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DOLERITE POUNDERS: PETROLOGY, SOURCES AND USE

by

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ABSTRACT

Dolerite pounders are hand-held stone tools that were widely used in Egypt from the third to late first millennium BCE for quarrying and dressing granite and other hard rocks. In addition to documenting the size distribution of 1,419 pounders from Aswan and describing red paint markings (owner labels, in part) found on about 4 percent of these, this study refutes two popular misconceptions about the dolerite pounders. First, the desired form of these tools was not the well rounded, nearly spherical balls now commonly seen in the ancient quarries and construction sites. Evidence from a dolerite quarry discovered by the authors in Aswan indicates that the pounders were initially angular, compact, and irregular to sub-rectangular in form. Progressive rounding during use eventually reduced them to a nearly spherical shape by which point they had lost much of their effectiveness and so were discarded. And second, these tools could not have been held by workmen when striking another rock, otherwise the impacts would have caused severe injuries to their hands and wrists. To avoid this, the workmen must have released the pounder just before impact on a downward throw and then caught it on the rebound.

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INTRODUCTION

Until the Egyptians started using iron tools for quarrying in the third or fourth century BCE (Röder 1965:523-524; Harrell and Brown 1999:19-20), hard rocks like granite were quarried and dressed with stone tools referred to variously as "pounders," "mauls" or "hammers." The smaller ones were usually elongated pieces of stone with a narrowed neck where a wooden handle was attached, probably with leather strips (Arnold 1991:260-261). Such a pick- or axe-like tool would have been used for trimming edges and corners off rock masses, or bruising away small areas on rock surfaces. The larger stone tools were unhafted and so hand-held, and these, in their most familiar form, have a well-rounded, sub-spherical shape (Arnold 1991:262). By repeatedly striking a surface with such a tool, and thereby pulverizing it to powder, the hardest rocks can be gradually worn away.

The vast majority of stone tools were fashioned from a black, fine-grained rock that is usually identified as "dolerite." Most of the rest are either fine-grained granite or silicified sandstone (also called quartzite). It is the hand-held, sub-spherical "dolerite pounders" that are the subject of the present paper. Many thousands of these iconic stone tools have been found in Dynastic (Table 1) quarries and mines, and most especially in the New Kingdom granite and granodiorite quarries at Aswan (Figures 1-3; Engelbach 1922:12, 1923:30; Kelany 2003). They have also been reported from many Eastern Desert gold mines (probably largely, if not entirely, of New Kingdom date; Engelbach 1922:12), and quarries for silicified sandstone at Gebel Ahmar near Cairo (Old Kingdom to Roman; Lucas and Harris 1962:410) and hard limestone at Qaw el-Kebir southeast of Assiut (Old or Middle Kingdom to Roman; Clarke and Engelbach 1930:30).

In addition, the present authors have seen dolerite pounders in numerous other Dynastic quarries (Figure 1), including those for basalt at Widan el- Faras (Old Kingdom), gypsum at Umm el-Sawan (Early Dynastic to Old Kingdom), chert in Wadi Umm Nikhaybar (New Kingdom) and Wadi el-Sheikh (Old to Middle Kingdom), silicified sandstone at Gebel Gulab and Wadi Abu Aggag (New Kingdom and Roman), tuff and tuffaceous limestone at Gebel Manzal el-Seyl (Early Dynastic), amazonite at Gebel Mig'if (New Kingdom), amethyst at Wadi el-Hudi (Middle Kingdom), and anorthosite and gabbro gneisses at Chephren's Quarry (Old to Middle Kingdom). Umm el-Sawan is unique among the aforementioned quarries in that its gypsum is a soft rock. Normally during the Dynastic period, the soft rocks (e.g., limestone and non-silicified sandstone) were worked with either copper and, later, bronze tools or the even harder stone tools fashioned from chert (or flint). Precise locations and other information for these quarries can be obtained from Harrell and Storemyr (2009). Large numbers of dolerite pounders have also been observed at Dynastic construction sites, including the pyramid-temple complexes at Giza and Saqqara (Old Kingdom) and El-Lisht (Middle Kingdom) southwest of Cairo (Arnold 1991:260), and on Elephantine Island (Old Kingdom) at Aswan. Pounders were presumably used at New Kingdom construction sites as well, given that they were so widely employed at this time for quarrying and mining.

There are seven important questions that can be asked about dolerite pounders. First, are they truly, geologically speaking, dolerite or some other kind of rock? Second, why was dolerite so widely used for tools? Third, what is the size distribution of the pounders? Fourth, what is the meaning of the red markings found on some of the Aswan pounders? Fifth, where did the stone for the pounders come from? Sixth, what was the original shape of the pounders prior to their first use? And seventh, how were the pounders handled during use? It is with the answers to these questions that this paper is concerned.

PETROLOGY

For geologists the term "dolerite" denotes an igneous rock with the following two characteristics. First, it occurs as tabular or sheet-like bodies (*i.e.*, dikes and sills) that intrude other rocks. And second, it has the same mineralogical composition as two other igneous rocks: "basalt" in volcanic lava flows, and "gabbro" in non-tabular intrusive bodies both larger and deeper than those of dolerite. The term "diabase" (especially in North America) and "microgabbro" are synonymous with dolerite. Mineralogically, according to the widely accepted International Union of Geological Sciences (IUGS) classification of intrusive (plutonic) igneous rocks (Streckeisen 1973:29-30; Brown and Harrell

Table 1. Ancient Egyptian chronology

Late Predynastic Period		c. 3100-2950 BCE	
Dynastic Period	Early Dynastic Period	2950- 2575 BCE	Dynasties 1 - 3
	Old Kingdom	2575 - 2125 BCE	Dynasties 4 - 6
	First Intermediate Period	2125 - 1975 BCE	Dynasties 9 -1 1
	Middle Kingdom	1975 - 1640 BCE	Dynasties 11 - 14
	Second Intermediate Period	1640 - 1540 BCE	Dynasties 15 - 17
	New Kingdom	1540 - 1075 BCE	Dynasties 18 - 20
	Third Intermediate Period	1075 - 715 BCE	Dynasties 21 - 25 (early)
	Late Period	715 - 332 BCE	Dynasties 25 (late) - 30
Greco-Roman Period	Ptolemaic Period	332 - 30 BCE	
	Roman Period	30 BCE - 395 CE	
	Byzantine (or Late Roman) Period	395 - 640 CE	
Islamic Period		640 CE - present	

Note:Dates are taken from Baines and Malak (2000:36-37).

