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James A. Harrell

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The building stones of ancient Egypt are those relatively soft, plentiful rocks used to construct most temples, pyramids, and mastaba tombs. They were also employed for the interior passages, burial chambers, and outer casings of mud-brick pyramids and mastabas. Similarly, building stones were used in other mud-brick structures of ancient Egypt wherever extra strength was needed, such as bases for wood pillars, and lintels, thresholds, and jambs for doors. Limestone and sandstone were the principal building stones employed by the Egyptians, while anhydrite and gypsum were also used along the Red Sea coast. A total of 128 ancient quarries for building stones are known (89 for limestone, 36 for sandstone, and three for gypsum), but there are probably many others still undiscovered or destroyed by modern quarrying.

إعتاد المصريون القدماء في بناء المعابد والمصاطب والأهرام، على استخدام أحجار غير صلبة نسبيا. استخدمت كذلك في الممرات الداخلية وحجرات الدفن وفي الكساء الخارجي لمصاطب وأهرام الدولة الوسطى المشيدة بالطوب اللبن. وبالمثل فقد استخدمت الأحجار للأبنية الخشبية وكذلك المشيدة بالطوب اللبن لما تتطلبه من تقوية للأعتاب العلوية والسفلية وأكتاف الأبواب وقواعد الأعمدة الخشبية. استخدم المصريون الحجر الجيري والحجر الرملي كأساس للبناء، بينما كانا العنصران الجبس والأنهدريت مستخدمين على طول ساحل البحر الأحمر. ويعتبر إجمالي المحاجر المخصصة للبناء التي عرفت قديما حوالي ١٣٥ محجراً (منها ٩٦ محجرا للحجر الجيري و٣٦ للحجر الرملي و٣ محاجر للجبس)، ولكن من المرجح وجود محاجر أخرى لاتزال هناك لم تكتشف بعد، أو ربما دمرت حديثا جراء أعمال التحجير الحديثة.

The building stones of ancient Egypt are those relatively soft, plentiful rocks used to construct most Dynastic temples, pyramids, and mastaba tombs. For the pyramids and mastabas made largely of sun-dried mud-brick, building stones were still employed for the interior passages, burial chambers, and outer casings. Similarly, building stones were used in other mud-brick structures of ancient Egypt (e.g., royal palaces, fortresses, storehouses, workshops, and common dwellings) wherever extra strength was needed, such as bases for wood pillars, and lintels, thresholds, and jambs for doors, but also occasionally for columns. Ptolemaic and Roman cities along the Mediterranean coast, Alexandria chief among them, followed the building norms of the rest of the Greco-Roman world, and so used stone not only for temples but also for palaces, villas, civic buildings, and other structures. Limestone and sandstone were the principal building stones used by the Egyptians. These are sedimentary rocks, the limestone consisting largely of calcite ($CaCO_3$) and the sandstone composed

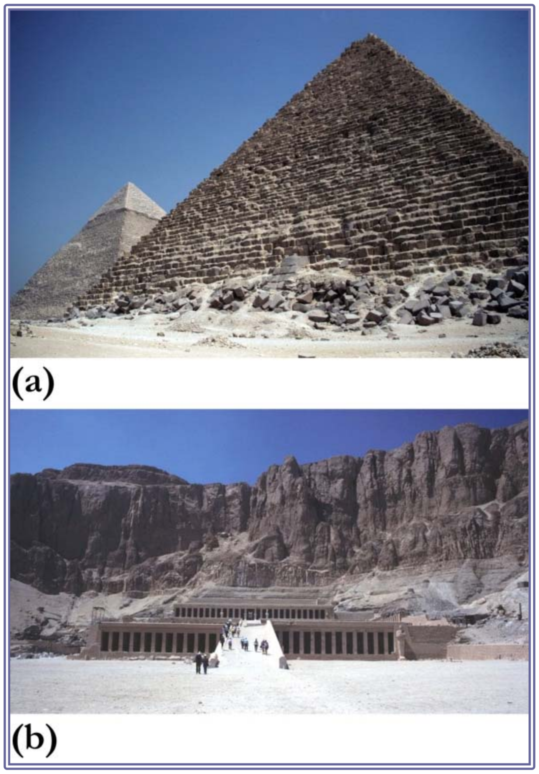

Figure 1. Examples of structures built with limestone: a) pyramids of kings Menkaura, foreground, and Khafra, background (Dynasty 4, Giza) (note tumbled blocks of Aswan granite and granodiorite from lower courses of Menkaura pyramid, and remaining casing of Tura-Masara limestone at top of Khafra pyramid); b) limestone funerary temple of Queen Hatshepsut, Deir el-Bahri (Dynasty 18, Thebes).

of sand grains of mostly quartz (SiO_2) but also feldspar and other minerals. The Egyptian names for limestone were *jnr ḥḏ nfr n ꜥjn* and *jnr ḥḏ nfr n r-ꜣw*, both translating as "fine white stone of Tura-Masara" (*ꜥjn* and *r-ꜣw* referring, respectively, to the cave-like quarry openings and the nearby geothermal springs at Helwan). Sandstone was called *jnr ḥḏ nfr n rwḏt*, or occasionally *jnr ḥḏ mnḫ n rwḏt*, both meaning "fine, or excellent, light-colored hard stone." Although usually translated as "white," here *ḥḏ* probably has a more general meaning of "light colored." Sandstone is not normally considered a hard rock (*rwḏt*), but it is often harder than limestone. In the above names, the *nfr* (fine) or *ḥḏ* or even both were sometimes omitted, and in the term for sandstone the *n* was later dropped (Harris 1961: 69 - 72).

From Early Dynastic times onward, limestone was the construction material of choice for temples, pyramids, and mastabas wherever limestone bedrock occurred—that is, along the Mediterranean coast and in the Nile Valley from Cairo in the north to Esna in the south (figs. 1a, 2). Where sandstone bedrock was present in the Nile Valley, from Esna south into Sudan, this was the only building stone employed, but sandstone was also commonly imported into the southern portion of the limestone region from the Middle Kingdom onward (figs. 2 - 4). The first large-scale use of sandstone occurred in the Edfu region where it was employed for interior pavement and wall veneer in Early Dynastic tombs at Hierakonpolis and for a small 3rd Dynasty pyramid at Naga el-Goneima, about 5 km southwest of the Edfu temple. Apart from this pyramid, the earliest use of sandstone in monumental architecture was for some Middle Kingdom temples in the Theban region (e.g., the Mentuhotep I mortuary temple at Deir el-Bahri and the Senusret I shrine at Karnak). From the beginning of the New Kingdom onward, with the notable exception of Queen Hatshepsut's limestone mortuary temple at Deir el-Bahri (fig. 1b), most Theban temples were built either largely or entirely of sandstone. Further into the limestone region, sandstone was also used for the Ptolemaic and Roman Hathor temple at Dendara, portions of the Sety I and Ramesses II temples at Abydos, and the 18th Dynasty Aten temple at el-Amarna. The preference for sandstone over limestone as a building material coincided with the transfer of religious and political authority from Memphis in Lower Egypt to Thebes in the 18th Dynasty. The Egyptians also recognized at this time that sandstone was superior to limestone in terms of the strength and size of blocks obtainable, and this permitted the construction of larger temples with longer architraves.

