Archaeological geology of Wadi Sikait

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Abstract

Emerald, a green transparent variety of beryl, was one of the most highly prized gemstones in antiquity. The earliest known emerald mine is located in the valley of Wadi Sikait in Egypt's southern Eastern Desert, where mining probably began toward the end of the Ptolemaic period in the 1st century BC. Most of the mining activity, however, dates to the Early and Late Roman periods (1st to mid–2nd centuries and 4th to early 6th centuries AD, respectively) with much reduced activity during the Middle Roman period (late 2nd to 3rd centuries AD). The Romans referred to emerald as *smaragdus* and named the Sikait region *Mons Smaragdus* or Emerald Mountain. An archaeological geology survey of Wadi Sikait was undertaken for the purpose of mapping the distribution of ancient mine workings, deducing the ancient mining methods, and describing the geologic occurrence of emerald. It was found that emerald and other green beryls occur within the contact zone between phlogopite schist and intrusive quartz and pegmatite veins. The workings, which were excavated in the softer phlogopite schist with flat–edged chisels and pointed picks, are mostly shallow open–cut trenches that follow the quartz/pegmatite veins. Some workings continue as much as 100 meter underground and are still largely unexplored. Steatite and quartz mica schist also occur in Wadi Sikait and were quarried by the Romans for building stone.

Key–words: Wadi Sikait, Eastern Desert, Egypt, ancient emerald mine, ancient steatite quarry, emerald, green beryl, archaeological geology

Contents:

1. Introduction

The following report on the archaeological geology of Wadi Sikait is based on five days of fieldwork by the author in June 2002 and a synthesis of the geological literature. The objectives of the fieldwork were three–fold: (1) to produce a detailed map of the mine workings, (2) to determine the geologic occurrence of beryl, and (3) to deduce the methods of prospecting and extraction used by the ancient miners.

Wadi Sikait's place in the history of emerald mining is particularly noteworthy. Egypt was the only known source of emerald and other green beryls for Europe and the Mediterranean region. Although it has been suggested (*e.g.,* Shaw *et al*., 1999: 203) that the emerald deposit at Habachtal near Salzburg, Austria, was worked as early as the Roman period, there is no conclusive evidence that it was known prior to the Middle Ages (Sinkankas, 1981: 371–377). There was ancient beryl mining not only in Wadi Sikait but also at several other sites within 15 km of this valley, including Gebel Zabara to the northwest, Wadis Nugrus and Abu Rushaid to the west, Wadi Gemal to the southwest, and Wadis Umm Kabu and Deba'a to the southeast. Mining began in Wadi Sikait sometime during the Ptolemaic period with most of the activity occurring in the subsequent Roman and Early Byzantine periods (1st through 6th centuries AD). All the other mining sites are strictly Roman–Byzantine or Islamic in date. None of the ancient mines has been previously mapped and it is thus fitting that the first to be so recorded is the oldest one in Wadi Sikait.

2. Emerald and other beryls

Beryl is a beryllium alumino–silicate mineral with the chemical formula $Be_3Al_2(Si_6O_{18})$. Ordinary beryl is colorless but the presence of various trace impurities give the gemstone varieties of this mineral their distinctive colors: green emerald, blue to bluish–green aquamarine, pink morganite, red bixbite, and yellow to yellowish–orange heliodor (Sinkankas, 1981: 206–235). Beryl almost always occurs as elongated crystals with a hexagonal cross–section. It has a Mohs scratch hardness of 7.5–8, which is exceeded by only a few other gemstones such as chrysoberyl at 8.5, ruby and sapphire corundum at 9, and diamond at 10. Although highly resistant to grinding and cutting, beryl does have a weakly developed basal cleavage. Skilled stonecutters can thus break (cleave) it along the crystal axis to produce hexagonal prisms of any desired length.

The name 'beryl' comes from Pliny the Elder who, writing in the 1st century AD, used *beryllus* to refer to a variety of minerals having long, prismatic crystals with hexagonal cross–sections (*NH* 37.20; Eichholz, 1962: 224–227). His *smaragdus* included the Egyptian beryl among other green stones (*NH* 37.16–19; Eichholz, 1962: 212–225), but he also recognized its relationship with *beryllus*: "many people consider the nature of *berulli* to be similar to, if not identical with, that of *smaragdi*" (*NH* 37.20.76; Eichholz, 1962: 224–225). The modern name 'emerald' is derived from the ancient *smaragdus*, which can be traced back at least as far as the late 4th or early 3rd century BC when Theophrastus used it as a catchall for green gemstones (*On Stones* 23–27; Caley & Richards, 1956: 50–51, 97–109). The Egyptian green beryl, however, was almost certainly unknown to him.

True emerald has a bright, uniform, medium to dark green color and is transparent. Beryls of this quality are very rare not only in Wadi Sikait but throughout the surrounding beryl–mining region. The Egyptian beryl almost always has a cloudy translucency and a light green color, and also commonly has minute mineral inclusions (usually mica or amphibole, or their weathered clay–mineral equivalents). Abundant submicroscopic fluid inclusions (water–filled vesicles) are the cause of the translucency. It is ironic, therefore, that Egypt's famous 'emerald mines' produced very few true emeralds.