1991:Chart 1), dolerite and its compositional equivalents consist of less than 5 % quartz in the total rock and more than 90 % plagioclase in the total feldspar, with the anorthite content of the plagioclase greater than 50 % and the plagioclase commonly of the 'labradorite' variety. Other rock classifications may not use the same percentages in defining dolerite, but the differences are minor.

Although dolerite is defined primarily on the basis of its quartz and feldspar contents, it also typically contains 10-40 % pyroxene (or secondary amphibole minerals replacing the pyroxene), plus minor amounts (usually totaling less than 10 %) of magnetite, olivine and sphene. Because of its mineralogy, dolerite and its compositional equivalents have a dark gray-to-black color when fresh. When altered by hydrothermal fluids or metamorphic processes, it takes on a greenish cast due to the addition of one or more of the following green minerals: actinolite, chlorite, epidote, and hornblende. Weathering at the Earth's surface commonly oxidizes the iron-bearing minerals and produces iron-oxides such as hematite that can stain the rock a brownish-red color. The mineral grains in dolerite are predominantly less than 5 mm across, so this rock overlaps texturally with basalt (grains mostly less than 1 mm) and gabbro (grains over 1 mm but commonly larger than 5 mm). Thus, if the geologic origin of the rock was unknown and the grain size was between 1 and 5 mm, one could not megascopically distinguish dolerite from basalt or gabbro.

R. Engelbach (1922:12) sent pounders from the Unfinished Obelisk granite quarry in Aswan to geologists W. F. Hume and H. Sadek of the Geological Museum in Cairo, who pronounced them to be "dolerite." This is apparently the beginning of the now widespread practice of referring to these tools as dolerite pounders. In order to verify and further investigate the petrologic identity of the pounders, the authors analyzed 24 stone tools, all megascopically fine-grained, black rocks that were collected from eight Dynastic quarries (Figure 1 and Table 2). The samples were thin-sectioned (i.e., 30 micron-thick slices were mounted on glass slides) and examined using a polarizing petrographic microscope.

Based on these petrographic analyses, all the pounders had compositions compatible with the IUGS classification of dolerite. Mineral grain sizes are highly variable in all samples, but are predominantly less than 3 mm. Given this grain size range (with basalts and gabbros tending to be finer and coarser grained, respectively), and the fact that dolerite dikes are common in the Aswan area as well as throughout the Eastern Desert, it is reasonable to identify these pounders as dolerite.

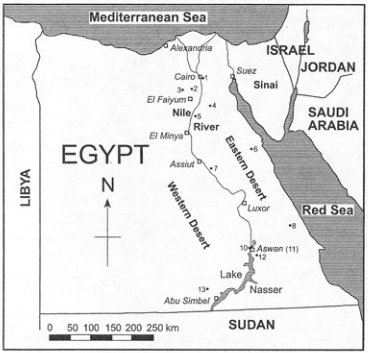

Figure 1. Map of Egypt showing ancient quarry localities where dolerite pounders have been found: 1 – Gebel Ahmar, 2 – Umm el-Sawan, 3 – Widan el-Faras, 4 – Wadi Umm Nikhaybar, 5 – Wadi el-Sheikh, 6 – Gebel Manzal el-Seyl, 7 – Qaw el-Kebir, 8 – Gebel Mig'if, 9 – Wadi Abu Aggag, 10 – Gebel Gulab, 11 – Aswan, 12 – Wadi el-Hudi, and 13 – Chephren's Quarry.

Figure 2. Dolerite pounders from the Unfinished Obelisk granite quarry in Aswan.

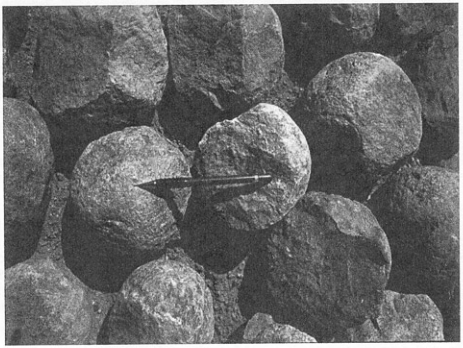

Figure 3. Close-up of the dolerite pounders in Figure 2. Pencil is 14 cm long.

Table 2. Sources of dolerite pounders analyzed

A. Widan el-Faris basalt quarry on Gebel Qatrani in the northern Faiyum (4th to 6th Dynasties, Old Kingdom; number 3 in Figure 1) - Pounders 1, 2, and 3.
B. Wadi Umm Nikhaybar chert quarry in the Wadi Araba area (19th to 20th Dynasties, New Kingdom; number 4 in Figure 1) - Pounder no. 4.
C. Wadi el-Sheikh chert quarry (Old to Middle Kingdom; number 5 in Figure 1) - Pounder no. 5.
D. Gebel Mig'if amazonite quarry in the southern Eastern Desert (18th Dynasty, New Kingdom; number 8 in Figure 1) - Pounders nos. 6 and 7.
E. Wadi Abu Aggag silicified sandstone quarry near Aswan (New Kingdom; number 9 in Figure 1) - Pounders no. 8 and 9.
F. Gebel Gulab silicified sandstone quarry near Aswan (New Kingdom; number 10 in Figure 1) - Pounders nos. 10, 11, 12, 13, 14, and 15.
G. Unfinished Obelisk granite quarry in Aswan (18th to 19th Dynasties, New Kingdom; number 11 in Figure 1 and site A in Figure 13) - Pounders nos. 16, 17, and 18.
H. Osiris Statue granite quarry in Aswan (18th or 19th Dynasty, New Kingdom; number 11 in Figure 1 and site B in Figure 13) - Pounders nos. 19, 20, 21, 22, 23, and 24.