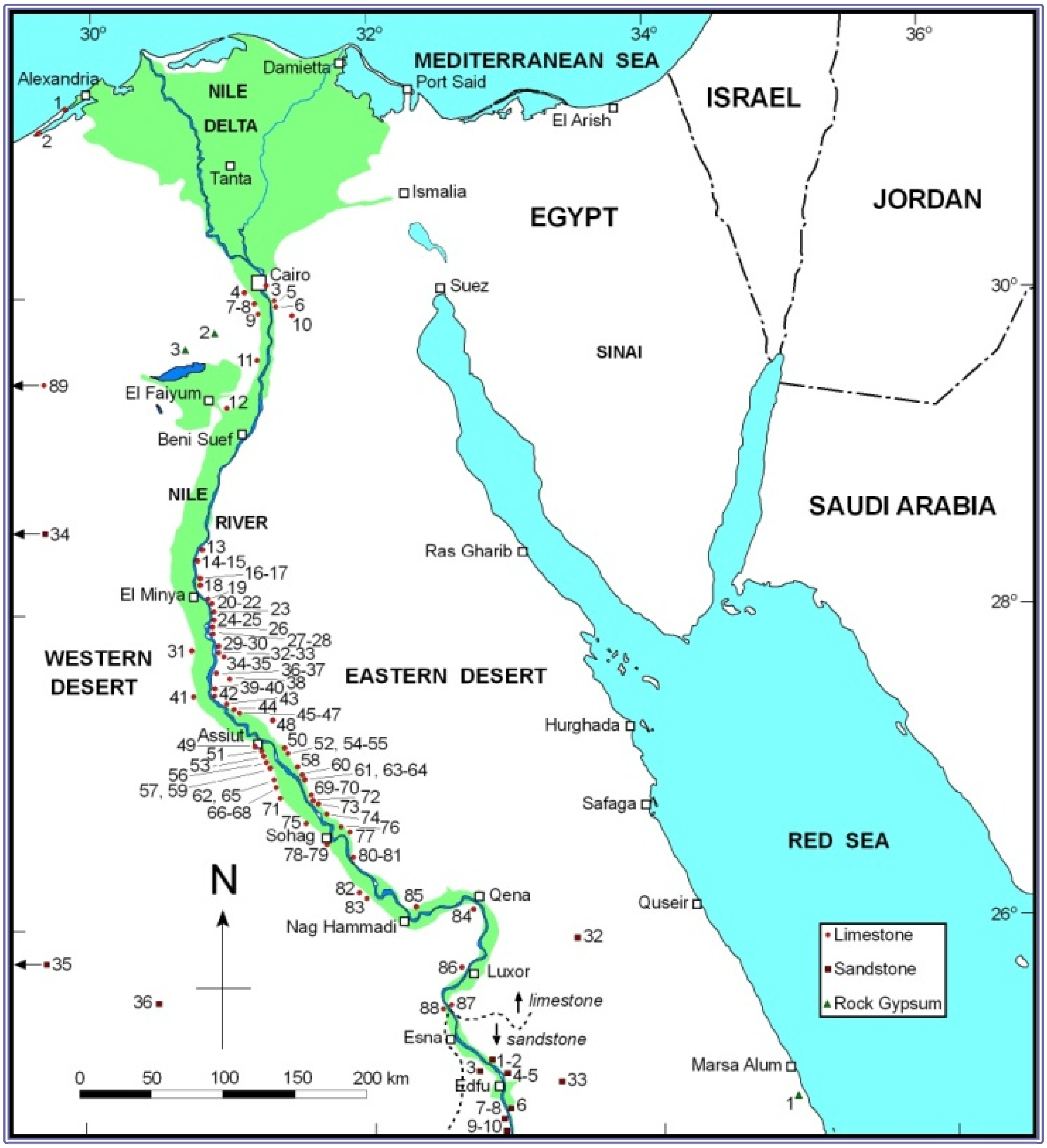

Figure 2. Map of ancient building-stone quarries in northern and central Egypt (numbered).

The Serabit el-Khadim temple in the Sinai is of sandstone, and temples in the Western Desert oases were built of either limestone (Fayum and Siwa) or sandstone (Bahriya, Fayum, Kharga, and Dakhla), depending on the local bedrock. In the Eastern Desert, limestone was used for the facing on the Old Kingdom flood-control dam in Wadi Garawi near Helwan (the "Sadd el-Kafara"; Fahlbusch 2004), and sandstone was the building material for numerous Ptolemaic and Roman road stations. Both types of bedrock in the Nile Valley and western oases hosted rock-cut shrines and especially tombs, and these are the sources of many of the relief scenes now in museum and private collections. Limestone and sandstone were additionally employed for statuary and other non-architectural applications when harder and more attractive ornamental stones were either unaffordable or unavailable. In such cases, the otherwise drab-looking building stones were usually painted

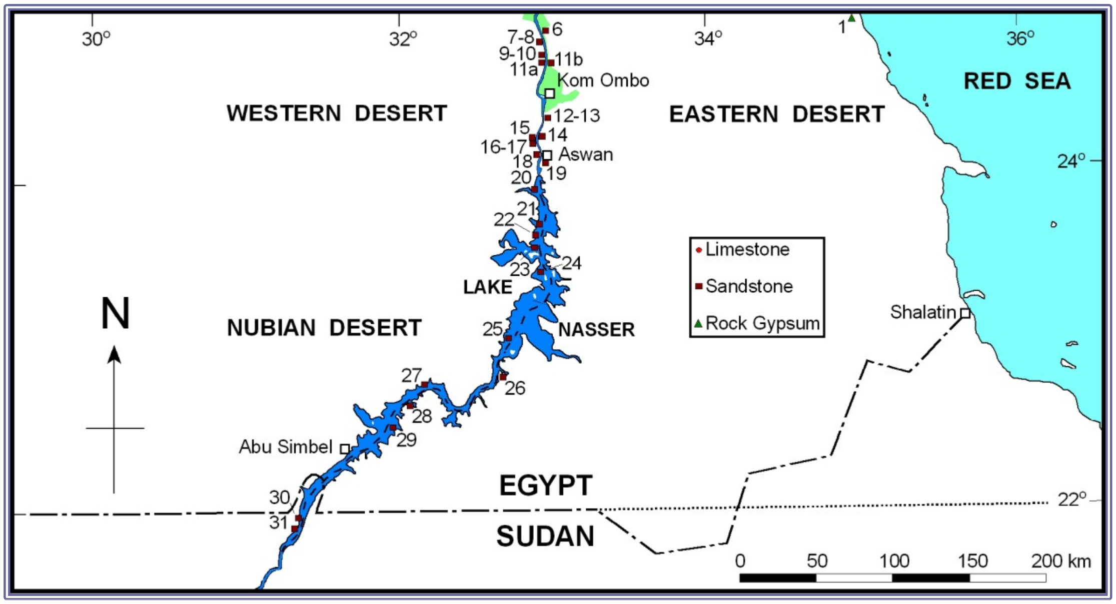

Figure 3. Map of ancient building-stone quarries in southern Egypt (Nubia) (numbered).

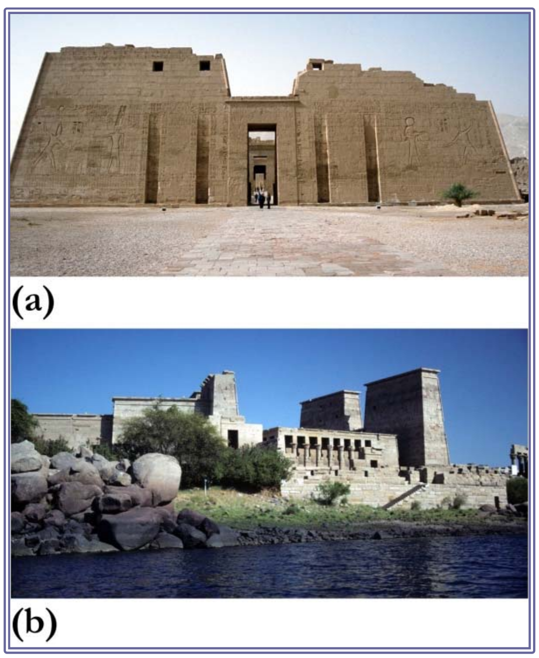

Figure 4. Examples of structures built with sandstone: a) funerary temple of Ramesses III, Medinet Habu (Dynasty 20, Thebes); b) Philae temple (Ptolemaic and Roman Periods, near Aswan).

in bright colors. Conversely, structures built of limestone and sandstone often included some ornamental stones, most notably granite and granodiorite from Aswan (see fig. 1a), as well as silicified sandstone, but also basalt and travertine in the Old Kingdom (see Harrell 2012c).

The only other building stones used in ancient Egypt are the closely related rock anhydrite and rock gypsum. The former consists predominantly of the mineral anhydrite ($CaSO_4$) and the latter, which the Egyptians referred to as *qḏ* (*qedj*), of the mineral gypsum ($CaSO_4 \bullet 2H_2O$). The Egyptian *qḏ* is derived from an Akkadian word, which is also the source of the later Greek γυψος (*gypsos*), and Latin and English "gypsum" (Harris 1961: 90 - 91). Although technically incorrect, geologists usually refer to these rocks by just their mineral names and this convention is followed here. Both anhydrite and gypsum were obtained from outcrops along Egypt's Red Sea coast and employed for temples and other important buildings in the Ptolemaic and Roman port cities of Berenike (modern Berenice) and the putative Nechesia (modern Marsa Nakari) south of Marsa Alum, and also for the walls of the late Roman fortress at Abu Sha'ar near Hurghada (el-Ghardaqa) (fig. 5). Along stretches of the Red Sea coast where these stones were absent, other locally available rocks were used, such as limestone at the Roman port city of Myos

Figure 5. Examples of structures built with anhydrite and gypsum: a) gypsum gate in wall of Abu Sha'ar fortress (late Roman Period; near Hurghada [el-Ghardaqa]); b) anhydrite and gypsum ashlars at Marsa Nakari, the putative ancient Nechesia (early Roman Period; near Marsa Alum).

Hormos (modern Quseir el-Qadim). Even at sites where some construction was done with anhydrite and gypsum, other materials were also utilized, including limestone at Marsa Nakari, and fossil coral (or "madrepore") heads at Berenike. Geologically speaking, the variety of rock gypsum used is known as alabaster gypsum or simply alabaster. This should not be confused with "Egyptian alabaster," which is a common misnomer for travertine, a calcitic rock that is one of the main ornamental stones used by the ancient Egyptians (see Harrell 2012c).