The poor quality of Egyptian beryl has been attested repeatedly in both the ancient and modern literature (for a partial summary see Sinkankas, 1981: 542–548). For example, Pliny the Elder complained that the "Ethiopian *smaragdus* is […] rarely flawless or uniform in tint" (*NH* 37.18.69; Eichholz, 1962: 218–219). It is not surprising, therefore, that of the several hundred engraved gemstones of Roman date reported by Richter (1971), only two were true emeralds. Although Egypt's ordinary green beryl may not have been highly esteemed by the Romans, it was still clearly much valued by them. It was the hardest green gemstone available to them and it also had the added mystic of coming from fabled Egypt. Perhaps another appeal of beryl was its naturally faceted hexagonal prisms that mimicked the more costly cut gemstones. The Roman interest in these stones is clearly demonstrated by the extensive mine workings in the Eastern Desert. It is also evidenced by archaeological finds elsewhere. At Berenike, for example, only two of the hundreds of green beryl specimens recovered from the excavation trenches and examined by the author had the color and transparency of true emeralds (see also the section below on 'Chronologic Distribution of Beryl at Berenike'). The rest were the translucent, light green variety and yet they too were probably destined for jewelry. The same poor quality stones were certainly used in jewelry found in Pompeii and Herculaneum (Siviero, 1959). Unlike in recent centuries, when beryl has been ground into faceted stones, the Romans used the natural hexagonal prisms cleaved from crystals. These were either fixed into metal settings or drilled along the prism axis and strung as beads. As suggested by Harrell & Brown (2002: 56), it may also be that some of the Egyptian beryl, perhaps only the broken or otherwise heavily flawed crystals, was used as an abrasive for sawing and grinding other stones.

3. Geology of Wadi Sikait

3.1. Rock units

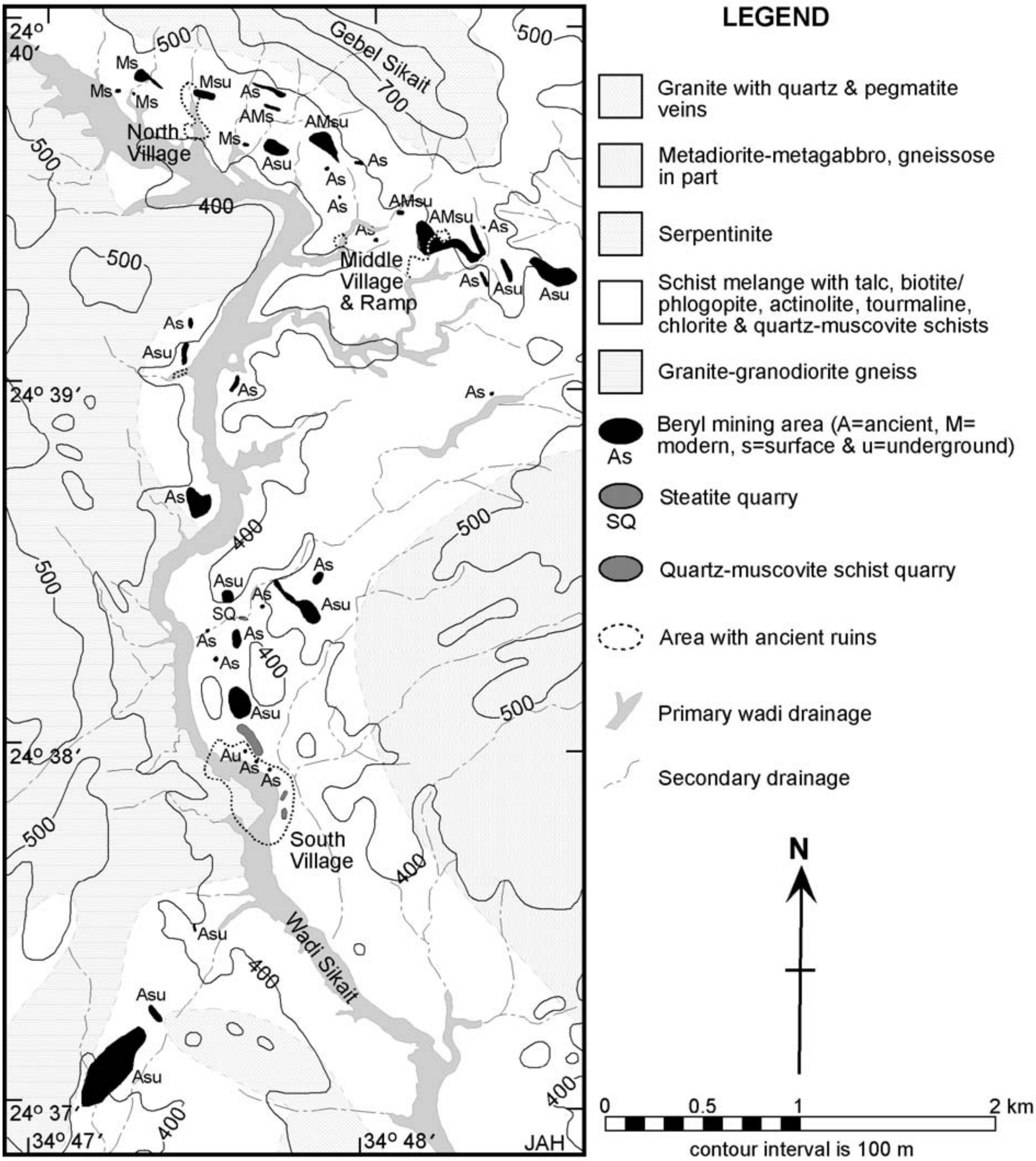

Figure 1. Topographic–geologic map of the Wadi Sikait area showing the extent of beryl mining. Drawn by the author.

