τὸν χρυσόν*".[4] Photius (drawing from the same source as Diodorus, i.e. Agatharchides) provides a similar illustration: "*κατὰ γοῦν τὴν εἰρημένην θάλατταν πλησίον ἐστί τινα τῶν καλουμένων χρυσίων πλῆθος ἔχοντα μετάλλων, τῇ χρόᾳ μὲν ὄντα καθ' ὑπερβολὴν μέλανα, μαρμάρου δὲ ποιοῦντα τοιαύτας ἐν αὐτοῖς ἐκφύσεις, ὥστε πᾶν λείπεσθαι τὸ διαμιλλώμενον, τῆς λευκότητος κρίσιν οὐκ ἐχούσης*".[5]

1.3. Development

Many ancient mines have been damaged, either by their immediate successors or much later during modern times. Technology has improved to such a standard that rock previously thought barren is now again considered economic. A perfect example is the gold mining settlement at Sokari. This was mined in the Roman period and then several times during the 20th century, when barren heaps were reworked and enough gold extracted to make the mine viable again.[6] In the Eastern Desert of Egypt the

[3] Pliny, *Naturalis historia*, 33.21 = H. Rackham (transl.), *Pliny. Natural History*, vol. 9, Harvard University Press, Cambridge MA, 1951, pp. 51-55.

[4] Diodorus, *Bibliotheca historica*, 3.12 = C. H. Oldfather, *Diodorus of Sicily*, vol. 2 (Books II.35-IV.58), Harvard University Press, Cambridge MA, 1953, p. 115 ("*For the earth is naturally black and contains seams and veins of a marble which is unusually white and in brilliancy surpasses everything else which shines brightly by its nature, and here the overseers of the labour in the mines recover the gold with the aid of a multitude of workers*").

[5] Photius, *Myriobiblon sive Bibliotheca*, cod. 250, (cap. X), in J. P. Migne, *Patrologia Graeca* [PG], vol. 104, 29B = Stanley M. Burstein, *Agatharchides of Cnidus. On the Erythrean Sea*, Ashgate, London, 1989, p. 59 (23a) ("*At this point, near the aforementioned sea, there are found some of the socalled 'noble rocks', which contain abundant mineral deposits. In colour they are jet black but they contain such great outcrops of quartz that everything else pales by contrast, there being no comparison to them for brilliance*").

[6] R. Klemm and D. Klemm, *Gold and Gold mining in Ancient Egypt and Nubia. Archaeology of the Ancient Gold Mining Sites in the Egyptian and Su-*

majority of the mines are on primary deposits, which are surfacing veins leading at times to underground galleries. The method used is both open-cast trenches/pits and wadi workings (or alluvial working). These are easily visible with the naked eye as the workings have disturbed the immediate environment and the surface now looks scarred. The mines were set up where the deposits occurred but the adjacent settlements were clearly organised (fig. 2).

Figure 2. Abu Daiba, where contours of open-cast trenches are still visible on the wadi bed (left) and on the hill slopes (right).

1.4. Exploitation

The ancient miners were only able to mine one mineral/metal at a time and therefore would look into the most profitable and easy mining method. In the Eastern Desert of Egypt they also did not have hydraulic installations or rivers to break deposits as they did in the Iberian Peninsula and Dolaucothi (South Wales). In Egypt only hammers and pounders combined with manual labour were used to break the auriferous quartz in the veins. Pliny the Elder mentions the use of fire setting in underground mining, but the only mine where there might be some evidence of this is at the entrance to the underground mine in Sokari (Roman), where the roof was blackened.[7] Diodorus gives the following description: "*τῆς δὲ τὸν χρυσὸν ἐχούσης γῆς τὴν μὲν σκληροτάτην πυρὶ πολλῷ καύσαντες καὶ ποιήσαντες χαύνην προσάγουσι τὴν διὰ τῶν χειρῶν κατεργασίαν*" (fig. 3).[8] Photius copied the same passage as Diodorus: "*τῶν ὀρῶν, φησίν, ἐν οἷς ὁ χρυσὸς εὑρίσκεται, τὰ μὲν ἀπότομα καὶ τελέως σκληρὰν ἔχοντα φύσιν ἐκπρήσαντες ὕλῃ καὶ χαῦνα τῷ πυρὶ ποιήσαντες, οὕτως αὐτοῖς προσάγουσι τὴν πεῖραν, τὰ δ' ἀνειμένα τῆς πέτρας σιδήρῳ λατομικῷ κερματίζονται*".[9]

danese Eastern Deserts, Springer, Heidelberg, 2013, pp. 212-220.

[7] Pliny Nat. Hist., 33.21 ("*occursant in utroque genere silices; hos igne et aceto rumpunt, saepius vero, quoniam id cuniculos vapore et fumo strangulat*") = Rackham, *supra* note 3, p. 55 ("*in both kinds of mining masses of flint are encountered, which are burst asunder by means of fire and vinegar, though more often, as this method makes the tunnels suffocating through heat and smoke*").

[8] Diodorus, *Bibl. Hist.*, 3.12 = Oldfather, *supra* note 4, p. 117 ("*The goldbearing earth which is hardest they first burn with a hot fire, and when they have crumbled it in this way they continue the working of it by hand*").

[9] Photius, *Myriob.*, 29C = Burstein, *supra* note 5, p. 61 (25a) ("*They pursue their task in the mountains where the gold is found. They light wood fires on the stone outcrops, which are jagged and extremely hard, and crumble them with the heat. They break the fractured rock into little pieces with iron sledges*").

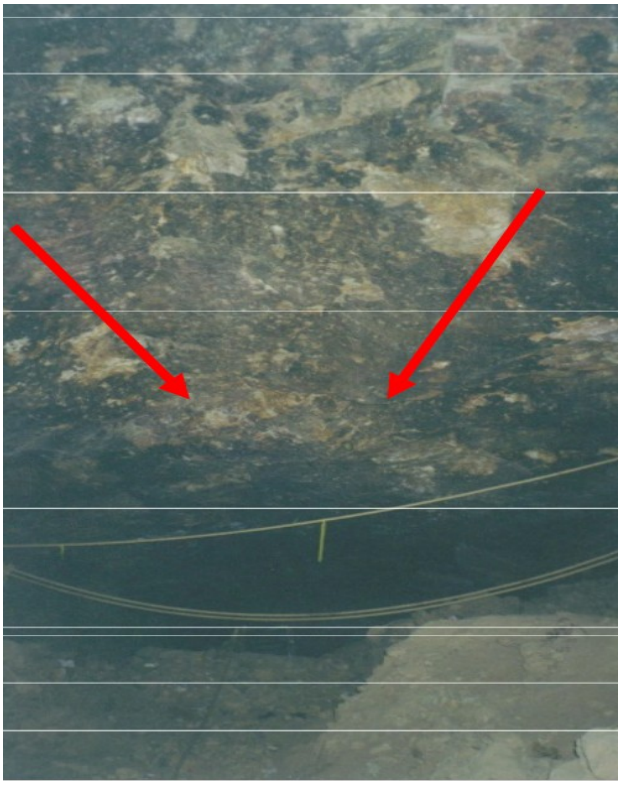


Figure 3. Sokari (Roman), the entrance to the underground gallery where it is alleged that fire setting was used by the Romans to break the rock (see arrows). This entrance is scorched and it is unclear if this should be dated to the Roman mine or to a fire that occurred during the reopening of the mine in the 19th century.