When gypsum is heated to between 100 - 200°C, it loses three-fourths of its water content to become calcium sulphate hemihydrate ($CaSO_4 \cdot \frac{1}{2}H_2O$), a material commonly known as "burnt gypsum" or "plaster of Paris." When mixed with water, it recrystallizes back to gypsum and in the process forms a moderately hard, solid material. Such "gypsum plaster" was produced from late Predynastic times onward, and was used to fill cracks and irregularities in the stone walls and ceilings of temples and tombs, and to cover surfaces in mud-brick buildings (Lucas 1962: 76 - 79; Arnold 1991: 292 - 293). The plastered surfaces were firm enough to be carved with reliefs and painted. Gypsum plaster was also sometimes employed as a sculptural medium as well as for repairs to stone statues. A mixture of gypsum and sand aggregate was commonly used for mortar between stone blocks, especially in Old Kingdom pyramids and mastabas.

"Concrete" or "lime plaster" made from limestone first appeared in Egypt during the Ptolemaic Period. Its late development in comparison to gypsum plaster stems from the much higher temperatures required (900 - 1000°C) to reduce (calcine) calcite ($CaCO_3$) to "quick lime" (CaO). When powdered quick lime is mixed with water (a process called "slaking"), it solidifies as calcium hydroxide ($Ca[OH]_2$), which over time undergoes recarbonation from atmospheric carbon dioxide gas (CO_2) to yield calcite (Adam 1994: 65 - 66, 72 - 74). For extra strength, sand or gravel aggregate was usually added to the quick lime/water mix. When the concrete needed to set underwater or be impermeable to water, crushed fired brick or pottery sherds (both ceramics made largely from clay minerals) were added to the mix to produce the so-called "hydraulic plaster" with its distinctive pinkish color due to the ceramic additives. There are a few individuals, on the scholarly fringes, who have argued that blocks of concrete, rather than of limestone, were used to build the Old Kingdom pyramids at Giza (e.g., Davidovits and Morris 1988), but these claims have been resoundingly refuted (e.g., Folk and Campbell 1992; Harrell and Penrod 1993). It has also been suggested that concrete was made as early as the Old Kingdom and used for mortar (Klemm and Klemm 1991), but the evidence for this is unconvincing.

Quarries

Table 1 lists the 128 known building-stone quarries of ancient Egypt, including 89 for limestone, 36 for sandstone, and three for gypsum, one of the latter also supplying anhydrite. A locality description is provided for each quarry along with its period of activity and general size (see table's endnotes for definitions of terminology and abbreviations used). Unless otherwise indicated in the table, the quarries are still either largely or entirely intact. Quarry locations are plotted in Figures 2 and 3. The building stones are sedimentary rocks belonging to various geologic formations. Numerous, conflicting stratigraphic units have been defined by geologists, but the formations described in Table 1 are the widely accepted ones of Klitzsch et al. (1986 – 1987) and Hermina et al. (1989). From these descriptions it can be seen that the character of limestone or sandstone from a given quarry will vary according to the formation supplying it. Because of their great value in cement production, far more geological information has been published on the limestone formations than on those of sandstone or gypsum, and this difference is reflected in the level of detail in the formation descriptions. The geologic ages of sedimentary rock layers (and consequently also formations) decrease from south to north in the Nile Valley due to their northerly inclination, and this means that quarry-stone characteristics also change in a downriver direction. With rare exception, it is not yet possible to identify by analytical means the specific quarry supplying a given building-stone sample, but the formation and, hence, general location in the Nile Valley can usually be established by petrographic microscopy. Although the list of known ancient quarries is long, it is still far from complete. There are undoubtedly many more quarries awaiting discovery, as well as others that are forever lost because they have been destroyed through urban growth, modern quarrying, or natural erosion and weathering. Modern quarrying of limestone for the cement industry and sandstone for rough construction blocks is responsible for most of the destruction. Although not destroyed, numerous sandstone quarries are no longer accessible because they are now under Lake Nasser.

The building stones used at ancient construction sites usually came from nearby quarries. This has been convincingly demonstrated by Klemm and Klemm (2010) for the Memphite necropolis, although few actual limestone quarries are known for this region (others are probably buried under wind-blown sand or obscured by weathering of exposed outcrops). A good example of one of the known quarries is beside the 4th Dynasty Khafra pyramid at Giza (no. 4 in Table 1 and Figures 2 and 6a). Notable exceptions to the local derivation of building stones are the high-quality limestones from Tura and Masara (nos. 5 - 6 in Table 1 and Figure 2) and sandstone from Gebel el-Silsila (no. 11 in Table 1 and Figure 3). These quarries, which are among the largest in Egypt, provided large, fracture-free blocks of uniform color and texture (fig. 6), and these were employed at sites distant from the quarries. The Tura and Masara limestones, for example, were used extensively for the exterior casing on Old and Middle Kingdom pyramids and mastabas in the Memphite necropolis as well as for the linings of interior passages and burial chambers within these structures. It has been claimed that this limestone was carried as far as Upper Egypt for other construction applications but this is unconfirmed. The Gebel el-Silsila sandstone was the principal building material for temples

Figure 6. Examples of opencut limestone quarries: a) quarry for pyramid core stones beside the Khafra pyramid (part of no. 4 in Table 1 and Figure 2); b) Sultan Pasha quarry (no. 19 in Table 1 and Figure 2); c) Beni Hassan el-Shuruq quarry (no. 25 in Table 1 and Figure 2).

in the Theban region, over 100 km north of the quarry. When there was no good source of local building stone, rock was usually brought from quarries upriver because it was easier to float a heavily loaded boat down the Nile than to sail it upriver against the current, even with a good northerly wind.

Limestone from the ancient quarries was typically light gray on unweathered surfaces (as in fig. 7a), but was also sometimes nearly white or pale yellowish to pinkish. The rock is relatively soft due to its abundant calcite and generally high porosity. The so-called "indurated" (i.e., more consolidated than normal) limestone owes its greater hardness to either more coarsely crystalline calcite (in crystalline limestone), or the presence of secondary dolomite ($CaMg[CO_3]_2$; in dolomitic limestone) or secondary quartz (SiO_2; in silicified or cherty limestone). Non-carbonate components are often present in the limestones, especially quartz silt/sand and clay minerals, and these were deposited in the original lime sediment. The extensively recrystallized limestones, which megascopically resemble metamorphic marble, are considered ornamental stones as are some of the colored limestone varieties—dark gray to black bituminous limestone, buff limestone, and red-and-white limestone breccia (for these see Harrell 2012c).

The quarried sandstone was usually light to medium brown in color (as in figs. 7b - c) with occasional yellowish, reddish, or purplish shadings. The hardness of the rock depends on the amount and type of cementing agent holding the sand grains together. The most common cements in Egyptian sandstones are quartz, iron oxides, calcite, and clay minerals (also referred to as "clay matrix"). The iron oxide is mainly yellowish to brownish goethite or limonite (nFeO[OH] or $FeO{\cdot}OH{\cdot}nH_2O$, respectively) but also sometimes reddish hematite (Fe_2O_3). The clay is whitish in color and usually either illite (of variable composition but similar to muscovite mica, $KAl_2[AlSi_3O_{10}][OH]_2$), kaolinite ($Al_2Si_2O_5[OH]_4$), montmorillonite ($[Na,Ca]_{0.3}[Al, Mg]_2Si_4O_{10}[OH]_2{\cdot}nH_2O$), or a