Much has been written about the geology of the Wadi Sikait region, including most notably MacAlister (1900), Hume (1934: 109–125), EGSMA (1951: 82–94), Basta & Zaki (1961), El Shazly & Hassan (1972), Hassan & El Shatoury (1976), EGSMA (1992: 31–83), El Dougdoug *et al.* (1997), and Abdalla & Mohamed (1999). There is no general agreement on the description of the rock units, the nature of their contacts or their relative ages, and this undoubtedly results from the considerable geologic complexity of the region. For the present study, the following rock units are recognized, from youngest to oldest following the widely accepted chronologies of El Gaby *et al.* (1990) and Hasan & Hashad (1990):

1. granite with quartz and pegmatite veins (the 'younger granite', 'white granite' and 'leucogranite' of others),
2. metadiorite–metagabbro, gneissose in part (the 'older granite', 'lineated diorite' and 'hornblende gneiss' of others),
3. serpentinite (the 'ophiolitic ultramafics' of others),
4. schist melange – talc, biotite/phlogopite, actinolite, quartz–muscovite, tourmaline and chlorite schists (the 'ophiolitic melange' and 'metasediments–metavolcanics' of others), and
5. granite–granodiorite gneiss (the 'psammitic gneiss,' 'biotite gneiss' and 'orthogneiss' of others).

These rock units are shown on the geologic map in figure 1. The unit contacts on this map were largely taken from the three very similar geologic maps in El Shazly & Hassan (1972: figure 1), EGSMA (1992: figure 3.2) and El Dougdoug *et al.* (1997: figure 1b). Figure 1 is the first geologic map of the Wadi Sikait area that also includes detailed topographic information. Elevation contours and some secondary drainage came from EGSA (1989), and primary wadi and additional secondary drainage was taken from a Corona satellite photograph (no. DS1102–2090DA052) available from the U. S. Geological Survey. The locations of mines, quarries and ruins shown in figure 1 were recorded in the field directly on the Corona photograph. From the distribution of the rock units visible in this photograph as well as from outcrop checks by the author, the position of some of the geologic contacts in figure 1 were modified from those on previously published maps.

Not shown in figure 1 are numerous dolerite dikes that post–date the granite and intrude all other rock units. The schist melange also contains some small pockets of metadiorite–metagabbro as, for example, in the Middle Village. All the rock units date to the Late Proterozoic era (roughly 550 to 900 million years ago) and belong to the Pan–African Series except the granite–granodiorite gneiss, which is older and dates to an earlier part of the Proterozoic or possibly even the preceding Archean eon (Gaby *et al.,* 1990; Hassan & Hashad, 1990).

3.2. Occurrence of beryl

The geologic occurrence of beryl in Wadi Sikait has been well described by Basta & Zaki (1961), EGSMA (1992: 31–83), El Dougdoug *et al.* (1997), Abdalla & Mohamed (1999) and Takla *et al.* (2003). Their findings are consistent with what is known generally about the global origins of beryl deposits (Sinkankis, 1981: 339–356). The account that follows is based on this literature as well as on the present author's own field observations.

For green beryl to form, two relatively rare elements need to be present: beryllium and chromium. Beryllium–bearing minerals are most commonly associated with hydrothermal veins that are offshoots of felsic (high silica and low ferromagnesian) magma bodies. At Wadi Sikait, such a magma body produced the granite with its quartz and pegmatite veins. The quartz veins consist almost entirely of white ('milky') quartz, and the pegmatite veins are a very coarse–grained intergrowth of mostly quartz, feldspar and mica. These veins generally vary from a few centimeters to up to one meter in thickness, and have intruded all the older rock units in the area. The veins are now much deformed and so commonly appear as contorted, discontinuous lenticular bands and pods. The occurrence of beryl is intimately linked with these beryllium–enriched veins, especially those of quartz which are the most plentiful.

Only minute amounts of chromium substituting for aluminum in the beryl crystal structure are needed to give the mineral a green color, with darker shades produced by higher chromium concentrations. Although vanadium can also color beryl green, chemical analyses have shown that chromium is the colorant for Wadi Sikait beryls (EGSMA, 1992: 81–82; El Dougdoug *et al.,* 1997: 225–230; Abdalla & Mohamed, 1999: 585–586). Chromium is often found in rocks of mafic (low silica and high ferromagnesian) composition where it occurs as an impurity in mica and amphibole minerals through substitution for the aluminum and iron in their crystal structures. In Wadi Sikait, these rocks are represented by phlogopite schist and actinolite schist in the schist melange, where phlogopite is a variety of black mica and actinolite is a kind of amphibole. There is some disagreement over whether the mica is phlogopite or biotite. The former mineral is basically an iron–poor variety of biotite and is chemically gradational with it. The two micas can be distinguished in the laboratory, but not in the field. The more recent, and presumably more analytically advanced, studies identify the mica as phlogopite and so this description is followed here. It is possible, however, that biotite schist also occurs in the schist melange.

The actinolite schist occurs as thin sheets and lenses within the much more abundant phlogopite schist. The two rock types are mineralogically gradational in that both contain phlogopite and actinolite, just in different proportions. They do, however, look very different in the field. The actinolite schist is characterized by radiating bundles of long (up to 10 cm), flat prismatic crystals of translucent, dark green actinolite whereas the phlogopite schist is black to dark gray with glittering, almost metallic–looking, surfaces due to the myriad fine mica flakes. Although the actinolite schist is considered to be one of the sources of chromium in Wadi Sikait, it apparently hosts very little, if any, of the beryl.