2. Mining methods

Three mining types have been identified in the Eastern Desert of Egypt: alluvial (panning/wadi workings), surface mining (open-cast trenches/pits) and subsurface mining (underground galleries).

2.1. Wadi workings

This method was used to mine the sediments of secondary deposits, also known as alluvial mining or "panning". The latter refers to washing the sediments of active rivers. A placer deposit is a mechanical concentration of heavy minerals, possibly an ore deposit.[10] In the dry riverbeds of the Eastern Desert the wind was used instead of washing the sediment in water. All it required was a sieve through which the sand would fall and be carried away by the wind. The gold particles that are larger remain in the sieve.[11] The wadi beds are pockmarked with shallow, round pits surrounded by low heaps of sand often found along the edges of the wadi and in foothills, and may also be visible on satellite images (fig. 4). This way of mining did not require stone tools such as hammers or pounders.

Figure 4. Wadi Su'igat el-Beda, localised wadi workings.

This type of mining often preceded more intrusive mining, such as open-cast trenches and probably also underground

[10] H. L. Hartman, *Introductory mining engineering*, Wiley, New York, 1987, p. 232.

[11] A geologist working at the Sokari mine described to me how the wind and basins were used during the early stages of prospection in which they sifted the soft sediment.

mining. When it appears that the river sediments were becoming exhausted they followed the river upstream. This was because the nuggets the miners were collecting are the eroded remains of a gold bearing veins that outcropped somewhere further upstream. Sokari (Roman) is an excellent example where the tailing heaps lie alongside open-cast trenches; these tailing heaps lay at the foot of a large mountain, near the entrance to the only known underground mine of the region (fig. 5).

Figure 5. Sokari, the entry to the underground mine halfway up the mountain (arrow) with wadi workings on the foreground.

2.2. Open-cast

This method is used to mine outcropping primary deposits which are auriferous quartz veins that had intruded the host rock. These trenches are usually long and narrow and their locations random, however, they often occur on the slopes and ridges of wadi hills. They are flanked by low heaps of discarded, barren quartz fragments, which function as landmarks and are often visible on satellite images (fig. 6).

Figure 6. Wadi Daghbag, open-cast trench and lighter-coloured debris on either side (arrow).

Where the vein was long, it was mined in parts with a "section wall" left standing between each partition. The thickness of the auriferous veins was not always consistent and in some cases the miners had to dig a lot deeper to reach the bottom, creating actual pits or shallow caves (fig. 7).

Figure 7. Wadi Daghbag, a "pocket" in the veins creating a shallow cave.

On a few occasions stone tools were found nearby these trenches which are usually hammers and large pounders to break up the quartz fragments (fig. 8). The mined material is then brought to what has been identified as workshops or "selection areas" (see section 6 *infra*).

Figure 8. Wadi Bakariya, hand-held hammers (up) and pounders (down) found near open-cast trenches at the mine.

2.3. Underground mining

This method is used to mine primary deposits, the auriferous quartz vein itself. Once the decision has been made to go underground, three methods can be employed: supported, unsupported, or caving.[12] There is little information on underground mining in the Eastern Desert of Egypt. We know from Agatharchides that there were underground mines as he describes the workings of one unfortunately that location remains nameless. The only clue is that it was Ptolemaic, as the account was written in the mid-2nd century B.C. This account from Agatharchides was copied by Diodorus and Photius. Another source of information is Pliny the Elder's *Naturalis Historia*, where he describes in detail how primary and secondary deposits should be mined and discusses methods.[13] The only known subsurface mine in Egypt is Sokari (Roman).[14]

The mine at Sokari (Roman) can be used as an example for the randomness in which these auriferous ores occur. The outcropping vein was located high up the mountain slope. But the level of the underground gallery where the ore occurred was a lot lower, almost at wadi level; which was quite a high height difference. The under-

[12] Hartman, *supra* note 10, p. 336

[13] Diodorus, *Bibl. Hist.*, 3.12 = Oldfather, *supra* note 4, p. 117; Photius, *Myriob.*, 29C = Burstein, *supra* note 5, p. 61; Pliny, *Nat. Hist.*, 33.21 = Rackham, *supra* note 3, pp. 51-57.

[14] B. Tratsaert, "*Understanding mining for gold in the Eastern Desert of Egypt during the Roman occupation*", *Ancient Egypt* 109 (1), August-September 2018, pp. 30-38 at 33; Klemm and Klemm, *supra* note 6, pp. 212-220.

ground gallery was sloped, the ceiling quite low (fig. 9).[15]

Figure 9. Sokari, subsurface gallery.

They left pillars to support and prevent the roof from collapsing, which are leftovers of the vein. If these were mined, then the gallery and potentially the entire mountain would collapse, as Pliny the Elder describes in *Naturalis Historia*.[16] Pillars are the ultimate form of ground control because they are part of the vein and provide near-rigid support. Underground mining is far more complex than surface mining, and a lot more comes into play to provide easy access and make the mine safe for miners. The access/exit is the same and needs to be made wide enough for traffic going in and out. In certain regions groundwater can cause difficulties and machinery had to be developed. In the past, as soon as they reached groundwater levels, the mine was abandoned. In the Ptolemaic and Roman periods machines were developed for the removal of water; the best known are the Archimedean screw and wooden wheels (fig. 10).

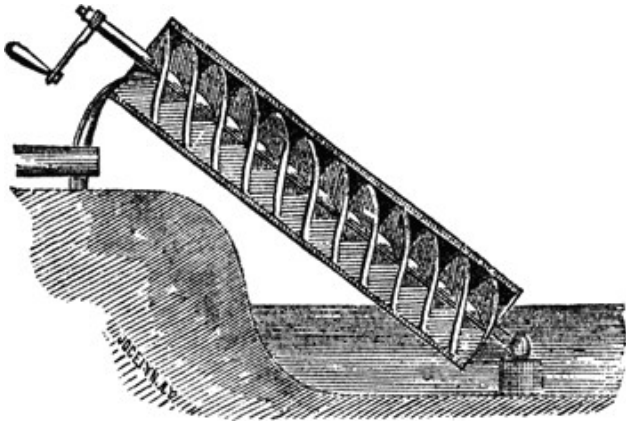


Figure 10. Archimedean Screw (Chambers's Encyclopædia, vol. 1, 1874, p. 374).

2.3.1. Mine ventilation

The most vital auxiliary operation in underground mining is ventilation, to maintain the quality of the atmospheric environment, and is vital to both the miner's life-support system and their health and safety.[17] However, there is little information available on this aspect of mining in the Eastern Desert of Egypt. Our main source of information for the western Roman provinces is Pliny the Elder's *Naturalis Historia*.[18] Domergue (2008) also explains how the

[15] When I visited this mine, I was unable to stand up fully.

[16] Pliny, *Nat. Hist.*, 33.21: "*peracto opere cervices fornicum ab ultimo caedunt*" = Rackham, *supra* note 3, p. 57 ("*when the work is completely finished, beginning with the last, they cut through, at the tops, the supports of the arched roofs*"); C. Domergue, *Les mines antiques. La production des métaux aux époques grecque et romaine*, 2008, Picard, Paris, p. 111.

[17] Hartman, *supra* note 10, p. 462-63.