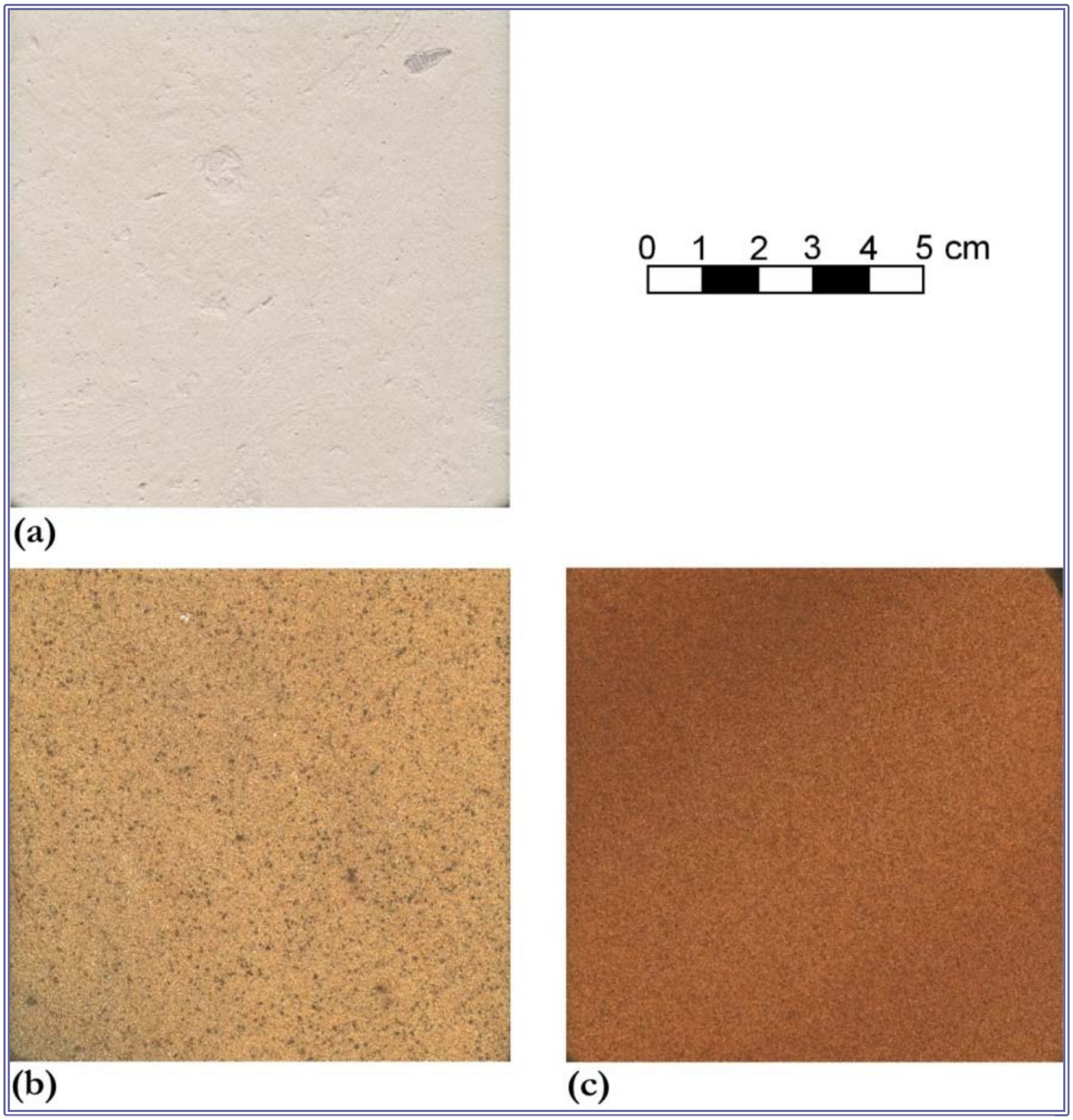

Figure 7. Typical examples of the most popular building stones: a) limestone from the Tura quarry (no. 5 in Table 1 and Figure 2); b and c) sandstone from the Gebel el-Silsila quarry (no. 11 in Table 1 and Figure 3).

mixture of these. When these cements are sparse, the rock is friable (i.e., easily crumbled), and when abundant and filling all the intergranular pore spaces, the rock is well-indurated. The sandstones with abundant quartz cement are the hardest of all and are referred to as silicified sandstone, one of the main ornamental and utilitarian stones (see Harrell 2012a and c).

Both limestone and sandstone (and other rock types as well) darken on weathered surfaces and where long exposed to the elements will develop a patina known as "desert varnish." This has a variable composition but normally consists of iron and manganese oxides plus clay minerals (Lucas 1905; Potter and Rossman 1977, 1979). It thickens and darkens with age, eventually becoming nearly black, especially on sandstone.

The quarrying of building stones in ancient Egypt was usually done in "opencut" (or

Figure 8. Examples of sandstone quarries: a) Gebel el-Silsila quarry, east bank portion (no. 11b in Table 1 and Figure 3); b) El-Mahamid quarry (no. 1 in Table 1 and Figure 3); c) Nag el-Hosh quarry (no. 8 in Table 1 and Figure 3).

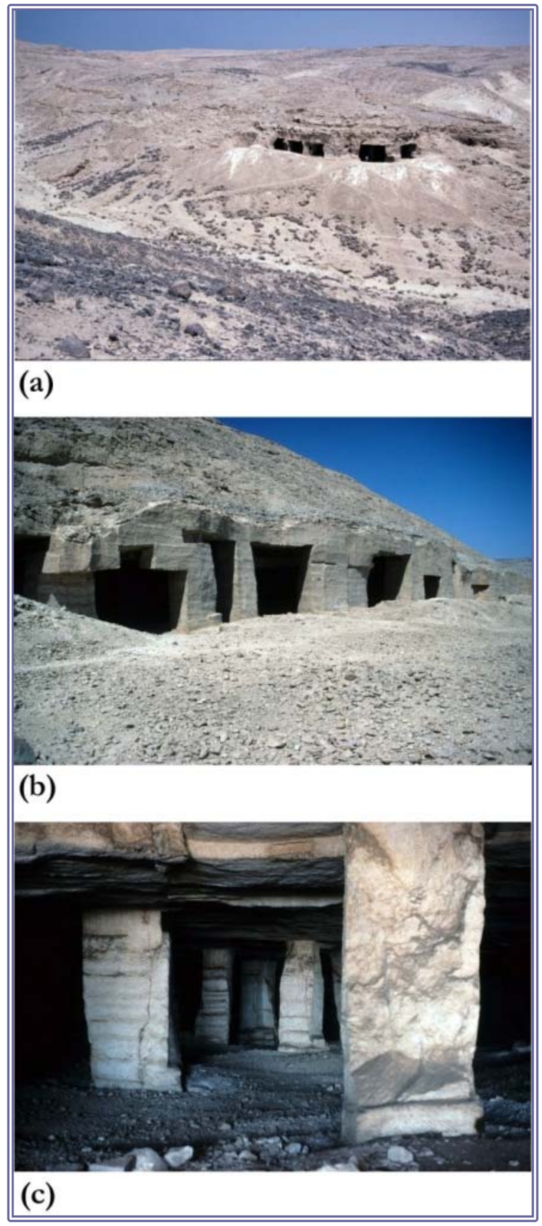

Figure 9. Examples of limestone gallery quarries: a) "Queen Tiy Quarry" near el-Amarna (no. 35 in Table 1 and Figure 2); b) Qaw el-Kebir quarry (no. 64 in Table 1 and Figure 2); c) View of bedrock support pillars in the gallery shown in "b."

"open-cast") workings on the sides of hills and cliffs (figs. 6, 8), but in some cases the workers followed desirable rock layers underground and in the process created cave-like "gallery" quarries (fig. 9). Unquarried rock pillars were left to support the roofs in the larger galleries but cave-ins have subsequently

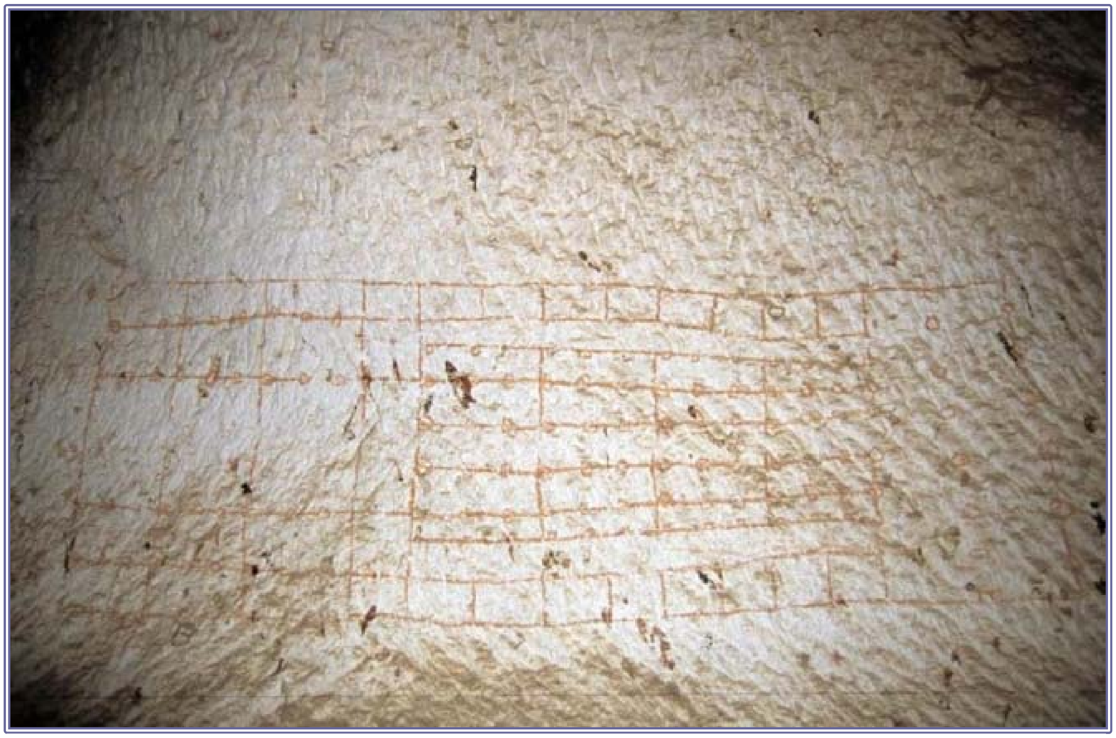

Figure 10. Plan of an unknown temple painted on a support pillar in the limestone gallery quarry at Gebel Sheikh Said (no. 33 in Table 1 and Figure 2). Plan is 1.6 m wide by 0.5 m wide.

occurred at some of these sites. Galleries are relatively common for limestone and such excavations locally penetrate over 100 m into hillsides. A gallery that is part of the 18th Dynasty limestone quarry on Gebel Sheikh Said (no. 33 in Table 1 and Figure 2), now largely destroyed, is unique for the 1.6 by 0.5 m temple plan painted on one of its bedrock pillars (fig. 10; Davies 1917; Harrell 2001: 38). Presumably the stone for the temple was to come from this quarry, but the plan does not correspond to any of the known limestone temples in Egypt. Many of the limestone galleries later became the sites of Coptic Christian hermitages and monasteries, with some of the latter still active today, such as, for example, at Deir el-Amir Tadros, Deir Abu Mina, Deir el-Aldra Maryam, and Deir el-Ganadla, all near Assiut (nos. 43, 44, 51, and 62, respectively, in Table 1 and Figure 2). With the exception of the Gebel el-Silsila quarry, galleries were never cut in sandstone.