In only a few cases (pounder numbers 5, 8, 9 and 11 in Table 2) is the original mineralogy largely preserved (with primary pyroxene and labradorite plagioclase grains). All other samples are highly altered by hydrothermal fluids and/or other metamorphic processes, with the result that the pyroxene is replaced by secondary amphiboles (the so-called "uralite" assemblage of actinolite and hornblende), and the plagioclase is replaced by sericite mica and clay minerals. Most of the samples (pounder numbers 1-4, 10, 12-19 and 21-23 in Table 2) exhibit one or more of the following deformation features: shearing, brecciation, and veins and patches of secondary quartz. The term "metadolerite" could be applied to the highly altered and deformed rocks, but in the interest of keeping the petrological terminology both simple and consistent with past usage by Egyptologists, it is recommended that all black, fine-grained pounders be referred to as "dolerite."

WHY DOLERITE?

Given their great abundance at Dynastic quarries and construction sites, dolerite pounders were clearly favored above the tools made from other stones. Among the latter, as previously mentioned, fine-grained granite from Aswan and silicified sandstone from both the Aswan and Cairo areas are most common, but anorthosite gneiss from Chephren's Quarry in the Nubian Desert (Harrell and Brown 1994; Harrell 2002:236-238) is also occasionally encountered (Figure 1).

The question is: what made dolerite so popular for pounders? Because they were used to work hard stones, the pounders needed to have a high resistance to impact fracturing, otherwise they would be quickly broken during use. Such strength arises primarily from a rock's texture: i.e., the size of its mineral grains and the manner in which the grains are interconnected. The mineralogy of the rock is only of secondary importance. From experimental studies with other rock types, as well as theoretical considerations (Brace 1961; Clarke 1964; Lowrison 1974:29; Harrell and Blatt 1978), it is to be expected that dolerite's fine-grained, crystalline texture (i.e., contiguous interlocking crystals) would make it one of the most fracture-resistant rocks available to the ancient Egyptians. The reason for this is that crystalline rocks with larger grain sizes have larger pre-existing flaws (i.e., potential fracture surfaces) along the grain boundaries, and they also have fewer grain boundaries to retard the propagation of fractures produced when striking another hard rock. The critical importance of grain size is evident from the fact that it is only the fine-grained granite (grains less than 4 mm) from Aswan that is sometimes used for pounders rather than the far more abundant, but much coarser-grained, granite (grains up to 4 cm) from the same area. Silicified sandstone can be as fine-grained as dolerite, but it has a weaker non-crystalline sedimentary texture, which makes for a less durable pounder.

Any geologist who has tried to break a piece of dolerite with a steel hammer can testify to how very tough this rock is. Engelbach (1922:12) commented that the only way he could break a dolerite pounder was by "hurling [it] down from a height of about 30 feet on to a pile of others, and then only after repeated attempts."

SIZE DISTRIBUTION

The unhafted dolerite pounders were hand-held tools used by individual workmen. This is evident not only from the tomb painting in Figure 4, but especially from the sizes of the pounders – they are all small enough to be held by one man. Engelbach (1922:12; 1923:42) reported for the "hundreds" of dolerite pounders he saw in Aswan (primarily in his excavation of the Unfinished Obelisk) that they vary from about 13 to 33 cm in diameter, and Klemm and Klemm (2001:636) said the pounders they saw in Aswan ranged between 20 and 30 cm in diameter. Elsewhere, dolerite pounders were observed to range up to 30 cm at the El-Lisht necropolis (Arnold 1991:Table 6.2) and up to 40 cm at the Djoser complex at Saqqara (Firth et al. 1935:128).

In the course of excavating the ancient granite quarries around Aswan's Unfinished Obelisk, Kelany (2003) uncovered thousands of dolerite pounders (Figures 2-3). The maximum dimensions of 1,419 of the whole and largely complete ones were measured to the nearest centimeter for the present study, with the results shown in Figure 5. The pounders ranged from 5 to 21 cm across with a mean of about 14 cm. This size range is noticeably smaller than those observed by Engelbach (13-33 cm) and Klemm and Klemm (20-30 cm) for the

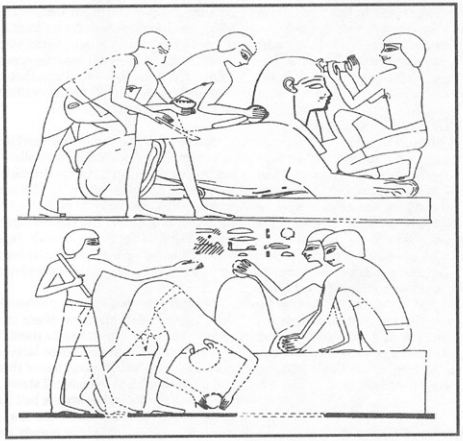

Figure 4. Scene from the Eighteenth Dynasty tomb of Rekmira in Thebes (near Luxor) showing workmen using spherical stone pounders to dress a stone statue (above) and block (below). Adapted from Plate 60 of Davies (1973).

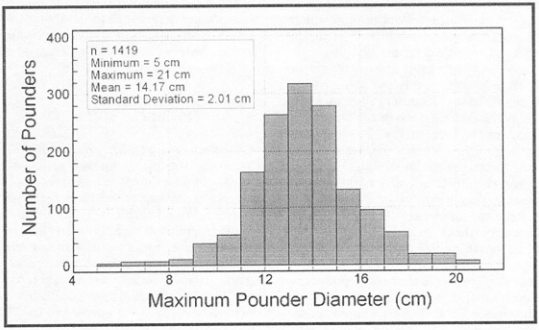

Figure 5. Size distribution of 1,419 dolerite pounders from the Unfinished Obelisk granite quarry in Aswan.

same general area. The reason for this discrepancy is unknown, but it may result from the fact that the size ranges reported by these investigators were based on casual, non-systematic observations rather than on rigorous measurements, as in the present study.