The beryl occurs in both the phlogopite schist and quartz/pegmatite veins, and is restricted to within tens of centimeters of their contact. It is found as individual crystals or, more often, as small clusters of crystals. Crystals can be up to a few centimeters in length but most are much shorter. The beryl in the quartz/pegmatite veins varies from colorless or white to light green, but in the phlogopite schist the color ranges from light to dark green. Given that the schist is a source of chromium, it is not surprising that this rock would have the greener beryl, including true emerald.

4. Beryl mining

4.1. Distribution, types and ages of workings

Figure 1 shows the extent of beryl mining in Wadi Sikait. The codes beside each mining area indicate the age of the workings ('A' for ancient or 'M' for modern) and the kind of excavations ('s' for surface and 'u' for underground).

Modern mining began with Frédéric Calilliaud's rediscovery of Wadi Sikait in 1816 and continued with his second visit in 1817 (Rivard *et al.,* 2002: 38–39; Sidebotham *et al.,* 2004: 11), but it is not clear whether in his brief engagements there he initiated new workings or simply reoccupied ancient ones. Mining was next resumed by E.W. Streeter from 1899 to 1905 through his Egyptian Gold and Gem Syndicate Ltd. D.A. MacAlister (of MacAlister, 1900) was the geologist on Streeter's initial expedition to the site. Prospecting licenses were issued to J. Bienenfield in the late 1920's and a Mr. James in the early 1930's (Hawari, 1934), but the extent of their activities is not known although Hume (1934: 125) reports that James sank a 26.5 meter–deep shaft somewhere on the east side of Wadi Sikait. Most of the traces of modern mining seen today probably date from Streeter's venture. These are found around both the Middle Village and especially the North Village. The remains of the stone well house in the middle of Wadi Sikait between the two ancient settlements dates to this time. All past attempts at reopening the Wadi Sikait mine were unsuccessful because of the generally poor quality and, hence, low market value of the beryl.

The modern workings can usually be distinguished from the ancient ones by, in the case of the latter, the presence of pottery sherds and the more weathered appearance of the mine walls and tailings. Many of the modern workings are boldly labeled with painted letters and numbers, and, unlike the ancient ones, tend to have much wider trenches and large blocks of stone strewn about. Some modern workings are clearly set in amongst ancient ones and undoubtedly traces of some of the latter have been completely obliterated by the former.

4.2. Ancient prospecting and extraction methods

The ancient mine workings are mostly shallow, open–cut trenches that follow the quartz/pegmatite veins within the phlogopite schist. Many adits, shafts and tunnels pursue these veins deep underground. Where less than a few tens of centimeters thick, the vein together with 1–2 meter of schist on both sides were removed, but for the thicker veins the schist was generally extracted along just one side. Some of the buildings in the South Village (Wadi Sikait) incorporate either open–cut or subterranean rooms that were excavated from the talc schist bedrock. Although these rooms resemble some of the mine workings, they cannot be the result of mining because the talc schist contains no beryl.

The underground portions of the Wadi Sikait mine have not yet received any study. There are instead only a few passing comments from earlier visitors. For example, MacAlister (1900: 544) says "the mining is of a most primitive character […] the ancients simply excavated […] a network of long and very tortuous passages just large enough to allow the body being dragged through, and only in a very few cases was any attempt made at […] excavating the entire seam." EGSMA (1951: 86) provides additional details: "some mines are very elementary, the galleries are very narrow and tortuous, that one has to creep all the time […][whereas] other mines are nearly perfect; [their] walls were cleanly cut, shafts and levels were systematically dug, tunnels are [so] wide and high that it is easy to walk comfortably through […][and] steps were carved in the floor of some inclined tunnels […][and] in all cases, one can notice the presence of big pillars of country rock being left for roof support." Judging from what can be seen from the surface, the two deep, squared shafts on the north side of the South Village (in figure 1 the site labeled 'Au' just to the left of the quartz–muscovite schist quarry) appear to be the most technically sophisticated of the ancient workings. The largest of these is 7 meter across and 10 meter deep with steps carved into the sides of the shaft (Rivard *et al.,* 2002: 40).

The ancient miners knew that beryl was to be found along the contact between the quartz/pegmatite veins and phlogopite schist, and so probably tested every such association where visible on the surface (figure 2). The fact that not all the vein–schist contacts in Wadi Sikait have been mined is an indication that the beryl deposits are erratic in their occurrence, but it may also be that the deposits were never fully exploited.

Figure 2. Quartz vein in phlogopite schist with traces of ancient mining. Photograph by the author.

V–shaped marks left by pointed picks are occasionally seen on the schist walls of some ancient workings (figure 3), but the most common tool mark encountered was made by a flat–edged chisel 1 to 1.5 centimeter wide (figure 4). These broad tracks are often several centimeters long and range up to 30 cm in length. Because of this it seems that these tracks could only have been made by hammered chisels rather than by flat–edged picks, which would tend to produce shorter gouges on the wall rock. These iron tools would have been too soft and brittle to be effective against the hard quartz/pegmatite veins and so these were probably removed by stoping (*i.e.,* excavating around rather than through the veins) with the actual digging occurring only in the much softer phlogopite schist.