The choice of quarry location would have been based on several factors, including the quality of the stone (appearance, soundness, and attainable block size), and proximity to the construction site or Nile River if water transport was needed. That quality was more important than ease of accessibility is evidenced by the many workings on hillsides and cliffs that are high above the more easily reached rock outcrops at lower elevations.

Throughout the Dynastic Period until near the end of the Late Period, building stones were quarried with copper (and later bronze) chisels and picks. The chisels were hammered with wooden mallets and the metal pick heads were hafted on wooden handles. It is probable that chert (or flint) pick heads were also used, as these are harder, although more brittle, than the metal tools, but so far there is little archaeological evidence for this. Implements of copper and the harder bronze were tough enough to work the softer stones, but were quickly blunted and abraded. They were entirely unsuited for the harder crystalline, dolomitic, and silicified limestones and well-cemented sandstones, and for such materials stone tools called pounders or mauls were much superior (see Harrell 2012a). Toward the end of the Late Period, the bronze and stone tools were replaced by harder ones of "iron" (actually low-grade steel).

Building stones were typically extracted from the quarries as rectangular blocks. Vertical trenches were first cut along the back and two lateral sides of an intended block, and then the block's open front face was undercut to complete the separation from bedrock. In a final step, using the same tools, the now loose block was often dressed (trimmed) to adjust its size and shape. This basic approach to quarrying remained unchanged from the Old Kingdom down to Roman times. During the Ptolemaic and Roman Periods, however, hammered iron wedges set in lines of pre-cut wedge-shaped holes were sometimes used to split limestone and sandstone, especially the harder varieties. The extracted stone blocks were transported from the quarries and to the construction sites on sledges during the Dynastic Period and on wagons thereafter. Transport by boat was also common when the construction sites were distant from the quarries.

There were two quarrying innovations introduced early in the New Kingdom. The first of these, dating to the Amarna Period, was the extraction of limestone and sandstone blocks with standardized dimensions that were small enough for one workman to carry (fig. 11a). These are the so-called *talatat* blocks, which measure about 52 cm (one cubit) by 26 cm (a half-cubit) by 26 cm. Unique to these blocks was a new method for detaching them from the bedrock (Harrell 2001: 37 - 38). A series of closely spaced, roughly cylindrical, horizontal holes were cut underneath the block from front to back (fig. 11b). The partitions between these holes would have been progressively cut away, leaving some in place for support, until the block was free. A second advance, first appearing during the reign of Amenhotep III, was in the limestone and, at Gebel el-Silsila, sandstone galleries, where annotated lines were painted on ceilings to mark the quarrying progress (fig. 11c). Numerous quarries have these markings, but the best example is at el-Dibabiya (no. 87 in Table 1 and Figure 2; Endo and Nishimoto 2009). Quarrying of *talatat* blocks ceased by the end of the 18th

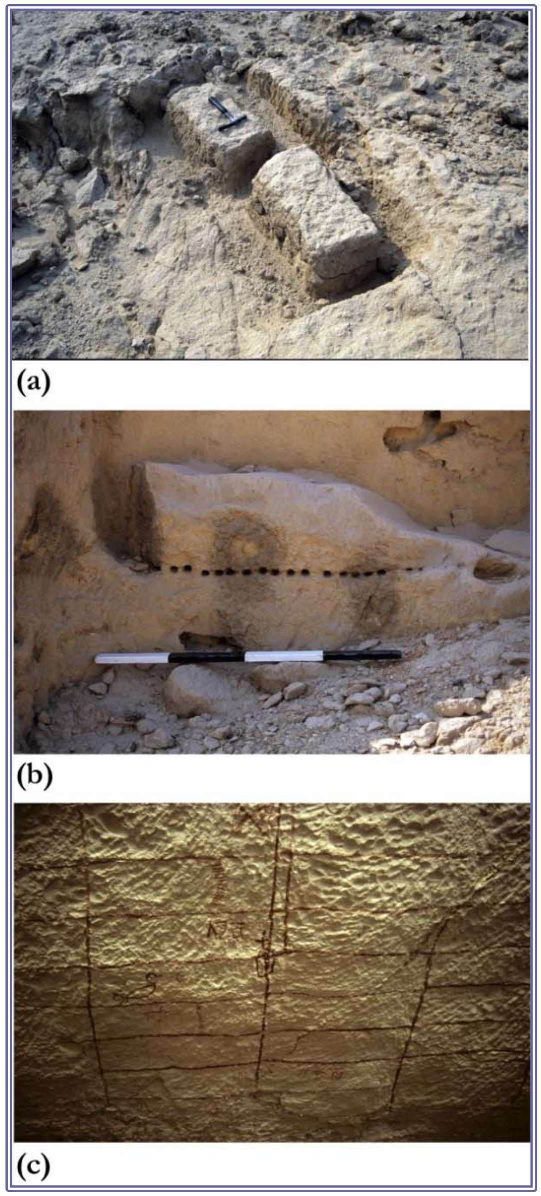

Figure 11. Dynasty 18 quarrying innovations: a) quarrying limestone *talatat* blocks, and b) undercutting a block with cylindrical holes in "Queen Tiy Quarry" near el-Amarna (no. 35 in Table 1 and Figure 2; hammer in "a" is 28 cm long and scale rod in "b" is 1 m long); c) annotated lines painted on ceiling of limestone gallery in el-Dibabiya quarry (no. 87 in Table 1 and Figure 2).

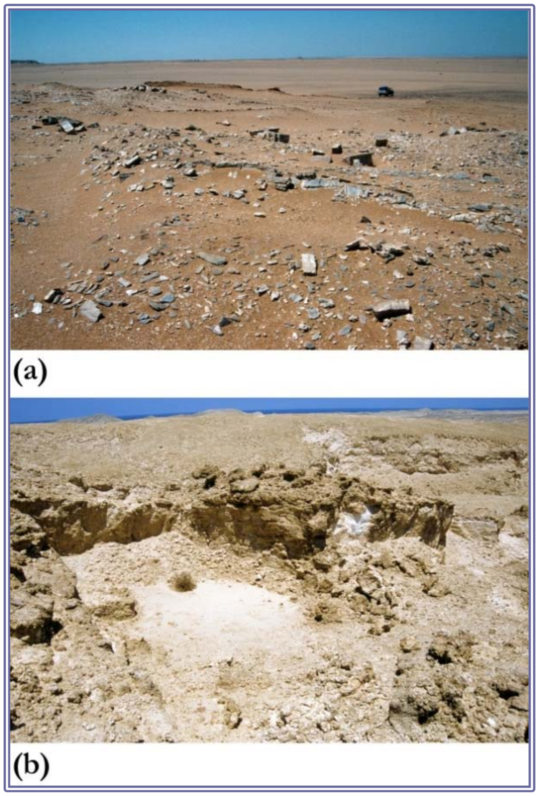

Figure 12. Examples of anhydrite and gypsum quarries: a) Umm el-Sawan gypsum quarry in the Fayum (no. 2 in Table 1 and Figure 2); b) Wadi el-Anba'ut anhydrite/gypsum quarry near Marsa Nakari (no. 1 in Table 1 and Figures 2 - 3).

Dynasty, but the marking of gallery ceilings continued into the Late Period.

Gypsum deposits in the form of veins within limestone and other sedimentary rocks are common throughout Egypt, and many of these occurrences were probably exploited during the Dynastic Period for gypsum plaster. Nowhere are these veins thicker or more numerous than in the Fayum's Umm el-Sawan and Qasr el-Sagha quarries (nos. 2 – 3 in Table 1 and Figures 2 and 12a), the former being the source of gypsum used for Early Dynastic and Old Kingdom vessels, and both also supplying the raw material for ancient Egypt's gypsum plaster. The anhydrite and gypsum along the Red Sea coast, in contrast, occur in bedded sedimentary formations and these would have been the source of gypsum plaster and building stones in the Ptolemaic and Roman settlements of this region. While there were probably many workings for these rocks, only one quarry is known. This is near Wadi el-Anba'ut (no. 1 in Table 1 and Figures 2 - 3, and 12b) and was primarily a source of ashlar blocks (both anhydrite and gypsum) for the nearby Roman port at Marsa Nakari (see fig. 5b).