Dolerite is a relatively "heavy" rock with a median density of 2.99 gm/cm³ (Engelbach 1922:12). For spherical pounders, the weights corresponding to the aforementioned sizes (diameters) are as follows: 5 cm, 0.65 kg; 14 cm, 1.44 kg; and 21 cm, 4.85 kg. The weights increase exponentially with size, reaching 14.14 kg and 33.51 kg for pounders with 30 and 40 cm diameters, respectively. Although pounders up to about 15 cm would be small and light enough for a workman to hold in one hand, it is more likely that two hands were used (as depicted in Figure 4) for all except the smallest given the manner in which the pounders were handled, as described in a later section. Although a pounder as large as 40 cm could be lifted by one strong man, in practice it probably took two men to wield it effectively.

RED MARKINGS

In the course of making the size measurements on the 1,419 dolerite pounders from the Unfinished Obelisk quarry, red paint markings were observed on nearly 4 % of them. One of the pounders (Figure 6) has a clearly drawn hieroglyphic sign, which represents either the phonogram "*mr*" or, more likely, the ideogrammatic determinative for "hack up" (Gardiner 1957:33, 516). The rectangle in Figure 7 (left side) is probably the hieroglyphic determinative for "stone" (Gardiner 1957:33, 497). Some markings resemble the fragmentary remains of hieratic script (Figures 8-9), while others are lines or geometric forms of unknown meaning, but possibly representing some form of identification (Figures 7-right side, 10-12). Similar markings have also been seen by the authors on dolerite pounders recovered from the Deutschen Archäologischen Institut's excavations of an Old Kingdom settlement on Aswan's Elephantine Island.

The clear implication is that some pounders were purposely labeled, perhaps with the mark or name of the person or work crew who owned it. Labels of this type have been seen on other ancient quarry tools, such as, for example, the Fourth Dynasty copper gad from Chephren's Quarry, which was inscribed with the name of a work crew (Rowe 1938:391-393, pl. 59). As the pounders were used, these labels would have been progressively obliterated. Thus those markings that now appear meaningless may simply be the partial remains of originally more extensive labels.

Alternatively, some of the markings may be paint picked up from the quarry walls. The walls of the granite quarry around the Unfinished Obelisk have many closely spaced red (and black) lines and other painted markings to both direct and gauge the progress of quarrying. The red paint was made from "ochre," a natural iron-oxide deposit. Some of this paint would inevitably be transferred to the pounders when used on the marked quarry walls.

No other investigator has previously reported the pounder markings, but there is an earlier observation that may relate to them. Engelbach (1922:12), after examing some large number of pounders, said "nearly every one of them has one, and often several, brownish-red stains, which are never seen on the inside when a ball [pounder] is broken." He did not describe the shapes of these stains and considered them merely the result of natural weathering of iron-bearing minerals within the dolerite, with the consequent precipitation of iron-oxide deposits on the weathered exteriors of the pounders. Such deposits are, in fact, to be expected when the dolerite contains magnetite grains (present in nearly all the pounders in Table 2), which quickly weather to produce brownish-red deposits. However, some of Engelbach's "stains" are probably red paint.

DOLERITE SOURCES

Dolerite, as well as other igneous rocks that are either compositionally equivalent (basalt and gabbro) or similar (andesite and diorite), plus the metamorphic rocks derived from these igneous precursors, are all relatively common in Egypt. With the exception of basalt, which is interbedded with sedimentary rocks across parts of northern Egypt, the igneous and metamorphic rocks (including dolerite and metadolerite) are largely confined to the Sinai Peninsula, the mountains of the Eastern Desert, the Aswan area, and the Nubian Desert northwest of Abu Simbel.

Unfortunately, every published geologic report or map gives different names for the same rocks in a given area. This is largely due to the use of different classification schemes (especially in the older literature) or elaborations on the aforementioned IUGS classification. Differences among geologists in both petrologic expertise and analytical methodology also account for some of the variation. This terminological problem is well-illustrated for Aswan, where black, fine-grained igneous and metamorphic rocks occur in both intrusive dikes (a, below) and non-tabular plutons (b, below). These two groups of dolerite-related rocks are variously described as: (a) mica-diabase, diorite-porphyry and basalt dikes and (b) micaceous and hornblende schist plutons (Ball 1907); (a) microdiorite dikes (Rittmann 1953); (a) andesite and lamprophyre dikes and (b) biotite gneiss and schist plutons (El-Shazly 1954); (a) andesite dikes and (b) epidiorite plutons (Attia 1955); and (a) diorite, bostonite, camptonite and dolerite dikes and (b) metadolerite, hornblende schist and gneiss, and amphibolite plutons (Gindy 1956).

Engelbach (1922:12; 1923:42) saw no dolerite quarries in Aswan and so suggested the pounders were imported from the mountains of the Eastern Desert where, he asserted, rounded "balls" of dolerite occur naturally. The present authors have seen outcrops of gabbro, but not dolerite, where the ground is littered with loose, naturally rounded pieces of rock. These pieces, however, are rarely ball-like and are, in any case, weakened by weathering and therefore unsuitable for pounders.