[18] Pliny, *Nat. Hist.*, 33.21 = Rackham, *supra* note 3, pp. 51-61.

miners were supplied with breathable air deep down in underground shafts and galleries. The Romans used existing drafts and air currents in shafts and tunnels, and dug new, narrow shafts to improve air circulation into and out of the mine.[19]

2.3.2. Illumination

Of this there is not much information for the mines in the Eastern Desert. The information comes again from Pliny the Elder: "*cuniculis per magna spatia actis cavantur montes lucernarum ad lumina; eadem mensura vigiliarum est, multisque mensibus non cernitur dies*".[20] Diodorus concurs: "*[οἱ] δὲ πρὸς τὴν ἀτυχίαν ταύτην ἀποδειχθέντ[ες] [...] διὰ τὰς ἐν ταῖς διώρυξι καμπὰς καὶ σκολιότητας ἐν σκότει διατρίβοντες λύχνους ἐπὶ τῶν μετώπων πεπηγμένους περιφέρουσι*".[21]

Each miner had his own oil lamp, and it is suggested that the oil ration was equal to the time of a shift. Many have been found nearby shaft entrances and are depicted in various mining scenes (fig. 11). From written descriptions, depictions and finds *in situ*, it appears that there was no general way of using lamps in the underground mines. In the figure below, a lamp is shown hanging from the ceiling to illuminate the entire or part of the cage. Domergue describes niches in the walls where the miner could temporarily place his lamp when. Oil lamps have been found regularly in mining settlements and are thought to have been the same as those used in daily activities (fig. 12).[22]

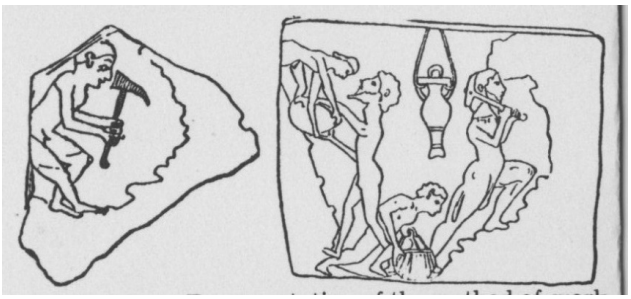


Figure 11. Corinthean Pinakes (A. Neuburger, Die Technik des Altertums, R. Voigtländer, Leipzig, 1919, p. 6, figs. 1-2).

[19] Domergue, *supra* note 16, pp. 117-20.

[20] Pliny, *Nat. Hist.*, 33.21 = Rackham, *supra* note 3, p. 55 ("*By means of galleries driven for long distances the mountains are mined by the light of lamps - the spells of work are also measured by lamps, and the miners do not see daylight for many months*").

[21] Diodorus, *Bibl. Hist.*, 3.12 = Oldfather, *supra* note 4, p. 117 ("*Those who are reassigned to this unfortunate task [...] working in darkness as they do because of the bending and winding of the passages, carry lamps bound on their foreheads*").

[22] Domergue, *supra* note 16, pp. 115-116; Th. Faucher, *Ptolemaic Gold: the Exploitation of Gold in the Eastern Desert*, in J.-P. Brun *et al.*, *The Eastern Desert of Egypt during the Greco-Roman Period: Archaeological Reports*, Paris, Collège de France, 2018, p. 6; F.-J. Sánchez-Palencia *et al.*, *Dossier III: Las Médulas (Léon)*, in Orejas (ed.), *Atlas historique des zones minières d'Europe*, vol. 1, Office des publications officielles des Communautés européennes, Luxembourg, 200, pp. 1-14 at 14; T. A. Rickard, *Man and metals. A history of mining in relation to the development of civilization*, vol. 1, Whittlesey House, London, 1932, pp. 442-445.

Figure 12. Sokari, oil lamp found at the mining settlement (unpublished).

3. Effect on the environment and the local population and industry

3.1. Environment

Mining has a great effect on its immediate surroundings and the internet has made information much more easily available for research. The Las Médulas gold-mining settlement in NW Spain had such a large effect on the landscape that it is still visible today. The mine itself was set on top of large alluvial sediments, and major hydraulic installations were used to break down the deposits. The result was the displacement of the sediments, which blocked the valley and created a lake. The valley is also partially filled in and is now used as agricultural land. Strabo describes the big repercussions that mining activities had on nearby farmers:

"*ἔχει δὲ καὶ χρυσεῖα ἡ τῶν Σαλασσῶν, ἃ κατεῖχον ἰσχύοντες οἱ Σαλασσοὶ πρότερον, καθάπερ καὶ τῶν παρόδων ἦσαν κύριοι. προσελάμβανε δὲ πλεῖστον εἰς τὴν μεταλλείαν αὐτοῖς ὁ Δουρίας ποταμὸς εἰς τὰ χρυσοπλύσια, διόπερ ἐπὶ πολλοὺς τόπους σχίζοντες εἰς τὰς ἐξοχετείας τὸ ὕδωρ τὸ κοινὸν ῥεῖθρον ἐξεκένουν. τοῦτο δ' ἐκείνοις μὲν συνέφερε πρὸς τὴν τοῦ χρυσοῦ θήραν, τοὺς δὲ γεωργοῦντας τὰ ὑπ' αὐτοῖς πεδία τῆς ἀρδείας στερομένους ἐλύπει, τοῦ ποταμοῦ δυναμένου ποτίζειν τὴν χώραν διὰ τὸ ὑπερδέξιον ἔχειν τὸ ῥεῖθρον. ἐκ δὲ ταύτης τῆς αἰτίας πόλεμοι συνεχεῖς ἦσαν πρὸς ἀλλήλους ἀμφοτέροις τοῖς ἔθνεσι*".[23]

In the Eastern Desert of Egypt changes to the landscape are also visible today. There are the obvious mining trenches and tailing heaps, and where there was a sustainable water source, remains of washing the gold dust can still be found. These marks are visible on the satellite photos and can act as landmarks today.

[23] Strabo, *Geography*, 4.6.7 = D. W. Roller (transl.), *The Geography of Strabo*, Cambridge University Press, Cambridge 2014, p. 212: "*The territory of the Salassians has gold mines, which the Salassians formerly possessed when they were powerful, just as they were masters of the passes. The Douria River was their most important partner in mining –in washing the gold– and because the water was diverted in many places to channels, the normal stream would be emptied. Although this was useful to those hunting for gold, those farming in the plains below were upset as they were deprived of irrigation, because the river used to be able to water the region since its stream was on higher ground. For this reason both peoples were constantly making war against each other*".

3.2. Local population

Large-scale mining always influences the local region and population, as it provides work and henceforth increases income. The mining settlements in the Eastern Desert of Egypt were located in isolated sections of that desert. There was not much local population that would have been displaced; though it might have had an effect on trade with the Nile Valley and Red Sea coast for provisions. But no concrete evidence so far has been documented.

4. Metallurgy or processing of mined ore

The main source of information on this process is based on the findings of a survey of Wadi Bakariya and Wadi Daghbag in the Eastern Desert of Egypt.[24]

The process is that the gold bearing ore is extracted in the trenches. The auriferous pieces are taking to another location for further processing and the barren pieces are left discarded alongside that trench. All over Wadi Bakariya small circular workshops have been found near the mining trenches. However there is a secondary location that is larger and remains found indicate that the final processing of the quartz fragments occurred here under supervision. The smaller workshops on location probably were for a first sorting through of the mined material. The larger workshop appears to be located strategically in the middle of the mine (fig. 13).

Figure 13. Wadi Bakariya, selection area near a group of open-cast trenches.