Although beryl occurs in the quartz/pegmatite veins, it could not have been extracted from these hard rocks without great effort and large losses of crystals through breakage. Given this as well as the generally inferior color of the beryl in the veins, the ancient miners were probably interested only in the phlogopite schist. The beryl crystals in the schist would also have been easy to carve out (the Mohs scratch hardness of phlogopite is 2.5, the same as a human fingernail). Presumably, a sharp–pointed metal tool, perhaps a blade or burin, would have been used to do this. From the great piles of fine–grained tailings around many of the workings, it appears that the removal of beryl crystals from the schist was done at the mine site. EGSMA (1951: 86) suggests that pieces of schist were ground to extract beryl using "mortars of country rock and balls of white quartz handful in size" found around the mine. This, however, seems unlikely as it would surely cause much breakage among the beryl crystals.

Figure 3 (left). Marks left by a pointed pick on phlogopite schist. Figure 4 (right). Marks left by a flat–edged chisel on phlogopite schist. Photographs by the author.

5. Building stone quarries

5.1. Steatite

The most common rock type in the schist melange unit is talc schist. This is the stone that the rock–cut temples in the South Village (Wadi Sikait) are carved from and much of the ruins are built upon. Like other foliated metamorphic rocks, this schist tends to readily break into thin slabs and chips. The rock is rich in talc, which is a very soft mineral that is easily scratched with a fingernail. These properties make the talc schist unsuitable as a building material. When the foliation is absent or poorly developed, what would otherwise be a talc schist is referred to as 'steatite' or, equivalently, 'soapstone.' Numerous steatite quarries have recently been discovered by the author in the Eastern Desert (Harrell & Brown, in press). These all date to the Islamic period and were worked exclusively for cooking pots (the Arabic *baram*). There is so far only scant evidence of Roman activity at any of these quarries, but it is clear that the Romans in Egypt did use steatite for a variety of small objects, including statuettes, vessels, platters, pendants and beads (Harrell, 1998: 145; Harrell, *in press*).

During the author's walking survey of Wadi Sikait, a small steatite quarry of apparent Roman age was discovered. This is within the talc schist unit where the foliation is locally absent. The site is located about 600 meter north of the South Village, and 250 meter up a narrow ravine on the east side of Wadi Sikait (marked in figure 1 by 'SQ'). The quarry extends 40 meter along this ravine. At its east end there is a 4.2 x 3.2 meter area where many ashlar blocks were removed. Most came from a shallow, rectangular pit 2.4 x 1.5 meter. Within this pit, for example, there are portions of two partially extracted ashlars, one 0.32 x 0.18 meter and the other 0.32 x 0.22 meter. Both are separated from the steatite bedrock by narrow trenches along the sides and are still attached at their bases. A rectangular void within the pit shows where a 0.32 x 0.22 meter block was removed. On the walls of the pit and the adjacent rock surfaces are regular sets of inclined, narrow grooves made with either a pointed chisel or pick.

About 20 meter west of the pit is a large, nearly rectangular block (1.5 x 1.0 x 0.75 meter). Along one side of this block is a line of seven pointillé pits (figure 5). These are 2–3 centimeter deep and 7–10 centimeter apart. The pointillé technique has been in use from the 6th century BC onward and is employed for the precisely controlled splitting of rocks. By sequentially and repeatedly hammering a pointed chisel into the pits, the rock will split along the line of pits (Waelkens *et al.*, 1990: 63–64). On two sides of this block are crudely incised figures: a camel and ibex on one side and the same plus a man on the other. Just up the slope from this block is another nearly square one that is about 0.70 meter on a side. One of the sides has been well dressed to a flat surface and, judging from the tool marks, this work was done with either a pointed chisel or pick. Elsewhere in the quarry are many fragments of steatite with chisel/pick marks as well as other surfaces with incised figures of camels and men.

At the west end of the quarry, on a high rock wall, there is a conspicuous circular scar (0.57 m in diameter) where a circular vessel or platter was cut directly from the steatite bedrock (figure 6). This is a distinctly Roman method of extraction. The pointillé pits and other chisel/pick marks are also consistent with a Roman age for this quarry.

Figure 5 (left). Block in the steatite quarry with pointillé pits. Figure 6 (right). Wall in the steatite quarry where a circular vessel or platter was cut directly from the rock. Photographs by the author.

5.2. Quartz–Muscovite Schist

The buildings of the South Village are constructed from pieces of quartz–muscovite schist, one of the rock types in the schist melange unit. The rock came from quarries on top of the ridge behind the village ruins (see figure 1), where they form a series of small, shallow, irregular pits. This hard variety of schist breaks naturally into slabs of uniform thickness and so is ideal for stacked–stone construction. Both the North and Middle Villages (North Sikait and Middle Sikait respectively) are also constructed from slabs of quartz–muscovite schist. Although this rock is locally available in both places, no quarries for it have yet been recognized.

6. Chronological distribution of beryl at Berenike

Green beryl is one of the gemstones commonly encountered in the excavations at Berenike, the Ptolemaic–Roman port city on the Red Sea coast, 110 km southeast of Wadi Sikait (Harrell, 1996: 112; 1998: 142–143; *in press*). In eight years of excavations (1994–2001), hundreds of beryl crystals were recovered from dated loci and this makes it possible to determine the chronological distribution of this gemstone at Berenike. This chronology is of interest here because it may also reflect changes in the level of beryl–mining activity in Wadi Sikait and the surrounding region.