The Aswan area is rich with dolerite and related rock types, and logically should be a source of dolerite pounders. Although Engelbach failed to see them, Klemm and Klemm (1993:315, 2008:241) discovered two sites in Aswan (their 678/679 and 665, and numbers 1 and 2, respectively, in Figure 13), where there are piles and scatters of angular, pounder-size pieces of dolerite near outcrops of the same rock. These authors assumed the dolerite fragments were produced by natural weathering processes but were used as pounders. It is more likely, however, that these outcrops were actively quarried for the pounders. The first of their two sites (678/679) has now been destroyed by urban development, but the other still exists (665; Figure 14). It was located by the present authors and found to have pottery dating generally to the New Kingdom, but also to the Twenty-seventh Dynasty of the Late Period. Klemm and Klemm (1993:421-422, 2008:320-321) did a petrographic analysis of the dolerite from the two sites and showed that the rocks do have the requisite basalt/dolerite/gabbro composition with, due to hydrothermal alteration, the original pyroxene replaced by secondary hornblende. In this regard, the rocks are similar to most of the dolerite pounders analyzed in the present study (pounder numbers 1-4, 10, 12-19 and 21-23 in Table 2).

The present authors found an ancient dolerite quarry on the south side of Aswan near Gebel el-Granite (number 3 in Figure 13). This is a low, sub-circular mound of fine-grained black rock that is about 60 m across and has the form of an irregular pluton rather than a tabular dike. On the published geologic maps of Aswan, this outcrop belongs to a group of rocks that is variously labeled as "micaceous and hornblende schist" (Ball 1907:map), "biotite gneisses and schists" (El-Shazly 1954:plate 7), and "metadolerite (hornblende schists and gneisses, amphibolites)" (Gindy 1956:map).

A sample collected from the outcrop was found to contain mainly andesine plagioclase and hornblende plus quartz and biotite, along with minor sphene and magnetite. Essentially all grains are less than 1 mm across. Metamorphic foliation is present, but is too poorly developed for the structural terms "schist" or "gneiss" to apply. Instead, this rock is best described as an "amphibolite," the metamorphic equivalent of dolerite, in which the original labradorite plagioclase and pyroxene have been replaced by andesine plagioclase and hornblende, respectively. "Metadolerite" would also be an acceptable name for this rock. With its metamorphic foliation, however, it is strikingly different from the 24 dolerite pounders in Table 2. Nevertheless, this rock is definitely a source of "dolerite" pounders.

The metadolerite outcrop has numerous places where both the bedrock surface and the loose boulders on top of it have been worked (Figures 15-16). Although no tool marks or other obvious traces of extraction are visible (with the two exceptions noted below), these places show relatively unweathered and unnatural-looking surfaces that could only have been produced by quarrying. Also, beside each of them is a pile of

angular pieces of metadolerite, which individually range from about 10 to 30 cm across, with most between 15 and 25 cm. These are new pounders (or pounder blanks), and it is estimated that there are between 1,500 and 2,000 of them in the quarry. Littering the ground, and in places forming a nearly continuous pavement, are metadolerite chippings, which are the by-product of the production of the pounders (Figure 17).

The actual extraction of the metadolerite was almost certainly done with the quarry's own pounders. It appears that pieces of rock were knocked off the bedrock surfaces and boulders, and then further reduced by trimming to the required size. The final product was an angular, compact, irregular to sub-rectangular piece of metadolerite that was small enough to be held in one or two hands. Unfortunately, no pottery analysis has yet been attempted for this site and so it can only be dated generally to the Dynastic period, based on the assumption that these pieces of rock are, in fact, new pounders.

At the northern edge of the quarry are two large pieces of metadolerite, each of which has a single primitive wedge hole (Figures 18-19). The wedge holes found in the Aswan granite and granodiorite quarries, as well as in all other hardrock quarries in Egypt, were cut with iron chisels and then fitted with iron wedges, which, when hammered, would split the rock along the line of wedge holes. Primitive ones like those in the metadolerite quarry have been reported only from Late Period and Ptolemaic quarries in the Eastern Desert (Harrell and Brown 1999:19-20; Harrell et al. 2002:211; Harrell 2009:179,181). Beginning with the Roman period, wedge holes were more carefully and systematically cut with smooth interior surfaces and more regular outlines. While it might seem that the wedge holes in the metadolerite quarry must be younger than, and hence unrelated to, the production of stone tools, it is also possible that, for a brief time, both iron wedges and pounders were employed together at Aswan. Perhaps dolerite pounders, a tool of long-proven effectiveness, were seen as a low-cost alternative to iron tools, at least in the early years after the iron-wedge technology was introduced and iron tools were still scarce and expensive.

Besides the one definite and two probable dolerite quarries now known, there must be others in the Aswan area, given the great abundance and variety of dolerite and related rocks used for pounders. For example, one probable source is actually within the Unfinished Obelisk granite quarry. This is a nearly 1 m wide dolerite dike at the northwest corner of the quarry (Figure 20), near the administrative offices for the site and just above the pounders shown in Figures 2-3. It looks like a section of this dike about 4 m long by 1-2 m deep has been removed. The area has been so heavily disturbed by ancient granite quarrying, modern construction, and archaeological excavations that one cannot say with certainty that this was a quarry for dolerite pounders, but it seems likely that this is the case.

For the source of dolerite pounders found in the quarries of the Aswan area, one need look no further than the local bedrock, but for those found elsewhere in Egypt, they could have come from closer sources in the Eastern Desert. However, it would not be surprising, at the Nile Valley sites at least, if the pounders came from Aswan. A good example of how far the rock used for pounders can travel is the anorthosite gneiss from Chephren's Quarry. Numerous unused pieces of this stone (Figure 21) were found at the Early Dynastic to Old Kingdom quarry for gypsum at Umm El-Sawan in the Faiyum (Harrell 2002:234), 830 km north of Chephren's Quarry, which is the only source in Egypt for this unusual stone (quarries 2 and 13, respectively, in Figure 1). Presumably, the anorthosite gneiss was brought to this site, as well as to others in the Nile Valley where it has been reported, for use as pounders. This stone has the same grain size as dolerite but its unusual crystalline texture, grains of similar size with triple-point contacts (Harrell and Brown 1994:footnote 20), should make it even more fracture resistant.