Table 1. Ancient Egyptian Building-Stone Quarries*

LIMESTONE
<u>MEDITERRANEAN COAST</u> **Alexandria Formation** (Pleistocene): fine-grained, packstone to mainly grainstone with mostly non-skeletal carbonate grains (especially ooliths and coated grains), making it a "oolitic limestone" or a "carbonate sandstone" or "calcarenite" due to abundant sand-sized carbonate grains. Non-clayey, non-dolomitic, and non-siliceous, but occasionally has detrital quartz silt and sand. 1. in eastern Mallahet Mariut marsh on north side southwest of Alexandria—largely destroyed *(Pt-R; medium)* 2. in western Mallahet Mariut marsh on both north and south sides near and between Abusir, Burg el-Arab, and el-Hawariya villages *(R-B; large)*

NILE VALLEY

Observatory Formation of the Mokattam Group (Middle Eocene, Lutetian stage): medium- to coarse-grained packstone to mainly fine-grained mudstone and wackestone with foraminifera (especially nummulitids, making it at times a "nummulitic limestone," but also commonly operculinids, globigerinids, globoratalids and others) and lesser amounts of other invertebrates, mostly echinoids. Occasionally dolomitic, gypsiferous, and clayey (marly) with common detrital quartz silt and sand. Slightly siliceous with nearly ubiquitous microscopic secondary quartz.

3. at Zawyet Nasr on Gebel Mokattam southeast of Citadel, East Bank—partially destroyed *(OK/MK-LP?; medium)*

4. at Giza pyramids, West Bank *(OK:4; large)*

5. at Gebel Tura east of Tura village, East Bank—partially destroyed *(ED:3, OK:4-R; large)*

6. at Gebel Hof east of el-Masara village, East Bank—partially destroyed *(ED:3, OK:4-R; large)*

7. between Abusir and Saqqara pyramids, West Bank *(OK:5; medium)*

8. at Saqqara pyramids, West Bank *(ED:3; small)*

Wadi Rayan Formation of the Mokattam Group (Middle Eocene, Lutetian stage): coarse-grained packstone with mainly oysters (making it a "coquinal limestone") and lesser amounts of other invertebrates (mostly echinoids). Non-dolomitic, non-clayey, and non-siliceous, but with common detrital quartz sand (at times making it almost a calcareous sandstone).

9. at Dahshur pyramids, West Bank *(OK:4, MK:12; small)*

10. at Sadd el-Kafara in Wadi Garawi east of Helwan city, East Bank *(OK:4-5; medium)*

11. north and south of el-Lisht pyramids, West Bank *(MK:12; medium)*

12. at el-Lahun pyramid, West Bank *(MK:12; medium)*

Samalut Formation of the Mokattam Group (Middle Eocene, Lutetian stage): medium- to mainly coarse-grained packstone and grainstone with mainly nummulitid foraminifera (making it a "nummulitic limestone"), and lesser amounts of other invertebrates, mostly echinoids and alveolinid foraminifera. Essentially non-silty/sandy, non-clayey, and non-dolomitic, but slightly siliceous with nearly ubiquitous microscopic secondary quartz.

13. east of el-Sawayta village, East Bank *(NK-LP?; large)*

14. at el-Babein northeast of Beni Khalid village, East Bank *(OK/MK?, NK:19-20; medium)*

15. within and east of Deir Gebel el-Teir village, East Bank *(OK/MK?; large)*

16. east and south of Tihna el-Gebel village near Akoris ruins, East Bank *(NK:20?, Pt-R; medium)*

17. east of el-Hawarta village, East Bank *(R?; large)*

18. north and southeast of Nazlet Hussein Ali village, East Bank *(R; large)*

19. east and north of Nazlet Sultan Pasha village and west of New el-Minya city, East Bank *(NK:18 & R; large)*

20. east and southeast Zawyet el-Amwat village, East Bank *(NK & Pt-R?; medium)*

21. in Wadi Sheikh Yasin east of Zawyet el-Amwat village, East Bank—partially destroyed *(NK-R?; medium)*

22. near Darb Tila Nufal southeast of Zawyet el-Amwat village, East Bank *(age?; large)*

31. west of Tuna el-Gebel tombs, West Bank *(Pt-R; small)*

Minia Formation (late Early Eocene to early Middle Eocene, Ypresian to Lutetian stages): fine- to medium-grained, wackestone and packstone to less often grainstone with mainly echinoids and foraminifera (especially alveolinids and nummulitids), and lesser amounts of other invertebrates and non-skeletal peloids. Essentially non-silty/sandy, non-clayey, and non-dolomitic, but slightly to moderately siliceous with microscopic secondary quartz.

23. northeast of Nazlet el-Diyaba village, East Bank *(R?; small)*—possibly lower part of Samalut Fm.

24. south of Beni Hassan tombs, East Bank *(age?; small)*—possibly lower part of Samalut Fm.

25. east of Beni Hassan el-Shuruq village, East Bank *(OK/MK-R; large)*—possibly lower part of Samalut Fm.

26. northeast, east and southeast of Nag Arab Misallam Abu Mubarik village, East Bank *(age?; medium)*—possibly lower part of Samalut Fm.

27. southeast of el-Sheikh Timay village, East Bank—partially destroyed *(OK/MK-Pt?; small)*—possibly lower part of Samalut Fm.

28. north and northeast of el-Sheikh Ibada village and Antinoopolis ruins, East Bank *(OK/MK-NK?, R; large)*—possibly lower part of Samalut Fm.

29. northeast, east, and southeast of Deir Abu Hennis village, East Bank *(OK/MK? & NK; large)*

30. northeast and east of Deir el-Bersha village and in Wadi el-Nakla, East Bank *(MK?, NK:18, L:30, Pt-R?; large)*

32. south of el-Bersha village, East Bank *(NK:18; small)*

33. on Gebel Sheikh Said north and south of entrance to Wadi el-Zebeida, East Bank *(NK:18; medium)*

34. in Wadi el-Zebeida, including Abd el-Azzis travertine quarry, East Bank *(MK; medium)*

35. north and east of el-Amarna ruins and Beni Umran village, East Bank *(NK:18; large)*

36. at South Tombs south of el-Amarna ruins, East Bank *(NK:18?; small)*

37. south of Hawata village on Gebel Abu Foda, East Bank *(age?; small)*

38. at Hatnub travertine quarry southeast of el-Amarna ruins, Eastern Desert *(NK?; small)*

39. on Gebel Abu Foda opposite the West Bank's el-Mandara Bahri village, East Bank *(age?; small)*

40. east of Deir el-Quseir village on Gebel Abu Foda, East Bank *(age?; medium)*

41. west of Meir village, West Bank *(OK/MK?; small)*

42. southeast of Quseir el-Amarna village in and near Wadi Abu Helwa and Wadi Magberi on Gebel Abu Foda, East Bank *(OK/MK-NK; large)*

43. at Deir el-Amir Tadros monastery on Gebel Abu Foda, East Bank—partially destroyed *(NK:19; small?)*

44. at, and south of, Deir Abu Mina monastery on Gebel el-Harrana, East Bank—partially destroyed *(LP-R?; medium)*

45. at el-Ketf promontory east and southeast of el-Maabda village on Gebel el-Harrana, East Bank—partially destroyed *(NK:19 & LP; medium)*

46. north of Deir el-Gabrawi village on Gebel el-Tawila, East Bank—partially destroyed *(NK:19; medium)*

47. north of Arab el-Atiat el-Bahriya village on Gebel el-Harrana, East Bank *(Pt-R; medium)*

48. at Talet el-Hagar promontory north of entrance to Wadi el-Assiut, East Bank *(age?; medium)*—possibly upper part of Serai Fm.

Drunka Formation of the Thebes Group (Early Eocene, Ypresian stage): fine-grained mudstone and grainstone to mainly wackestone and packstone with primarily foraminifera (mostly nummulitids, alveolinids and operculinids), echinoids and nonskeletal peloids, and lesser amounts of other invertebrates, mostly bivalves, gastropods and calcareous algae. Essentially non-silty/sandy and non-dolomitic, but occasionally clayey (marly) and slightly to moderately siliceous with microscopic secondary quartz.