Table 1 lists all the excavation loci at Berenike where beryl has been found. The loci dates are based on pottery or, when datable pottery was absent, were interpolated (or in some cases extrapolated) from the bounding dated loci using trench matrices. The numbers (and percentages) of the 140 loci of known age are as follows:

Late Ptolemaic to Early Roman = 5 (3.6%), Late Ptolemaic to Early Roman plus Late Roman = 1 (0.7%), Early Roman = 19 (13.6%), Early Roman to Middle Roman = 1 (0.7%), Early Roman to Late Roman = 2 (1.4%), Early Roman plus Late Roman = 7 (5.0%), Middle Roman to Late Roman = 2 (1.4%), and Late Roman = 103 (73.6%).

Trench Age	Trench Number	Locus Age	Locus Numbers
ER+MR+LR	**BE–1**	LR	007, 045, 073
ER+MR+LR	**BE–4**	LR	004
LP+ER+MR+LR	**BE–5**	LR	012, 025, 031, 033, 050, 054, 069, 084
		ER+LR	022, 040
LR	**BE–6**	LR	043, 070, 077, 085, 091
		ER–LR **?**	102
ER+MR+LR	**BE–7**	LR	011
		ER–MR	078
EP–LP+ER+MR+LR	**BE–10**	unknown[3]	001, 006, 009, 018, 023, 032, 069, 091
		LR	002, 005, 013, 017, 022, 100, 111, 132,134, 154, 159 (bead), 221
		MR–LR	158, 425
		ER+MR–LR	435
		ER	393, 423, 431, 486 (3), 489, 517, 620
		LP–ER+LR	036
		LP–ER	558, 559
ER+LR	**BE–12**	LR	005, 113, 216, 299 (2), 302, 303
ER	**BE–13**	ER	002, 003
LP+ER+LR	**BE–16**	LR	014, 032, 055
		ER+LR	118
		LP–ER	152, 169, 181
ER+LR	**BE–17**	LR	002, 003, 006, 034, 061, 083
		ER+LR	063
		ER	086 (2), 114
LR	**BE–18**	LR	005
LR	**BE–20**	LR	004, 020, 023, 027, 053
LR	**BE–21**	LR	001 (2), 003, 004, 012, 017, 023 (3), 027, 030 (bead), 033, 040
ER+LR	**BE–22**	LR	024, 061
		ER	104, 112
ER+LR	**BE–26**	LR	004, 009, 022 (3)
LR	**BE–27**	LR	009, 015, 020 (3), 021, 023, 024, 026
ER+LR	**BE–28**	LR	021
		ER+LR	028
ER	**BE–29**	ER	014 (possibly worked)
ER+LR	**BE–30**	LR	002, 033, 136
		ER+LR	163, 174
EP+ER	**BE–31**	ER	002
ER	**BE–33**	ER	004, 013
LR	**BE–34**	LR	008 (2), 011
LR	**BE–37**	LR	006 (2), 008, 017, 018, 023 (3), 026, 027 (2), 029
ER+LR	**BE–38**	LR	002
LR	**BE–41**	LR	005, 031, 041
ER+MR+LR	**BE–43**	LR	001 (4), 002 (3), 004, 024, 032 (2), 036
ER+LR	**BE–44**	LR	091
EP+MR+LR	**BE–47**	LR	012, 022 (5), 025, 033 (3), 045
ER+MR	**BE–48**	ER	020, 030 (5)

Table 1. Distribution of green beryl in Berenike trench loci for the 1994 through 2001 season. [1]Trench numbers are denoted by "BE–#" and three–digit numbers are excavation loci. Single beryl specimens were found in each locus except where a greater number is indicated in the parentheses and also except for samples from the 1994–1996 seasons when beryl specimens were not counted. All beryls are unworked crystal fragments except where otherwise indicated. Loci dates are based on pottery. For loci lacking datable pottery, the dates are interpolated or, in some cases, extrapolated from the dated bounding loci using trench matrices. Abbreviations for pottery dates are as follows: EP (Early Ptolemaic, 3rd through mid 2nd century BC), LP (Late Ptolemaic, late 2nd through 1st century BC), ER (Early Roman, 1st through mid 2nd century AD), MR (Middle Roman, late 2nd through 3rd century AD), and LR (Late Roman, 4th through early 6th century AD). Underlined trench ages reflect the predominant pottery dates. Hyphenated loci ages (e.g., MR–LR) indicate that the pottery could date to either period, and loci ages joined with a '+' (e.g., MR+LR) indicate that the pottery dates from both periods. [2]Beryls were not found in the following trenches (pottery dates given): BE–2 (ER+MR+LR), BE–3 (ER), BE–8 (LR), BE–9 (ER+LR), BE–11 (LP), BE–14 (undated), BE–15 (undated), BE–19 (LP+ER), BE–23 (LR), BE–24 (undated), BE–25 (undated), BE–32 (LR), BE–35 (undated), BE–36 (EP+LP), BE–39 (LR), BE–40 (LP), BE–42 (EP+LR), BE–45 (EP), BE–46 (LR), BE–49 (EP+MR+LR), and BE–53 (LR). [3]These loci are probably Late Roman in age because the stratigraphically adjacent, dated loci are of this age. No trench matrix is available and so it is not possible to obtain interpolated dates.