POUNDER SHAPE

It is implicitly assumed by nearly all previous investigators that a well-rounded, sub-spherical shape was the desired form for dolerite pounders because this was the most comfortable shape for the workmen to hold. The Eighteenth Dynasty tomb painting in Figure 4 certainly re-enforces this notion, but it is probably an idealized scene where the pounders are shown in their most recognizable form. As previously mentioned, Engelbach

(1922:12; 1923:42) thought the dolerite pounders came from the Eastern Desert with a naturally acquired ball-like shape. Other authors have apparently either accepted this view or thought the pounders were somehow rounded by the workmen prior to their use. The only dissenting views thus far have been Röder (1965:480-481) and Klemm and Klemm (1993:313-315, 2008:239-241), who argued that the pounders were originally angular pieces of rock that became rounded through use. The ball-like pounders like those seen in Figures 2-3 would therefore be the worn-out discards. The present authors are in complete agreement with this interpretation. Some may argue that angular pounders are too uncomfortable for the workmen to hold, but it is a quick and easy matter to knock off the worst of the sharp edges and corners prior to use. Also, whether an angular pounder is comfortable or not really depends on how it is handled during use.

A final indication that dolerite pounders were originally angular is that they are sometimes found in this form in the quarries for other rock types. For example, Figure 22 shows a new, unused pounder in the Wadi Abu Aggag quarry for silicified sandstone (Harrell and Madbouly 2006). This particular example is fine-grained granite, but similarly shaped dolerite pounders have also been found. Angular pounders were originally present in the Unfinished Obelisk granite quarry, but when this site was excavated, they were not recognized as ancient tools and were discarded. Now only the well-rounded pounders remain.

POUNDER HANDLING

Along with having an originally nearly spherical shape, it is also widely assumed by scholars that stone pounders were held by the quarrymen when striking another rock. The problem with doing this should be immediately obvious. The experimental archaeologist D. A. Stocks (2003:43) said it well in wondering how a "worker's hand and wrist were jolted with each blow...which after many blows would cause injury and pain...[and so] probably suffered some form of repetitive strain injury." Such injury is surely unavoidable if the pounder is still held at the time of impact. Arnold (1991:37) seems to recognize that the pounders had to be handled differently in suggesting that the workmen were employing "rhythmic and regular bounces of...dolerite balls." In his quarrying experiments with dolerite pounders at Aswan, Engelbach (1922:13) "threw the pounder down and caught it on the rebound" and observed that this "broke up the granite at a much greater rate" than if the pounder were still held at impact. He dismissed this method, however, as too impractical for the workmen because the pounders rebounded at "very unexpected angles."

The present authors disagree with Engelbach's assessment, based on their own informal experiments. With only a little practice, it is easy to release the pounder an instant before striking the rock and then catching it on the rebound before it rises more than a centimeter or two above the rock surface. This bouncing technique solves two problems. First, it is not necessary for the pounder to fit comfortably into the hands of the workmen, because it is not held at the time of impact and also does not need to be held as tightly on the downward throw. And second, releasing the pounder just prior to impact prevents injuries to the hands and wrists. Handling pounders in this way probably necessitated that they be held in two hands for better control, as depicted in Figure 4, even when small and light enough to be wielded with one hand.

Engelbach (1922:13; 1923:48) and Röder (1965:509-510) conducted experiments on the rate of granite quarrying using dolerite pounders. Röder managed 2-3 cm^3/min and Engelbach achieved 7.5 cm^3/min, but both agreed that the more experienced ancient quarrymen could probably remove about 12 cm^3/min. Röder and Engelbach were apparently holding the pounders at the time of impact, but had they been bouncing the pounders, they probably would have achieved higher rates and been able to sustain them over longer periods.

Although there is no question that the dolerite pounders found in hard rock quarries were used to extract blocks of stone, this does not preclude their being used for secondary purposes. For example, Junker (1951:16) experimentally demonstrated that pounders can be placed under large stone blocks and used as rollers for moving the blocks. In order for this to work, however, the pounders would have to be nearly spherical and of relatively uniform size, and the ground surface would have to be both flat and hard.

CONCLUSIONS

The hand-held stone tools known as "pounders" and used for quarrying and dressing hard rocks during the Dynastic period are usually fashioned from a black, fine-grained rock widely referred to as "dolerite." Petrologic analyses confirm that these pounders are indeed either dolerite, an intrusive igneous rock, or metadolerite when slightly metamorphosed. Dolerite was favored for pounders because it was one of the hardest rocks available to the ancient Egyptians. Its fine grain size and crystalline texture give it a high resistance to impact fracturing.

The sizes of 1,419 dolerite pounders from the Unfinished Obelisk granite quarry in Aswan were found to range between 5 to 21 cm across and average about 14 cm. Other studies have found that pounders up to about 30 cm across are also common. About 4% of the 1,419 pounders examined bear markings in brownish-red paint. These represent the abraded remains of labels or, in some cases, paint picked up from the quarry walls.

Dolerite and metadolerite outcrops are common in the Aswan area, as well as in the mountains of the Eastern Desert and, thus, there are many potential dolerite sources for the pounders. Those pounders found in the granite, granodiorite and silicified sandstone quarries in and near Aswan came from the local dolerite and metadolerite outcrops, where one definite and two probable pounder quarries have been discovered and others probably exist. The dolerite pounders found in quarries and construction sites in or near the Nile Valley could have come from the Eastern Desert, but most likely originated in Aswan.

The stereotypical dolerite pounders are well rounded, nearly spherical balls, and this has misled many into believing that such a form was the most desirable shape for this tool because it is the most comfortable to hold. This form, however, was acquired only after much use. Evidence from the Aswan dolerite quarries, as well as quarries for other rock types where pounders were used, indicate that the dolerite pounders were initially angular, compact, and irregular to sub-rectangular in form. With continued use and progressive rounding of the edges and corners, the pounders lost much of their effectiveness and were eventually discarded when they acquired a nearly spherical form.