In these secondary locations the working areas are also circular and cleared of rubble and marked with a low wall of barren quartz. Nearby large heaps of quartz have been found in conjunction with tools. Upon a closer look at these heaps the stones appear to have various sizes, which lead to the theory that the mined fragments were grouped per size prior to further processing. The tools found in conjunction are large pounders (fig. 14). These were used to break up the mined fragments into smaller pieces so they would be small enough to be "*fed to the querns*".

[24] B. Tratsaert, *Roman Gold Mining in the Eastern Desert: The Mining Settlement in Wadi Bakariya*, in H. Barnard and K. Duistermaat, *The History of the Peoples of the Eastern Desert*, Cotsen Institute of Archaeology Press, Los Angeles, 2013, pp. 214-225; Tratsaert, *supra* note 14, pp. 31-38.

Figure 14. Wadi Bakariya, example of a pounder found near the selection areas.

The quartz was broken up on anvils; these were either made for this purpose or were reused tools that were no longer fit for purpose, such as the lower section of the millstones or querns. Large boulders found nearby were used as well. These "anvils" are pockmarked with shallow depressions caused by the hammering of the quartz into smaller pieces. The pounders were also the same tools used in the trenches for the extraction of the gold bearing ore.

The next phase in the refinery process was grinding the fragments in millstones or querns to dust, so that impurities could be separated during washing in the next phase. Two types of querns have been identified at the mining settlements in this study: the saddle type, dated to the Ptolemaic period, and the rotary quern dated to the Roman period. These tools were made of local stone and left behind when the mine was abandoned. They are large tools, made of two parts: an immobile lower part and a mobile upper part. The sole purpose was to grind the quartz fragments to dust; Diodorus gives a description of their use: "*παρὰ δὲ τούτων τὸν ὀροβίτην λίθον αἱ γυναῖκες καὶ οἱ πρεσβύτεροι τῶν ἀνδρῶν ἐκδέχονται, καὶ μύλων ἑξῆς πλειόνων ὄντων ἐπὶ τούτους ἐπιβάλλουσι, καὶ παραστάντες ἀνὰ τρεῖς ἢ δύο πρὸς τὴν κώπην ἀλήθουσιν, ἕως ἂν εἰς σεμιδάλεως τρόπον τὸ δοθὲν μέτρον κατεργάσωνται*".[25] The saddle or Ptolemaic quern had a square-like upper part with two handles; this was to rub this part back and forth over the lower section that had a similar shape (fig. 15).

Figure 15. Wadi Bakariya, top and bottom half of saddle quern, thought to be Ptolemaic.

The rotary or Roman quern rotated its upper part onto the lower section, thus creating a basin-like feature (fig. 16). An interesting fact with these querns is that the saddle querns have been reused as building material in various buildings in Wadi

[25] Diodorus, *Bibl. Hist.*, 3.13 = Oldfather, *supra* note 4, p. 119 ("*Thereupon the women and older men receive from them the rock of this size and cast it into mills of which a number stand there in a row, and taking their places in groups of two or three at the spoke or handle of each mill they grind it until they have worked down the amount given them to the consistency of the finest flour*").

Bakariya and Wadi Daghbag; whilst the rotary quern are found *in situ* amongst buildings at wadi level. The average measurements for the saddle quern are 40-45x30 cm (lower part) and 50 cm^2 (upper part, handles included), for the rotary mill stone is 45x48 cm. When comparing both types on an industrial level, it is clear that the rotary quern could yield more than the saddle type and would therefore be preferable at industrial sites.

Figure 16. Wadi Bakariya, rotary quern, dated Roman.

Forbes states that the rotary quern did not develop from the saddle quern, but he rather links this tool with the spread of the armies in Greece and Rome.[26] The Klemms suggest that the saddle quern was introduced via the Minoans of Crete and that the Ptolemaic version was based on those and the ones used in Greek mines. They stated however, that the "*final improvement in effectiveness of gold processing was the import of the Roman quern (rotary) technology*".[27] Most of the querns are found on the surface and are not easy to date without further excavation and associated stratigraphy.

The dust from the querns was then collected and washed. The washing of this gold dust requires a lot of water and the arid climate of the Eastern Desert of Egypt meant that not every mine had a washing station. There are sites where there was an aquifer that could be tapped in or where there was a continuous water supply. Wadi Bakariya had a large well but was not enough to wash the gold on site. Wadi Daghbag has a well that to this day contains water, and had at least two large circular washbasins, which will be described further below. Of the 52 mining settlements studied in this research, 12 sites had washing tables. For the Ptolemaic period there is Hangalia and Atolla; the Roman sites are Umm Russ, Sokari and Umm Balad; with the majority dated to both periods: Gidami, Bir Sirbakis, Bir Umm Fawakhir, Wadi Baramiya, Wadi Daghbag, Samut mines and Wadi el-Hudi. Another 6 sites were active as washing centres, for their own ore and others and are dated to the Ptolemaic period: Abu Zawal, Semna, Bir Samut and al-Ghuzza/Ghozza; for the Roman period there is only Umm Russ; and Wadi el-Sid belongs to both peri-

[26] R. J. Forbes, *Studies in Ancient Technology*, vol. 3, Brill, Leiden, 1965, p. 148-150.

[27] D. Klemm, R. Klemm and A. Murr, "*Gold of the Pharaohs – 6000 years of gold mining in Egypt and Nubia*", *Journal of African Earth Sciences* 33 (3-4), 2001, pp. 643-659 at 656-657.

ods. These centres appear to have tapped into aquifers that provided water throughout the year, as wells are usually seasonal. Finding an explanation for this difference between periods is not easy as most data comes from surveys, which often involve short-term visits and personal observations.[28] Another difficulty researchers face are publications from earlier periods, most of which are more about the authors' observations, such as Tregenza, Ball and many others, these describe their trips and not always the finds and ruins in details.[29] Strabo and Diodorus Siculus are the only classical writers who mention the washing of precious metals in the western Roman province. Unfortunately, these are comments and not detailed descriptions.[30]

4.1. Washing tables

There are three types of washing tables: the inclined washing table, the large circular ones, as seen at Wadi Daghab (Ptolemaic/Roman), Gidami/Bir Sirbakis (Ptolemaic/Roman), Wadi Baramiya (Ptolemaic/Roman) and Samut (Ptolemiac/Roman) and a third industrial-sized installation so far only found at western Roman gold mines. The likely reason why an installation of latter size was never used in Egypt is its drier climate and lack of continuous water. However, the circular installation has been found at several sites in this desert, all at wadi level, and the mining settlements that housed these lay near or on top of an aquifer. Some of these wells still provide water to the Bedouins today.

4.1.1. The inclined washing table

This type of washing installation is the smallest of the three and has so far been found at both Ptolemaic and Roman gold-mining sites in the Eastern Desert of Egypt. This installation has been described by Agatharchides who had seen one at an underground mine in this desert in the 2nd century B.C. Klemm and Klemm describe them as being in use from New Kingdom till at least the Arabic period.[31]

[28] Due to the lack of surface pottery and other diagnostics, it is not always possible to determine to which period the washing tables belong.

[29] J. Ball, *Egypt in the Classical Geographers*, Government Press, Cairo, 1942; G. W. Murray, *Dare me to the desert*, Allen & Unwin, London, 1967; L. A. Tregenza, *The Red Sea mountains of Egypt*, and *Egyptian years*, American University in Cairo Press, Cairo, 2004 [1955 and 1958].