49. on Gebel Drunka west of Assiut city, West Bank—partially destroyed *(MK-NK?; medium)*

50. northeast of el-Matmar village and south of entrance to Wadi Emu, East Bank—largely destroyed *(age?; small)*

51. north, west and south of Deir Drunka village and at Deir el-Adra Maryam monastery, West Bank *(OK/MK?; large)*

52. north and east of el-Khawalid village, East Bank *(age?; medium)*

53. northwest and west of Deir Rifa village, West Bank *(NK & later?; medium)*

54. east of Nazlet el-Mustagidda village, East Bank *(age?; small)*

55. between Nazlet el-Mustagidda and el-Ruwegat villages, East Bank *(age?; medium)*

56. southwest of el-Zawya village, West Bank *(age?; medium)*

57. west of el-Balayza village, West Bank *(OK/MK?; medium)*

58. northeast of el-Iqal Bahri village, East Bank *(age?; medium)*

59. west of el-Zaraby village, West Bank *(OK/MK-NK?; medium)*

60. south of el-Sheikh Isa village, East Bank *(age?; small)*

61. east of el-Iqal el-Qibli village, East Bank *(R?; medium)*

62. at Deir el-Ganadla monastery, West Bank—partially destroyed *(OK/MK?; medium)*

63. north, east, and south of el-Hammamiya village, East Bank *(OK/MK?-NK:18; medium)*

64. north and northeast of Antaeopolis ruins and former Qaw el-Kebir village, East Bank *(OK/MK-NK?, Pt-R; medium)*

65. northwest of el-Mashaya village, West Bank *(age?; medium)*

66. northwest and west of el-Ghanayim village, West Bank *(R in part; medium)*

67. northwest and west of el-Qutna village, West Bank *(age?; large?)*

68. west of el-Qarya Bil Diweir village, West Bank *(age?; medium)*

69. southeast of el-Nawawra village, East Bank *(OK/MK-NK?, Pt-R?; medium)*

70. north of el-Khazindariya village on Gebel el-Haridi, East Bank *(NK:20; small)*

71. west and south of Nazlet Khatir village, West Bank *(age?; small)*

72. north, east and southeast of Nazlet el-Haridi village on Gebel el-Haridi, East Bank *(Pt; medium)*

73. northeast and north of el-Galawiya village on Gebel el-Haridi, East Bank *(OK/MK?; medium)*—possibly upper part of Serai Fm.

74. at Istabl Antar southeast of el-Haradna village, East Bank *(age?; small)*—possibly upper part of Serai Fm.

75. northwest of el-Ghirizat village, West Bank (*OK/MK-NK?; medium*)

76. on Qurnet Salamuni promontory south of Qurnet Salamuni village and northwest of el-Salamuni village, East Bank *(NK:18 & Pt; medium)*—possibly upper part of Serai Fm.

77. on north side of entrance to Wadi Abu Gilbana, East Bank *(NK; small)*

78. northwest of Nag Hamad village, West Bank *(age?; medium)*

79. southwest of Athribis ruins, West Bank *(Pt-R; medium)*

80. southeast of Nag el-Ahaywa village, East Bank *(3IP; small)*

82. west of el-Salmuni village and north of Abydos ruins, West Bank—partially destroyed *(NK? & R; large)*

Serai Formation of the Thebes Group (Early Eocene, Ypresian stage): fine-grained wackestone and, less often, packstone with mainly foraminifera (mostly globigerinids, globoratalids, nummulitids and operculinids) and lesser amounts of other invertebrates, mostly bivalves and echinoids. Commonly clayey (marly) and dolomitic with detrital quartz silt and sand, and moderately to highly siliceous with microscopic secondary quartz.

81. on Gebel Tukh, East Bank *(OK/MK-R; large)*

83. south of Nag el-Ghabat village and southeast of Abydos ruins, West Bank *(LP:30; medium)*

84. at Gebel el-Gir west of el-Tiweirat village, West Bank *(LP:30-R ?)*

85. west of Nag el-Buza village, East Bank *(age?; small)*—possibly lower part of Drunka Fm.

86. northwest of el-Tarif village and south of New Qurna village, West Bank *(NK:18, LP:26 & R; medium)*

88. southeast of el-Ghrera village at north end of el-Gebelein hills, West Bank—completely destroyed *(age?; small)*

Tarawan Formation (Late Paleocene, Thanetian stage): fine-grained mudstone and wackestone with mainly globigerinid foraminifera, and lesser amounts of other invertebrates, mostly other foraminifera. Non-siliceous and non-silty/sandy, but commonly clayey (marly) and dolomitic.

87. northeast of el-Dibabiya village, East Bank *(NK:19, 3IP:21, R; medium)*

WESTERN DESERT

Moghra Formation (Early Miocene, Aquitanian to Burdigalian stages): medium- to mostly fine-grained packstone with mainly echinoids and pelecypods (especially oysters). Non-clayey, non-silty/sandy, non-dolomitic, and non-siliceous.

89. in Siwa Oasis at Gebels Takrur, Mawta, and Aghurmi, and at Bilat el-Rum *(Pt-R; medium)*

SANDSTONE

All rock formations belong to the **Nubia Group** and, with the exception of the Duwi Formation, are together informally referred to as the **Nubian Sandstone**.

NILE VALLEY

Duwi Formation (Upper Cretaceous, Late Campanian to Early Maastrichtian stages): very fine- to medium-grained sandstone with mainly massive to planar bedding and occasional tabular cross-bedding.

1. at el-Mahamid village northwest of el-Kab ruins, East Bank *(MK ?, Pt; medium)*

2. at Shesmetet temple in Wadi Hilal northeast of el-Kab ruins, East Bank *(NK:19, Pt; small)*

3. in Wadi Tarifa southwest of Hierakonpolis ruins, West Bank *(NK-R; small?)*

4. southeast of el-Keijal village, East Bank *(Pt or R?; small)*

Quseir Formation (Upper Cretaceous, Early to Late Campanian stage): very fine- to mainly fine- to medium-grained sandstone with mostly tabular cross-bedding and occasional planar bedding.

5. at Nag el-Dumariyya village, East Bank *(Pt-R; small)*

6. below el-Bueib ruins on Gebel el-Sirag, East Bank—partially destroyed *(MK-NK:18; small)*

7. south of Nag el-Raqiein village, West Bank *(NK or younger; small)*

8. at Nag el-Hosh village, West Bank *(Pt-R; medium)*

9. in Wadi el-Shatt el-Rigal, West Bank *(MK; small)*

10. north and south of Nag el-Hammam village, West Bank *(MK-NK)*

11a. at Gebel el-Silsila, West Bank *(MK-NK; large)*

11b. at Gebel el-Silsila, East Bank *(MK-NK, Pt-R; large)*

Umm Barmil Formation (Upper Cretaceous, Santonian to Early Campanian stages): fine- to coarse-grained sandstone with planar to mainly tabular cross-bedding.

12. at Nag el-Falilih village in Gharb el-Gaafra district, East Bank *(Pt-R; medium)*

13. south of Nag el-Sheikh Garad village in Gharb el-Gaafra district, East Bank—partially destroyed *(Pt-R; large)*

14. at Gebel el-Hammam north of Khor Abu Subeira, East Bank—completely destroyed *(NK:18; size?)*

15. south of Nag el-Fuqani village in the Gharb Aswan district, West Bank *(Pt; medium)*

16. at Hagar el-Ghorab in the Gharb Aswan district, West Bank *(Pt or R; small)*

17. at Gebel el-Qurna in the Gharb Aswan district, West Bank *(Pt or R; medium)*

Abu Aggag Formation (Upper Cretaceous, Turonian stage): mainly medium- to coarse-grained, often conglomeritic, sandstone with planar to mainly trough cross-bedding.

18. at St. Simeon Monastery, West Bank *(MK or B?; small)*

19. east and southeast of Aswan city, East Bank—mostly destroyed *(R in part; medium?)*

20. near Dabod temple, West Bank—under Lake Nasser *(Pt-R; small?)*

21. west and south of Qertassi temple, West Bank—under Lake Nasser *(Pt-R; medium?)*

22. near Tafa temple, West Bank—under Lake Nasser *(R; small or medium?)*

23. at Kalabsha temple, West Bank—under Lake Nasser *(Pt-R; small or medium?)*

24. between Abu Hor and Merowa villages, West Bank—under Lake Nasser *(Pt-R; small or medium?)*

Sabaya Formation (Lower to Upper Cretaceous, Albian to Early Cenomanian stages) and **Lake Nasser Formation** (Lower Cretaceous, Aptian stage) undifferentiated: fine- to coarse-grained, occasionally conglomeritic, sandstone with both trough and tabular cross-bedding.

25. near Qurta temple, West Bank—under Lake Nasser *(NK:18, Pt? & R; small or medium?)*

26. near Agayba village in the Mitiq district, West Bank—under Lake Nasser *(NK?; small?)*

27. west of Tumas village, West Bank—under Lake Nasser *(NK:18-19; small or medium?)*

28. below and north of Qasr Ibrim ruins, East Bank *(MK:12?, NK-R?; small?)*

29. at Nag Deira village in Tuskha East district, East Bank *(NK?; small)*

Abu Simbel Formation (Upper Jurassic to Lower Cretaceous, Neocomian to Barremian stages): a sandstone of uncertain character but probably similar to the Sabaya/Lake Nasser formations.