It is widely assumed that dolerite pounders were tightly held in one or two hands when striking another rock during quarrying or block dressing. This cannot have been the case, however, because such a practice would quickly cause severe injury to the workmens' hands and wrists. Experiments demonstrate that the most painless and efficient means of using a pounder is to release it just before impact and then catch it on the rebound. It is this kind of bouncing motion that the ancient Egyptians probably used when employing this tool.

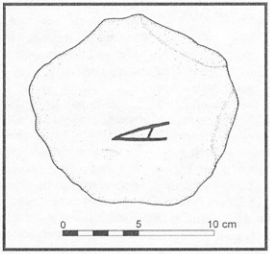

Figure 6. Hieroglyphic sign for either the phonogram '*mr*' or, more likely, the determinative 'to hack' in red paint on a dolerite pounder from the Unfinished Obelisk granite quarry in Aswan.

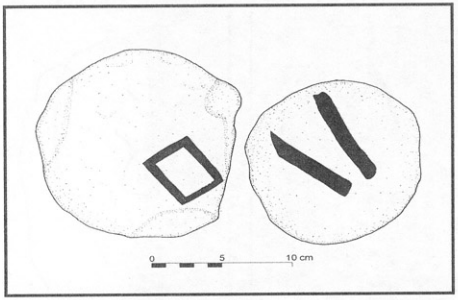

Figure 7. Hieroglyphic sign for the determinative 'stone' (left) and parallel lines of unknown meaning (right) in red paint on two dolerite pounders from the Unfinished Obelisk granite quarry in Aswan.

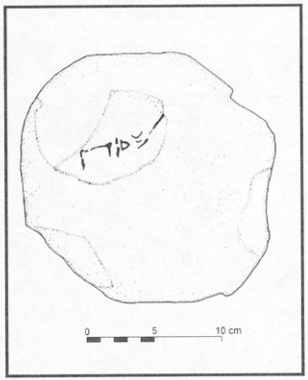

Figure 8. Fragmentary remains of a hieratic inscription in red paint on a dolerite pounder from the Unfinished Obelisk granite quarry in Aswan.

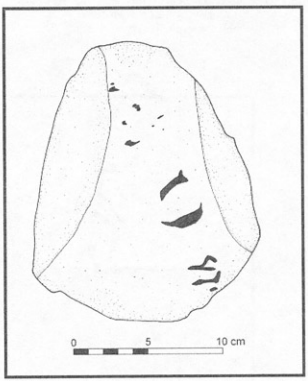

Figure 9. Fragmentary remains of a hieratic inscription in red paint on a dolerite pounder from the Unfinished Obelisk granite quarry in Aswan.

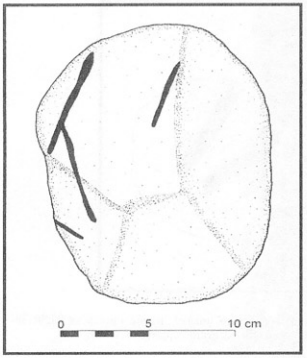

Figure 10. Lines of unknown meaning in red paint on a dolerite pounder from the Unfinished Obelisk granite quarry in Aswan.

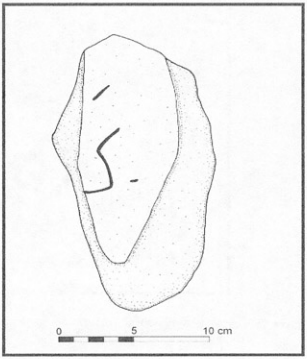

Figure 11. Lines of unknown meaning in red paint on a dolerite pounder from the Unfinished Obelisk granite quarry in Aswan.

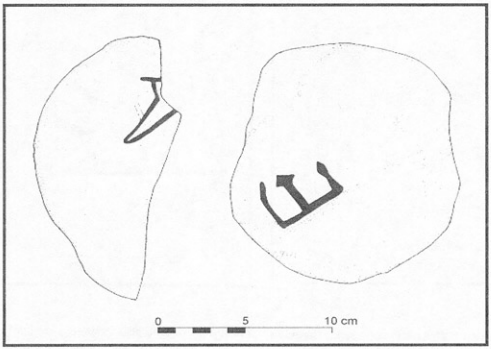

Figure 12. Markings of unknown meaning in red paint on two dolerite pounders from the Unfinished Obelisk granite quarry in Aswan.

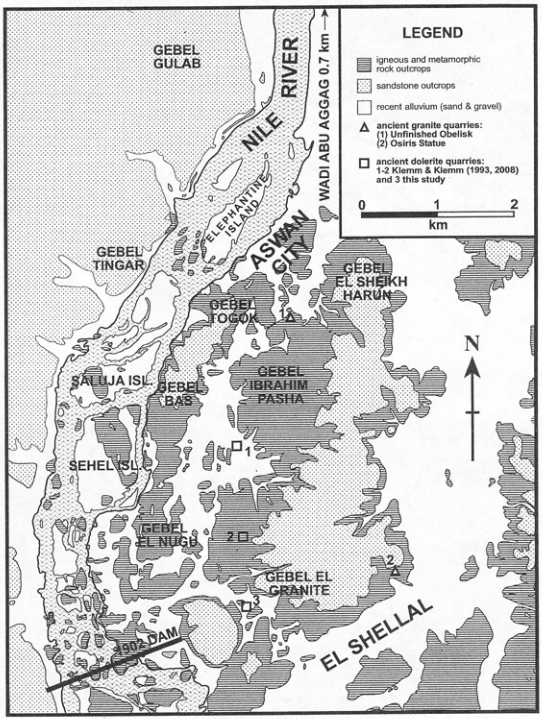

Figure 13. Map of the Aswan area showing ancient granite and dolerite quarries mentioned in the text. Geology and topography from Ball (1907:pl. 2) as republished in Hume (1935:pl. 158).

Figure 14. Scatter of pounder-size pieces of dolerite at Aswan site 665 of Klemm and Klemm (1993:315, 2008:241) and site number 2 in Figure 13.