[30] Strabo, *Geogr.*, 3.2.10, 4.6.7, 5.1.8; Diodorus, *Bibl. Hist.*, 3.14.

[31] Klemm *et al.*, *supra* note 27, pp. 652-653, fig. 13; Al. Castiglioni, An. Castiglioni et J. Vercoutter, *Das Goldland der Pharaonen. Die Entdeckung von Berenike Pancrisia*, Von Zabern, Mainz, 1998 (= *L'Eldorado dei faraoni: alla scoperta di Berenice Pancrisia*, Istituto geografico De Agostini, Novara, 1995), p. 31, 134 (fig.), 175; S. E. Sidebotham, *Berenike and the Ancient Maritime Spice Route*, University of California Press, Berkeley and Los Angeles, 2011, pp. 116-117.

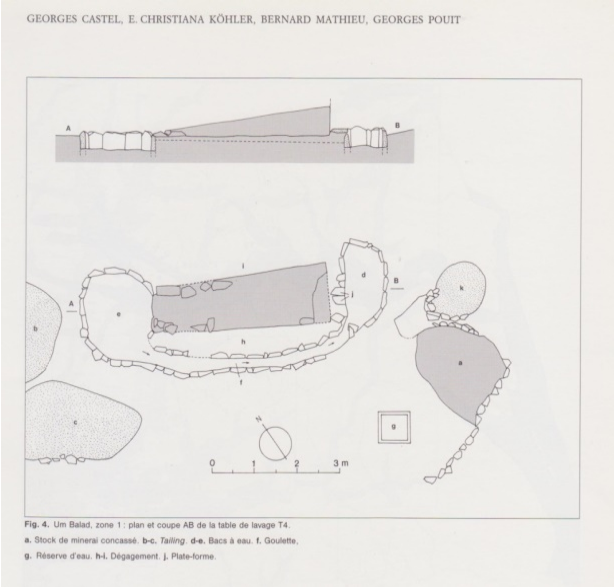


Figure 17. Wadi Umm Balad, inclined washing table, (G. Castel et al., "Les mines du ouadi Um Balad (désert Oriental)", Bulletin de l'Institut français d'archéologie orientale 98, 1998, pp. 57-87 at 76, fig. 4).

It is made of local stone, and usually found near a water source. The structure is rectangular with a sloping surface (fig. 17). At the base (or lowest part of the table) a basin was dug in which was connected through a shallow ditch to the top of the table (highest part). This ran parallel with the table and directed runoff water back to the high end for it to be recycled. The heavier gold particles remained on the table top while the sand was washed away with the water. The basins were regularly cleared of sediment and dumped nearby, which caused the wadi level around the installation to rise. These heaps are described by surveyors as "tailing heaps". The sand is of a much finer/ looser grain and resembles silt. This can be seen at four Ptolemaic gold-mining settlements: Abu Zawal, Su'iegat el-Beda (a.k.a. Wadi Shuwehat?), Samut and al-Ghuzza/ Ghozza.[32] At these sites it is thought that the auriferous dust from surrounding mines was washed, and this created an artificial island around the well.

4.1.2. Large circular washing tables or helicoidal installation

This type of installation is also made from local material and shaped in a near-per-

[32] *Abu Zawal*: D. Meredith, "*The Roman Remains in the Eastern Desert of Egypt*", *Journal of Egyptian Archaeology* 38 (1), pp. 94-111 at 101-102, 110; Tregenza, *supra* note 29 (*The Red Sea* ...), pp. 40-41; R. B. Jackson, *At Empire's Edge. Exploring Rome's Egyptian Frontier*, Yale University Press, New Haven, 2002, p. 68; Sidebotham, *supra* note 31, p. 100, 131; Klemm and Klemm, *supra* note 6, pp. 70-80 (also known as Fatiri). *Su'iegat el-Beda / Wadi Shuwehat*: S. E. Sidebotham, M. Hense and H. M. Nouwens, *The Red Land. The Illustrated Archaeology of Egypt's Eastern Desert*, The American University in Cairo Press, Cairo and New York, 2008, pp. 319-340; Sidebotham, *supra* note 31, p. 112, 131. *Samut*: Sidebotham *et al.*, *supra*, p. 332; Sidebotham, *supra* note 31, pp. 105-106, 135; Klemm and Klemm, *supra* note 6, pp. 238-244; R. Klemm and D. Klemm, "*Chronologischer Abriß der Antiken Goldgewinnung in der Ostwüste Ägyptens*", *Mitteilungen des Deutschen Archaölogischen Institutes Abteilung Kairo* 50, 1994, pp. 189-222 at 221; Faucher, *supra* note 22; B. Redon and Th. Faucher, "*Gold mining in Ealry Ptolemaic Egypt*", Egyptian *Archaeology. The Bulletin of the Egypt Exploration Society* 46, Spring 2015, pp. 17-19. *Al-Ghuzza / Ghozza*: Meredith, *supra*, p. 109; Sidebotham, supra note 31, p. 97; Klemm and Klemm, *supra*, p. 219; Sidebotham *et al.*, *supra*, p. 224; Klemm and Klemm, *supra* note 6, *passim*.

fect circle about 10-12 m in diameter. To date five sites are known to have this type of washing installation: Wadi Daghbag (Ptolemaic/Roman), which has at least two at wadi level near the mouth of a side wadi (one is still complete, the other partially destroyed) and Gidami/Bir Sirbakis, Semna, Wadi Baramiya and Samut, all dated to both the Ptolemaic and Roman periods, which have the remains of circular washeries (fig. 18).[33]

Figure 18. Wadi Daghbag, circular washing tables or helicoidal installation.

The best known helicoidal (or circular) installations have been found at Lavrion, the silver mine in Attica (Greece, 5th-4th B.C.) (fig. 19), and are often used as a reference for those found at Egyptian mining settlements. At Lavrion, the diameter is approximately 7m and the ring is made of marble; the stones were hand carved to fit. A groove with shallow depressions/bowls was hand-cut and polished prior to using it. It used to wash the auriferous dust similar to the inclined washing tables, and the water was recycled here as well.[34]

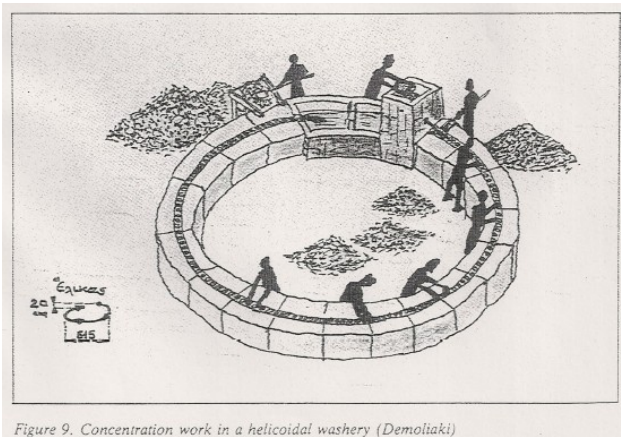


Figure 19. Lavrion, technical drawing of helicoidal washing installation (Konofagos, supra note 34, p. 22, fig. 9).