These results suggest that beryl mining was especially active during the Early Roman (1st to mid 2nd centuries AD) and the Late Roman (4th to early 6th centuries AD) periods, and was much reduced or absent during the Ptolemaic (3rd to 1st centuries BC) and Middle Roman (late 2nd to 3rd centuries AD) periods. Given that Strabo, writing about 24 BC, mentions beryl (*smaragdos*) mining in Egypt (Geography, 17.1.45; Jones, 1959: 120–121), it is certain that there was some mining activity at least as early as the Late Ptolemaic period (late 2nd to 1st centuries BC). Oddly, however, apart from Strabo and a possibly Ptolemaic inscription on an altar in the large rock–cut temple in Wadi Sikait's South Village (Sidebotham *et al.,* 2004: 19), there is no unequivocal evidence for the mining of beryl prior to the Roman period. The apparent hiatus during the Middle Roman period may just reflect a dearth of Middle Roman levels so far excavated at Berenike, but other evidence suggests that it may also represent a real reduction in mining activity. For example, from pottery and other finds, Wadi Sikait's three settlements can be dated as follows: (1) South Village (Wadi Sikait) – late 1st century BC or early 1st century AD into the 6th century AD, with most of the occupation in the 4th and subsequent centuries; (2) Middle Village (Middle Sikait) – 1st to 2nd and 4th centuries AD; and (3) North Village (North Sikait) – 5th to 6th centuries AD (Sidebotham *et al.,* 2004). Although there is some Middle Roman activity in the South Village, this period is clearly not as well represented in Wadi Sikait as the Early and Late Roman periods. Whether this pattern is repeated at other sites in the beryl–mining region remains to be determined.

Another way of assessing when beryl mining occurred is to look at the so–called 'Fayum mummy portraits' (Doxiadis, 1995; Geoffroy–Schneiter, 1998; Walker, 2000). These date from the Early through Late Roman periods, and come not only from the Fayum but also from many sites in the Nile Valley. These realistic portraits, which were placed over the faces of the deceased, show Romanized Egyptians in the prime of life and wearing their finest clothes and jewelry. Many of the women are adorned with what can only be beryl necklaces and earrings, judging from the elongated, prismatic green stones depicted. Of the scores of portraits reproduced in Doxiadis (1995), Geoffroy–Schneiter (1998) and Walker (2000), a total of twenty–six show women with beryl jewelry. Of these, twenty are Early Roman (four from the mid to late 1st century AD and sixteen from the early to mid 2nd century AD), five are Middle Roman (all from the late 2nd century AD), and one is Late Roman (4th century AD). A reduced level of Middle Roman mining activity, especially in the 3rd century AD, is once again indicated.

Beryl mining certainly did not cease in the 3rd century as evidenced by a surviving Roman document. This is a rescript (*i.e*., a legal ruling) in the *Digest of Justinian* 39.4.16 (Mommsen *et al.,* 1985: 406–407). The rescript was excerpted from *De Delatoribus Liber Singularis*, a manuscript on fiscal law written by the Roman jurist Aelius Marcianus in the early 3rd century AD (Honoré, 1962: 212–213; Jolowicz & Nicholas, 1972: 394). Line 7 of the rescript gives a long and varied list of trade items that are subject to import duty, and among these are *smaragdus* and *beryllus* (Harrell, 1999: 120–121). Although these do not necessarily include Egyptian beryl (see the section on 'Emerald and other beryls' above), it is likely that at least one of them, probably *smaragdus*, does.

Based on all of the above evidence for pre–Islamic activity, it can be concluded that most of Egypt's beryl mining occurred during the 1st and 2nd centuries and 4th through early 6th centuries AD, with much reduced operations beginning sometime in the Late Ptolemaic period and occurring again during the 3rd century AD. Although not at Wadi Sikait, beryl mining continued on a limited scale elsewhere in the region during the subsequent medieval Islamic period.

7. Cited literature

Abdalla, H.M. & F.H. Mohamed. 1999. Mineralogical and geochemical investigation of emerald and beryl mineralization, Pan–African Belt of Egypt – genetic and exploration aspects. – Journal of African Earth Sciences 28, 3: 581–598.

Basta, E.Z. & M. Zaki. 1961. Geology and mineralisation of Wadi Sikeit area, South–Eastern Desert. – Journal of Geology of the United Arab Republic (later Egyptian Journal of Geology) 5, 1: 1–36.

Caley, E.R. & J.F.C. Richards. 1956. Theophrastus on stones. – Columbus, Ohio State University Press.

EGSA. 1989. Jabal Sakit (sheet NG 36 D4b, 1:50,000). – Cairo, Egyptian General Survey Authority.

EGSMA. 1951. Report on the Prospecting Expedition in Wadi El Gemal Area, 1950–1951, unpublished internal report. – Cairo, Egyptian Geological Survey and Mining Authority.

EGSMA. 1992. Study of Gemstones in the Eastern Desert and Sinai (Chapter 3, Emerald), unpublished internal report. – Cairo, Egyptian Geological Survey and Mining Authority: 31–83.

EGSMA. 1992. Study of Gemstones in the Eastern Desert and Sinai (Chapter 3, Emerald), unpublished internal report. – Cairo, Egyptian Geological Survey and Mining Authority: 31–83

El Dougdoug, A., M.A. Takla, A.A. Surour, A.A. Hussein & F. El Eraky. 1997. Mineralogy and origin of Wadi Sikait emerald, S. E. Desert, Egypt. In: **1997.** Proceedings of the Third Conference on Geochemistry; Volume 1, Geochemistry of Igneous Rocks and Geochemical Exploration. – Alexandria, Alexandria University: 221–239.

Doxiadis, E. 1995. The Mysterious Fayum portraits. Faces from ancient Egypt. – New York, Harry N. Abrams.