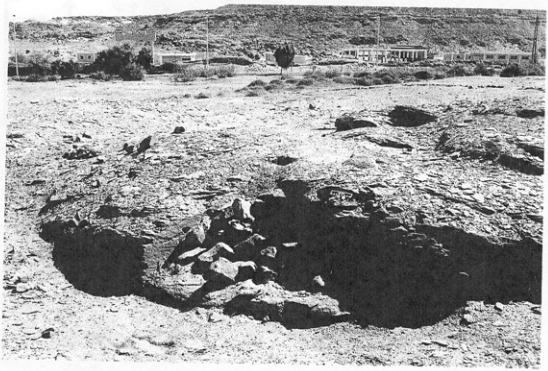

Figure 15. Worked bedrock surface with dolerite blanks in the metadolerite quarry near Gebel el-Granite in south Aswan.

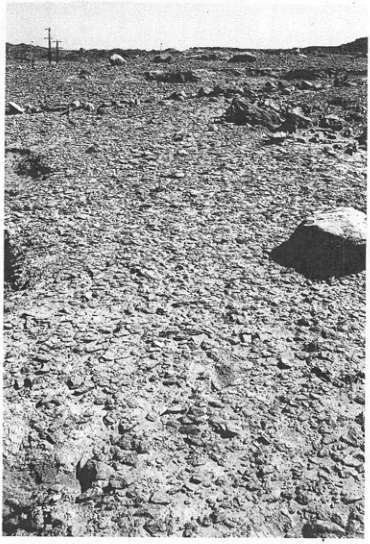

Figure 17. Ground surface littered with dolerite chippings in the metadolerite quarry near Gebel el-Granite in south Aswan.

Figure 16. Worked boulder with dolerite blanks in the metadolerite quarry near Gebel el-Granite in south Aswan.

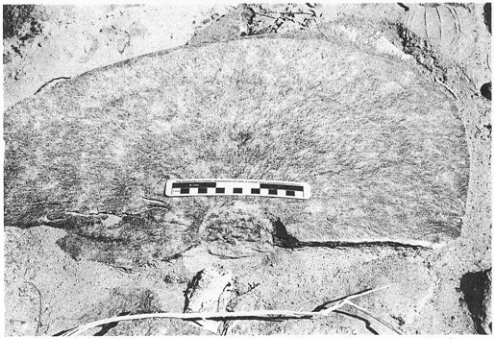

Figure 18. First of two wedge holes (centered below the photo scale) in the metadolerite quarry near Gebel el-Granite in south Aswan.

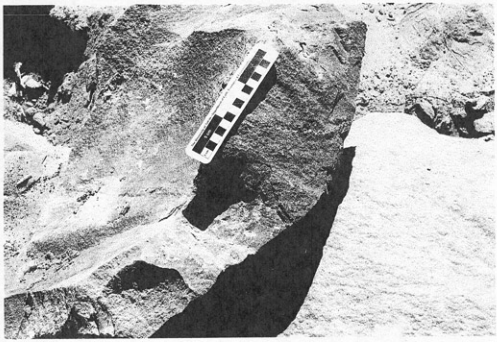

Figure 19. Second of two wedge holes (just below and to the left of the photo scale) in the metadolerite quarry near Gebel el-Granite in south Aswan .

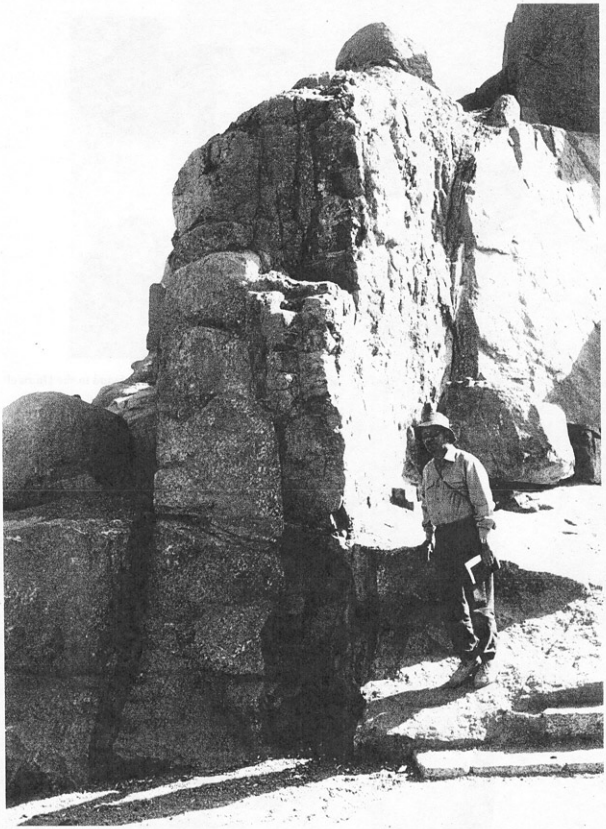

Figure 20. Dolerite dike (the dark vertical rock layer just to the right of the man) in the Unfinished Obelisk granite quarry in Aswan.

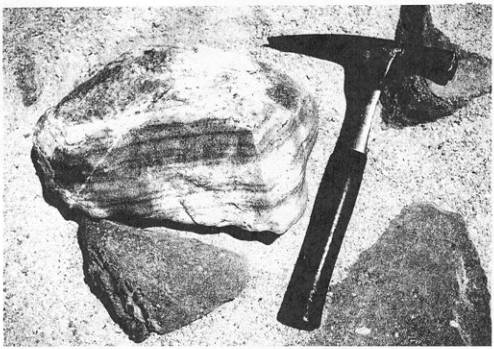

Figure 21. Piece of anorthosite gneiss from Chephren's Quarry in the Nubian Desert as found in the Umm el-Sawan gypsum quarry in the Faiyum. Hammer is 28 cm long.

Figure 22. Unused pounder of fine-grained granite in the Wadi Abu Aggag silicified sandstone quarry near Aswan. Hammer is 27 cm long.

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