[33] *Wadi Daghbag*: Klemm and Klemm, *supra* note 6, pp. 166, fig. 5.109; Klemm *et al.*, *supra* note 27, p. 656, fig. 18, and personal observation. *Gidami*: Klemm and Klemm, *supra* note 6, pp. 102-103, fig. 5.109. *Bir Sirbakis*: S. E. Sidebotham, "*Newly Discovered Sites in the Eastern Desert*", *Journal of Egyptian Archaeology* 82 (1), December 1996, pp. 181-192 at 190, Klemm and Klemm, *supra* note 6, p. 102, state that Bir Sirbakis is also Gidami. *Semna*: Sidebotham, *supra* note 31, p. 116, 162-163; *Wadi Baramiya*: Klemm *et al.*, *supra* note 27, p. 656. *Samut*: Redon and Faucher, *supra* note 32.

[34] Domergue, *supra* note 16, pp. 148-152, fig. 91; K. Κονοφάγος [K. Konofagos (also known as Conophagos in modern publications)], *Το αρχαίο Λαύριο και η ελληνική τεχνική παραγωγής αργύρου* [*Ancient Lavrion and the Greek technique of silver production*], National Metsovian Technical University Press, Athens, 1980, p. 21, fig. 6-9; Th. Rehren, D. Vanhove & H. Mussche, "*Ores from the ore washeries in the Lavriotiki*", *Metalla (Bochum)* 9 (1), 2002, pp. 27-46 at 40-43, fig. 12-13.

4.1.3. Industrialised washing tables

This installation has industrial proportions and has so far not been found Egypt. It is suggested (until otherwise proven) that this type only occurred in wetter climates where rivers were plentiful, as in the western Roman provinces. The principle is the same as the circular type in that there is a continuous flow of water running over an inclined surface. The top plan is rectangular with a sloping surface over its entire length so the water could run off, and has a basin along its width filled with water which is released through openings on one side onto the lower platform. The auriferous dust was placed on the surface and water ran over it while men with rakes distributed the dust. As with the other two types, the heavier gold particles remained on the platform, while the sand washed away with the water into channels along the sides and then back to two collection basins on opposite sides of the washing platform.[35]

4.2. Smelting the ore

The washed gold was then placed in furnaces to smelt and separate it from other (precious) metal impurities. The process was described by Agatharchides in 150 B.C. (as transmitted by Diodorus): "*τὸ δὲ τελευταῖον ἄλλοι τεχνῖται παραλαμβάνοντες μέτρῳ καὶ σταθμῷ τὸ συνηγμένον εἰς κεραμεοῦς χύτρους ἐμβάλλουσι· μίξαντες δὲ κατὰ τὸ πλῆθος ἀνάλογον μολίβδου βῶλον καὶ χόνδρους ἁλῶν, ἔτι δὲ βραχὺ καττιτέρου, καὶ κρίθινον πίτυρον προσεμβάλλουσιν· ἁρμοστὸν δ' ἐπίθημα ποιήσαντες καὶ πηλῷ φιλοπόνως περιχρίσαντες ὀπτῶσιν ἐν καμίνῳ πέντε ἡμέρας καὶ νύκτας ἴσας ἀδιαλείπτως· ἔπειτα ἐάσαντες ψυχθῆναι τῶν μὲν ἄλλων οὐδὲν εὑρίσκουσιν ἐν τοῖς ἀγγείοις, τὸν δὲ χρυσὸν καθαρὸν λαμβάνουσιν ὀλίγης ἀπουσίας γεγενημένης*". [36]

Unfortunately no furnaces have been found in the Eastern Desert, or along the Nile Valley. Vercoutter suggests that pre-arranged pick-up areas were set up to hand over the gold dust to passing caravans on their way to the Nile Valley.[37] Ground auriferous dust did not take up much space; therefore transport would not be expensive or excessive.

[35] Konofagos, *supra* note 34, p. 16, pl. 6.1, 6.2, fig. 3, 4, 5; Rehren *et al.*, *supra* note 34, pp. 38-39, fig. 10-11; Domergue, *supra* note 16, pp. 149-152, fig. 92-93.

[36] Diodorus, *Bibl. Hist.*, 3.14 = Oldfather, *supra* note 4, p. 121 ("*Then at last other skilled workmen take what has been recovered and put it by fixed measure and weight into earthen jars, mixing with it a lump of lead proportionate to the mass, lumps of salt and a little tin, and adding thereto barley bran; thereupon they put on it a close-fitting lid, and smearing it over carefully with mud they bake it in a kiln for five successive days and as many nights; and at the end of this period, when they have let the jars cool off, of the other matter they find no remains in the jars, but the gold they recover in pure form, there being but little waste*").

[37] Castiglioni *et al.*, *supra* note 31, p. 111, 132.

5. Tools

The majority of the tools found *in situ* at mining settlements in the Eastern Desert of Egypt are made of stone which was resourced locally. These tools were mass produced and left behind when the mine was abandoned. Some of the miner's tools have already been discussed in the various sections above: querns/mill stones, hammers and pounders, lamps, washing tables. Other tools such as anvils and mortars, polish stones and metal tools will be discussed here. No evidence has been found yet for the metal tools but traces have been found. At Wadi Daghbag scratch marks were found on a wall of a trench during a survey of the mining trenches and at Abu Gerida and Samut, moulds for metal tools and remains of slag were found, but not the tools, though they are mentioned by classical writers (fig. 20).[38]

Strabo mentions iron works: "*ἔξω δ' ἐστὶ τῶν Ἑνετικῶν ὅρων ἡ Ἀκυληία. διορίζονται δὲ ποταμῷ ῥέοντι ἀπὸ τῶν Ἀλπείων ὀρῶν, ἀνάπλουν ἔχοντι καὶ διακοσίων σταδίων ἐπὶ τοῖς χιλίοις εἰς Νωρηίαν πόλιν, περὶ ἣν Γναῖος Κάρβων συμβαλὼν Κίμβροις οὐδὲν ἔπραξεν. ἔχει δὲ ὁ τόπος οὗτος χρυσιοπλύσια εὐφυῆ καὶ σιδηρουργεῖα*".[39]

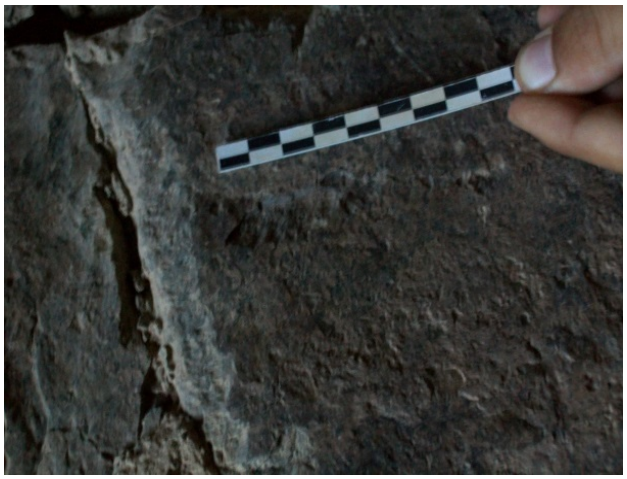


Figure 20. Wadi Daghbag, chisel marks in underground cave.

Pliny the Elder gives a generic description about the situation in western Roman provinces: "*cuneis eam ferreis adgredi-*

[38] Y. Abd El-Rahman *et al.*, "*Ancient Mining and Smelting Activities in the Wadi Abu Gerida Area, Central Eastern Desert, Egypt: Preliminary Results*", *Archaeometry* 55 (6), December 2013, pp. 1067-1087, is a study of the iron slags found at Wadi Abu Gerida. See also Faucher, *supra* note 22, pp. 6-7, fig. 3; Sidebotham, *supra* note 31, p. 116.