El Gaby, S., F.K. List & R. Tehrani. 1990. The basement complex of the Eastern Desert and Sinai. In: **Said, R. Ed. 1995.** The Geology of Egypt. – Rotterdam, A. A. Balkema: 175–184.

El Shazly, E.M. & M.A. Hassan. 1972. Geology and radioactive mineralisation at Wadi Sikait–Wadi El Gemal area, Eastern Desert. – Egyptian Journal of Geology 16, 2: 201–234.

Geoffroy–Schneiter, B. 1998. Fayum Portraits. – London, Thames and Hudson.

Harrell, J.A. 1996. Geology. In: **Sidebotham, S.E. & W.Z. Wendrich. Eds. 1998.** Berenike 1995. Preliminary report on the 1995 excavations at Berenike (Egyptian Red Sea Coast) and the survey of the Eastern Desert. – Leiden, Centre for Non–Western Studies: 99–126.

Harrell, J.A. 1998. Geology. In: **Sidebotham, S.E. & W.Z. Wendrich. Eds. 1998.** Berenike 1996. Report of the excavations at Berenike (Egyptian Red Sea Coast) and the survey of the Eastern Desert. – Leiden, Centre for Non–Western Studies: 121–148.

Harrell, J.A. 1999. Geology. In: **Sidebotham, S.E. & W.Z. Wendrich. Eds. 1999.** Berenike 1997. Report of the excavations at Berenike and the survey of the Egyptian Eastern Desert, including excavations at Shenshef. – Leiden, Centre for Non–Western Studies: 107–121.

Harrell, J.A. In press. Geology. In: **Sidebotham, S.E. & W.Z. Wendrich. Eds.** In press. Berenike 1999/2000. Report on the Excavations at Berenike, Including Excavations in Wadi Kalalat and Siket, and the Survey of the Mons Smaragdus Region. – Los Angeles, Cotsen Institute of Archaeology.

Harrell, J.A. & V.M. Brown. 2002. Rock sawing at a Roman diorite quarry, Wadi Umm Shegilat, Egypt. In: **Herrmann, J.J., N. Herz & R. Newman. Eds. 2002.** Interdisciplinary studies on ancient stone. Proceedings of the fifth international conference of the Association for the Study of Marble and Other Stones in Antiquity, Museum of Fine Arts, Boston 1998. – London, Archetype Publications: 52–57 (ASMOSIA 5).

Harrell, J.A. & V.M. Brown. In press. Discovery of a medieval Islamic industry for steatite cooking vessels in Egypt's Eastern Desert. In: **Rowan, Y.M. & J.R. Ebeling. Eds. In press.** New Approaches to Old Stones – Recent Studies of Ground Stone Artifacts. – London, Equinox Archaeology Books.

Hassan, M.A. & H.M. El Shatoury. 1976. Beryl occurrences in Egypt. – Mining Geology 26: 253–262.

Hassan, M.A. & A.H. Hashad. 1990. Precambrian of Egypt. In: Said, R. Ed. 1990. The Geology of Egypt. – Rotterdam, A.A. Balkema: 201–245.

Hawari, M. 1934. Beryl – Emerald, unpublished internal report. – Cairo, Egyptian Geological Survey and Mining Authority.

Honoré, A.M. 1962. The Severan lawyers. A preliminary survey. – Studia et Documenta Historiae et Iuris 28: 162–232.

Hume, W.F. 1934. Geology of Egypt. Volume II, Part I. – Cairo, Survey of Egypt.

Jolowicz, H.F. & B. Nicholas. 1972. Historical introduction to the study of Roman law. – Cambridge, Cambridge University Press.

Jones, H.L. 1959. The geography of Strabo. Volume 8, Book XVII and General Index. – Cambridge, Harvard University Press.

MacAlister, D.A. 1900. The emerald mines of northern Etbai. – Geographical Journal of London 16: 537–549.

Mommsen, T., P. Kruger & A. Watson. 1985. The digest of Justinian. Volume 3. – Philadelphia, University of Pennsylvania Press.
Richter, G.M.A. 1971. The engraved gems of the Greeks, Etruscans and Romans. Part II. Engraved gems of the Romans. – London, Phaidon Press.
Rivard, J.–L., B.C. Foster & S.E. Sidebotham. 2002. Emerald city. – Archaeology 55, 3: 36–41.
Shaw, I., J. Bunbury & R. Jameson. 1999. Emerald mining in Roman and Byzantine Egypt. – Journal of Roman Archaeology 12: 203–215.
Sidebotham, S.E., H.M. Nouwens, A.M. Hense & J.A. Harrell. 2004. Preliminary report on archaeological fieldwork at Sikait (Eastern Desert of Egypt), and environs: 2002–2003. – Sahara 15: 7–30.
Sinkankas, J. 1981. Emerald and other beryls. – Radnor, Chilton Book Company.
Siviero, R. 1959. Jewelry and amber in Italy. A collection in the National Museum in Naples. – New York, McGraw–Hill.
Takla, M.A., A.A. Surour & S.M. Omar. 2003. Mapping source of beryllium and genesis of some beryl occurrences in the Eastern Desert of Egypt. – Annals of the Geological Survey of Egypt 76: 153–182.
Walker, S. Ed. 2000. Ancient faces. Mummy portraits from Roman Egypt. – New York, Metropolitan Museum of Art.
Waelkens, M., P. De Paepe & L. Moens. 1990. The quarrying techniques of the Greek world. In: **1990.** Marble – Art Historical and Scientific Perspectives on Ancient Sculpture. – Malibu, J. Paul Getty Museum: 47–72.

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