30. west of Gezira Dabarosa island, West Bank, Sudan—under Lake Nasser *(age?; small)*

31. west of Buhen ruins, West Bank, Sudan *(MK-NK?; small or medium?)*

EASTERN DESERT (**Nubia Group** undifferentiated)

32. west of *Krokodilô praesidium* in Wadi el-Muweih on Qift-Quseir Road *(R; medium)*

33. southwest of Bir el-Kanayis temple and *Hydreuma to epi tou Paneiou praesidium* in Wadi el-Kanayis on Edfu-Marsa Alum Road *(NK:19, R; small)*

WESTERN DESERT (**Nubia Group** undifferentiated)

34. at Qaret el-Farangi hill in Bahriya Oasis *(LP26? or Pt-R?; small?)*

35. at el-Muzawqa tombs near el-Qasr village in Dakhla Oasis *(Pt or R?; small)*

36. on Gebel el-Teir in Kharga Oasis *(LP26-R?; small?)*

ANHYDRITE AND GYPSUM

1. south of Wadi el-Anba'ut on the Red Sea coast *(early R; small)*: beds of opaque white to pinkish anhydrite and alabasterine gypsum [**Abu Dabbab Formation**, Miocene]

2. at Umm el-Sawan in northeast Fayum *(ED-OK, possibly R; large)*: veins of opaque white alabasterine gypsum with brownish to dark gray streaks, and of colorless selenite gypsum [**Qasr el-Sagha Formation**, Late Eocene]

3. north of Qasr el-Sagha temple in north Fayum *(age?; small?)*: veins of colorless to white, satin spar gypsum [**Qasr el-Sagha Formation**, Late Eocene]

*Limestone and sandstone quarries are numbered and ordered from north to south, but are grouped according to region and geologic formation. The formation descriptions apply only to areas bordering the Nile River. All quarries are plotted in Figures 2 and 3.

Quarry age and size are given in parentheses after the quarry location. Abbreviations for quarry age are: *ED* = Early Dynastic, *OK* = Old Kingdom, *1IP* = First Intermediate Period, *MK* = Middle Kingdom, *2IP* = Second Intermediate Period, *NK* = New Kingdom, *3IP* = Third Intermediate Period, *LP* = Late Period, *Pt* = Ptolemaic, *R* = Roman, *B* = Byzantine or Late Roman, and *Is* = Islamic. Other abbreviations include: *OK:4* = Fourth Dynasty of the Old Kingdom, *OK/MK* = Old Kingdom and/or Middle Kingdom, and *NK-R* = New Kingdom through Roman Period. Quarry size corresponds to the maximum dimension of an area of workings or the cumulative maximum dimensions for multiple areas of workings. Three size classes are recognized: small (< 100 m), medium (100 - 1000 m), and large (> 1000 m).

The standard Udden-Wentworth grain-size scale is used for sandstones: gravel (in conglomeritic sandstone) > 2 mm, very coarse sand 1 - 2 mm, coarse sand 0.5 - 1 mm, medium sand 0.25 - 0.5 mm, fine sand 0.125 - 0.25 mm, very fine sand 0.0625 - 0.125 mm, and silt < 0.0625 mm. The predominant grain size for limestones is characterized as: coarse > 1 cm, medium 2 mm - 1 cm or fine < 2 mm, where the grains (all larger than 0.03 mm) are fossil bioclasts, non-skeletal carbonate grains (e.g., ooliths and peloids) and non-carbonate grains (e.g., quartz silt and sand). Carbonate mud is composed of material finer than 0.03 mm. The popular Dunham (1962) textural classification is applied to the limestones: mudstone (nearly all carbonate mud with rare grains), wackestone (mostly carbonate mud with common grains), packstone (mostly grains with carbonate mud filling the interstices), and grainstone (mostly grains with calcite cement filling the interstices).

Bibliographic Notes

The literature on ancient Egyptian building-stone quarries is not extensive. General descriptions of the stones are given by Harrell (1992) and Aston et al. (2000: 40 - 42, 54 - 56), and about half of the 128 quarries in Table 1 are described by Klemm and Klemm (2008: 23 - 145, 167 - 213, 327 - 330), which is a revised English edition of Klemm and Klemm (1993). Lucas (1962: 52 - 57) also discusses some of the limestone and sandstone quarries. The most complete list of quarries, and the one on which Table 1 is largely based, is provided by Harrell and Storemyr (2009). There are relatively few published descriptions of individual quarries, apart from those in Klemm and Klemm (2008). Those for limestone, from north to south, include Röder (1967) for the Mallehet Mariut quarries (nos. 1 - 2 in Table 1 and Figure 2), Klemm and Klemm (2010) for quarries in the Memphite necropolis and on the opposite bank of the Nile (nos. 3 - 9 in Table 1 and Figure 2), Verner (2005) for the Abusir quarry (no. 7 in Table 1 and Figure 2), Welc (2011) for the Saqqara quarry (no. 8 in Table 1 and Figure 2), Depauw (2008) for the Deir el-Bersha quarry (no. 30 in Table 1 and Figure 2), Harrell (2001) and Klemm and Klemm (2009) for quarries in the el-Amarna region (nos. 29 - 30 and 32 - 35 in Table 1 and Figure 2), de Morgan et al. (1894: 353 - 379) for the Gebel Tukh quarry (no. 81 in Table 1 and Figure 2), Bickel (1997: 15 - 35) and Nishimoto et al. (2002) for the Qurna quarry (no. 86 in Table 1 and Figure 2), and Endo and Nishimoto (2009) for the el-Dibabiya quarry (no. 87 in Table 1 and Figure 2). Sandstone quarries are described by Caminos (1955) for Gebel el-Silsila (no. 11 in Table 1 and Figure 2), and by Heldal and Storemyr (2007: 122 - 128) for the west bank near Aswan (nos. 15 - 18 in Table 1 and Figure 3). Heldal et al. (2009) report on the Fayum's gypsum quarries (nos. 2 - 3 in Table 1 and Figure 2) and Harrell (2010) describes the Wadi el-Anba'ut anhydrite/gypsum quarry (no. 1 in Table 1 and Figures 2 and 3). For information on the standard techniques used for quarrying and dressing limestone and sandstone see Clarke and Engelbach (1930: 12 - 22) and Arnold (1991: 27 - 47). Related *UEE* articles are Bloxam (2010) on general quarrying and mining, and Harrell (2012a, b, and c) on utilitarian stones, gemstones, and ornamental stones, respectively.

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Figure 1. Examples of structures built with limestone: a) pyramids of kings Menkaura, foreground, and Khafra, background (Dynasty 4, Giza) (note tumbled blocks of Aswan granite and granodiorite from lower courses of Menkaura pyramid, and remaining casing of Tura-Masara limestone at top of Khafra pyramid); b) limestone funerary temple of Queen Hatshepsut, Deir el-Bahri (Dynasty 18, Thebes). Photographs by the author.

Figure 2. Map of ancient building-stone quarries in northern and central Egypt (numbered). Drawing by the author.

Figure 3. Map of ancient building-stone quarries in southern Egypt (Nubia) (numbered). Drawing by the author.

Figure 4. Examples of structures built with sandstone: a) funerary temple of Ramesses III, Medinet Habu (Dynasty 20, Thebes); b) Philae temple (Ptolemaic and Roman Periods, near Aswan). Photographs by the author.

Figure 5. Examples of structures built with anhydrite and gypsum: a) gypsum gate in wall of Abu Sha'ar fortress (late Roman Period; near Hurghada [el-Ghardaqa]); b) anhydrite and gypsum ashlars at Marsa Nakari, the putative ancient Nechesia (early Roman Period; near Marsa Alum). Photographs by the author.

Figure 6. Examples of opencut limestone quarries: a) quarry for pyramid core stones beside the Khafra pyramid (part of no. 4 in Table 1 and Figure 2); b) Sultan Pasha quarry (no. 19 in Table 1 and Figure 2); c) Beni Hassan el-Shuruq quarry (no. 25 in Table 1 and Figure 2). Photographs by the author.

Figure 7. Typical examples of the most popular building stones: a) limestone from the Tura quarry (no. 5 in Table 1 and Figure 2); b and c) sandstone from the Gebel el-Silsila quarry (no. 11 in Table 1 and Figure 3). Photographs by the author.

Figure 8. Examples of sandstone quarries: a) Gebel el-Silsila quarry, east bank portion (no. 11b in Table 1 and Figure 3); b) El-Mahamid quarry (no. 1 in Table 1 and Figure 3); c) Nag el-Hosh quarry (no. 8 in Table 1 and Figure 3). Photographs by the author.

Figure 9. Examples of limestone gallery quarries: a) "Queen Tiy Quarry" near el-Amarna (no. 35 in Table 1 and Figure 2); b) Qaw el-Kebir quarry (no. 64 in Table 1 and Figure 2); c) View of bedrock support pillars in the gallery shown in "b." Photographs by the author.

Figure 10. Plan of an unknown temple painted on a support pillar in the limestone gallery quarry at Gebel Sheikh Said (no. 33 in Table 1 and Figure 2). Plan is 1.6 m wide by 0.5 m wide. Photograph by the author.

Figure 11. Dynasty 18 quarrying innovations: a) quarrying limestone *talatat* blocks, and b) undercutting a block with cylindrical holes in "Queen Tiy Quarry" near el-Amarna (no. 35 in Table 1 and Figure 2; hammer in "a" is 28 cm long and scale rod in "b" is 1 m long); c) annotated lines painted on ceiling of limestone gallery in el-Dibabiya quarry (no. 87 in Table 1 and Figure 2). Photographs by the author.

Figure 12. Examples of anhydrite and gypsum quarries: a) Umm el-Sawan gypsum quarry in the Fayum (no. 2 in Table 1 and Figure 2); b) Wadi el-Anba'ut anhydrite/gypsum quarry near Marsa Nakari (no. 1 in Table 1 and Figures 2 - 3). Photographs by the author.