[39] Strabo, Geogr., 5.1.8 = Roller, *supra* note 23, 220: "*Aquileia is outside the boundaries of the Enetians. Their boundary is the river flowing from the Alpine Mountains, which one can sail up 1,200 stadia to the city of Noreia, where Gnaeus Carbo engaged the Kimbrians, accomplishing nothing. This place has gold washeries and iron mines*".

untur et isdem malleis nihilque durius putant".[40]

A third mill stone not yet described is termed the "*third type*". They have been found in areas that seemed to be for domestic purposes only. Similar to the saddle and rotary quern this tool is made of an immobile lower and a mobile upper half. The lower part is not shaped in a rectangle or square as the other two are; instead, large, boulders found at wadi level were usually used (fig. 21). Smaller handheld tools are found near them and might have been used with them? Sucah as grinding flour maybe? This is a hypothesis as this group was found near the domestic area of Wadi Bakariya. Figure 22 is a potential example of how it would have been used.

Figure 21. Wadi Bakariya, third type, found near the shrine.

Hammers and pounders are found everywhere near mining trenches and workshops, and come in all sizes, shapes and weights. The stone used is found locally, and sections along the foothills and small side wadis have their surfaces covered with stone debris which were reshaped into these tools. The stones were probably the result of the hills weathering over time, and their "natural" shape must have attracted the eyes of miners who found their format suitable for tools. At Wadi Bakariya there are two locations, each with a different type and size of stone. One was used as hand-held hammers, the other as heavyweight pounders (fig. 23).

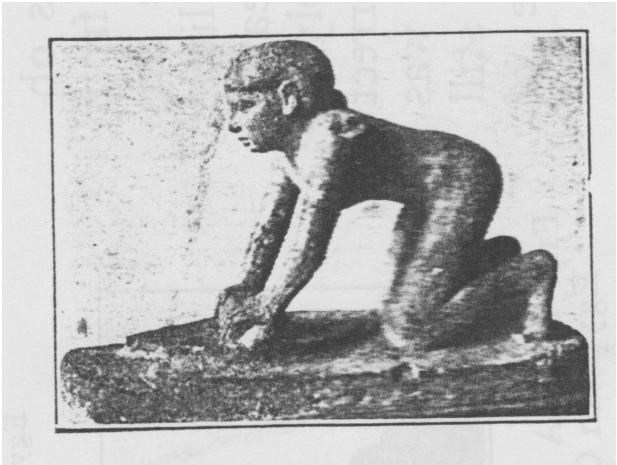


Figure 22. Statue of girl milling corn on "third type quern" (Neuburger, supra fig. 11, p. 92, fig. 147).

Figure 23. Natural occurrence of small dice-shaped stones used as hammers in the mine, Wadi Bakariya.

[40] Pliny, *Nat. Hist.*, 33.21 = Rackham, *supra* note 3, p. 57.

The pounder is the largest tool found at Wadi Bakariya, and found near the mine. The examples found are heavy –up to two kilos– and both hands were required to use them; average measurements are 30-35x10-15x10-15 cm (figs. 39-40). The edges have been worked on to fit a grip. The pounder is used to break quartz in the veins, which has created shallow depressions or flat surfaces on the sides and in turn smoothened the edges where it was held. A second function attributed to this tool is that it was used to break up the mined quartz into smaller fragments, as a few have been found near a selection area. This was probably done to determine whether there was any gold inside or just to break it up for further processing (fig. 24).

Figure 24. Wadi Bakariya, heavy pounders.

The hammers are smaller and used in conjunction with the pounder, average measurements are approx. 7-9 cm^2. Also made of local stone and also used to break up the stone. The fragments were taken to small work platforms nearby and broken into smaller pieces with these hammers (fig. 25).

Diodorus describes how the physically strongest men broke up the quartz veins and then boys collected and carried the blocks outside. Another group of men above the age of 30 broke these fragments into smaller pieces so they could be "*fed*" to the querns by women and older men.[41]

Figure 25. Wadi Bakariya, hand-held hammers.

5.1. Other mining related tools

Other tools included mortars, anvils and polish stones; all are found in association with trenches and mining activities. The few mortars found were partially

[41] Diodorus, *Bibl. Hist.*, 3.12-13.

covered by tailings near the centre of Site 1 at Wadi Bakariya (fig. 26). They are roughly cone shaped with a deep depression ending in a sharp end. It is unclear whether these tools were ever used as none found show any signs of usage. The stone is local biotite-hornblende granite-granodiorite, similar to the querns; average measurements are 40x30x20 cm. No other tools were found in the vicinity that offer an explanation for the mortar's function, but a theory is that it was used for breaking the mined auriferous quartz as part of the refining process.

Figure 26. Wadi Bakariya, mortars.

Anvils were also used to pound the mined auriferous quartz to smaller fragments so it could be further processed at the mills. This is a term used for the boulders and other large stones reused for pounding quartz fragments, average measurements are approx. 45x57 cm, thickness 30-40 cm (fig. 27). The flattened surface has a circular concave depression created by the incessant pounding of quartz fragments over a long period of time. Some anvils of a similar measurement were found as built-in features in the wadi sands, a setup that looks intentional (fig. 28).

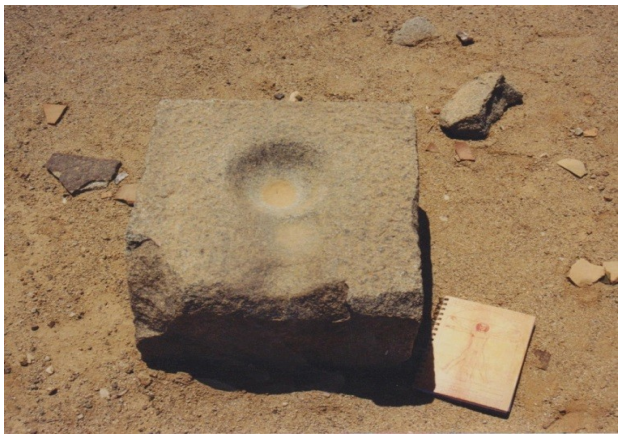


Figure 27. Wadi Bakariya, various types of anvils used to crush auriferous quartz.

Figure 28. Wadi Bakariya, working platforms with built-in querns and paved areas.

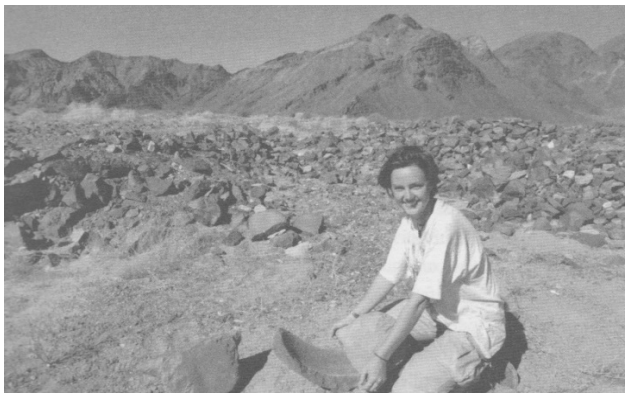
A number of small hand-held polishing stones have been found along the trenches north of Wadi Bakariya, which are thought to have been used to grind or rub the gold-bearing dust to powder or smaller fragments. This continued motion polished one side of the tool, giving it a very distinct look and a convex surface. Average measurement is 5-7 cm², roughly the same size as an adult hand. Apart from the polished side, the edges are also worn smooth from using. This tool might have also been used for domestic activities (fig. 29), like grinding flour (see fig. 22).

Figure 29. Wadi Bakariya, hand-held polish stones on top of an anvil.

6. Workshops

The workshops were an integral part of mining; its function can be identified by looking at the surrounding and associated activities. At Wadi Bakariya (Ptolemaic/Roman) there are two types of workshop found. The first are small ones grouped together near pits and trenches and two larger ones set up at strategic location. Both present in the same manner: cleared circular working surface surround by a low wall of rocks, usually one row high. The difference between the two groups is that the smaller version was probably used for on the spot checks if the mined material was gold bearing. The larger ones was where all the mined material was gathered and selected according to size and content probably before further processing, such as pounding to small sizes so they can be fed to the mill stones. At the mine at Umm Howeitat al-Qibli (Ptolemaic/Roman) the workshops lie in line with each working area (figs. 30-31).

Tools such as hammers and pounders have been found nearby this area, indicating that breaking the mined material also took place here. This is the same for the area found at Wadi Daghbag (Ptolemaic/Roman). These workshops were not built as temporary installations as their structure and location are too defined and they were in use at least for as long as the trenches of that section of the mine were open.



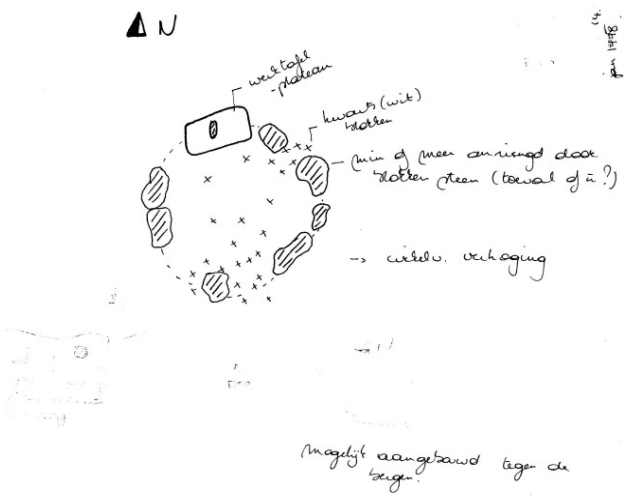


Figure 30. i) Um Howeitat al-Qibli, workshops with saddle querns (Sidebotham et al., supra note 32, p. 245, fig. 9.2), ii) unpublished sketch of a workshop by Barbara Tratsaert.

Figure 31. Wadi Bakariya, the larger workshop.

7. Recapitulation

Roman goldmining settlements seem to have followed a predefined layout similar to military camps, which are identical all over the empire and easy to identify. Some changes can occur as the locations were dependent on gold deposits and were not therefore based on strategic or other considerations. Internally, there were differences between western and eastern settlements, though, again, not by choice, as the arid environment and climate of the east did not offer the favourable conditions of the western provinces.

It is difficult to make valid comparisons between mining sites of different periods in the Eastern Desert of Egypt because the number of sites known for each period is unequal and only 25 sites of the 52 studied yielded useable data. Of these 10 sites have been dated to both periods as there are not enough finds to give a more specific date; 11 sites belong to the Ptolemaic period and 4 to the Roman. Remarkably, the majority of querns found on Ptolemaic sites are saddle querns, with only one Ptolemaic site holding rotary querns (al-Ghuzza). The sites that belong to both periods have both types of querns in more or less equal amounts, and the 4 Roman sites also have a majority of rotary querns, with 1 site containing both types (Umm Russ). This could point towards a chronological difference between the periods; the fact that both types were found at Roman sites could indicate that they either continued the Ptolemaic site or reopened it at a later stage, as is still being done today.

Tools such as the hammers, pounders, anvils, etc. are not widely recognised. The tools found at mining settlements in the Eastern Desert were made of stone, but at one site, Umm Russ (Roman period), an early 19th-century report claimed that a bronze hammer was discovered (present location unknown). Two other sites, Samut and Abu Gerida (Ptolemaic period), have remains of slag and moulds for tools other than stone, and chisel marks were found on a trench wall in Wadi Daghbag (Ptolemaic/Roman period). Classical writers also describe metal tools, but physical evidence at the mining sites is close to non-existent, however, their use should not be excluded. It is impossible that most tools were made of stone only, but what can be stated is that the stone tools were left behind on abandonment of the mine. Querns are easier to identify than smaller tools as they are larger and easier to see and also tend to appear near identifiable structures, such as Umm Howeitat al-Qibli (Ptolemaic/Roman period) and in the case of Wadi Bakariya they occur in the centre of the settlement. Hammers and pounders were the tools used in the mines and were therefore spread out over the entire site, lying in side wadis and on hill slopes rather than grouped in the prominent section(s) most likely to be visited by surveyors and archaeologists. It is also possible that smaller tools used at wadi level have

been washed away by floods. Wadi Daghbag (Ptolemaic/Roman period) has a large pile of saddle querns stacked up against a natural bend in the wadi, the severe damage to its fort shows that this wadi has been flooded many times.

Eastern Desert mines are predominantly placed on top of primary deposits, and although there might have been panning or alluvial mining at wadi level (also referred to as wadi workings). The latter is often the eroded debris from outcropping auriferous veins higher up the hills. Of the 25 desert sites, only 2 have published data on wadi workings: Samut (Ptolemaic period) and Sokari (Roman); 10 have remains from mining primary deposits: Samut, Wadi Baramiya and Hangaliya (Ptolemaic period); Wadi el-Hudi, Wadi Daghbag and Umm Russ (Roman period); Wadi Bakariya, Bir Umm Fawakhir and Umm Howeita al-Qibli (both periods). It is not unusual for both mining types to occur at the same site or even for wadi workings to predate, albeit briefly, the opening of trenches or underground galleries, but most of this phase was destroyed by later works and general life at the settlements. When studying satellite images of this desert, many sites with potential wadi workings can still be identified but on ground level this is often not that obvious. The only tool required to extract alluvial gold is a sieve. Unlike in the Western Roman Empire, water was not readily available to wash the sediment so they had to dry-sieve the sands, which involves wind blowing away the sand while the gold particles collect in the sieve.

Alluvial gold is pure gold and does not need washing or smelting as does vein gold. Gold from primary deposits required more tools, such as pounders, hammers and chisels, to excavate the veins and break up the fragments at the work platforms. Mortar and anvils were then used to crush the quartz into even smaller fragments so they can be "*fed*" to the querns. Finally, the dust was washed on an individual table or larger installation to filter the waste from the gold. A final separation happened in the furnaces, though this later process does not appear to have taken place in the Eastern Desert as there is not enough fuel for fires to burn for up to five days. Agatharchides, however, discusses the use of furnaces at an underground mine in this desert. Could he have combined various observations into one description? A total of 25 sites have evidence of mining with tools, 39 out of the 52 studied have evidence in one shape or another that (gold) mining took place.

The workshops did not have a universal approved layout but nonetheless tend to be the same at all sites. This is because the geography of the desert is similar and because the miners over time perfected their space for optimal use. In general, they had a cleared working space or platform where the worker(s) sat with tools and debris scattered in a large circle around him. An excellent site is Umm Howeitat al-Qibli (Ptolemaic/Roman) where each surface is marked by a

low wall so they could keep their working spaces clean. The same applied to the selection area, albeit on a larger scale, where more individuals were employed.

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