The Journal of **Ancient Egyptian Architecture**

vol. 1, 2016

Varieties and sources of sandstone used in Ancient Egyptian temples

James A. Harrell

Cite this article:

J. A. Harrell, 'Varieties and sources of sandstone used in Ancient Egyptian temples', *JAEA* 1, 2016, pp. 11-37.

JAEA

www.egyptian-architecture.com

ISSN 2472-999X

Varieties and sources of sandstone used in Ancient Egyptian temples

J. A. Harrell[1]

From Early Dynastic times onward, limestone was the construction material of choice for Ancient Egyptian temples, pyramids, and mastabas wherever limestone bedrock occurred, that is, along the Mediterranean coast, in the northern parts of the Western and Eastern Deserts, and in the Nile Valley between Cairo and Esna (fig. 1). Sandstone bedrock is present in the Nile Valley from Esna south into Sudan as well as in the adjacent deserts, and within this region it was the only building stone employed.[2] Sandstone was also imported into the Nile Valley's limestone region as far north as el-'Sheikh Ibada and nearby el-'Amarna, where it was used for New Kingdom temples. There are sandstone temples further north in the Bahariya and Faiyum depressions, but these were built with local materials. The first large-scale use of sandstone occurred near Edfu in Upper Egypt, where it was employed for interior pavement and wall veneer in an Early Dynastic tomb at Hierakonpolis[3] and also for a small 3rd Dynasty pyramid at Naga el-Goneima.[4] Apart from this latter structure, the earliest use of sandstone in monumental architecture was for Middle Kingdom temples in the Abydos-Thebes region with the outstanding example the 11th Dynasty mortuary temple of Mentuhotep II (Nebhepetre) at Deir el-Bahri. From the beginning of the New Kingdom onward, with the exceptions of some portions of Karnak temple and especially Hatshepsut's mortuary temple at Deir el-Bahri, which are of limestone, Theban temples were built either largely or entirely of sandstone, and this was also true for most of the temples in the southern portion of the limestone region. When limestone and sandstone are both present in a temple, they are usually employed for different architectural applications with the sandstone particularly favored for segmented columns and architraves. Uniquely, however, in the Seti I temple at Abydos, limestone and sandstone are used side-by-side for wall reliefs with scenes beginning on one rock type and then continuing across the other.

Appendix 1 lists the temples (and other monuments) containing significant amounts of sandstone and figure 1 shows their locations. There are undoubtedly temples missing from this list that are either destroyed, still undiscovered, or known but with unrecognized sandstone elements. The southernmost temple built by Egyptians, also of sandstone, is at Jebel Barkal near the west end of the Nile River's fourth cataract in Sudan.

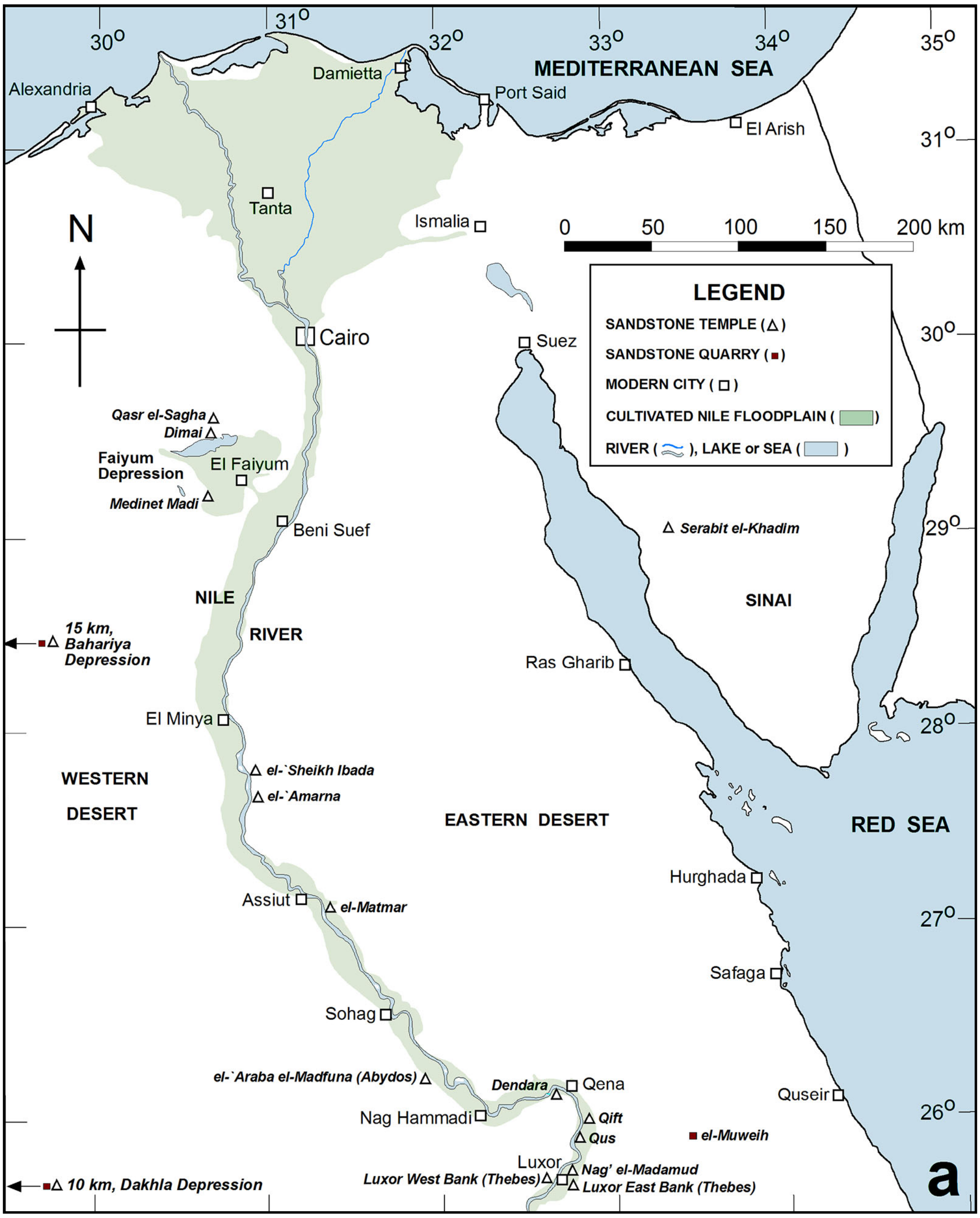
---

1 Professor Emeritus of Geology, Department of Environmental Sciences, The University of Toledo, 2801 West Bancroft St., Toledo, Ohio 43606-3390, USA (e-mail: james.harrell@utoledo.edu, phone: 419-530-2193, fax: 419-530-4421).

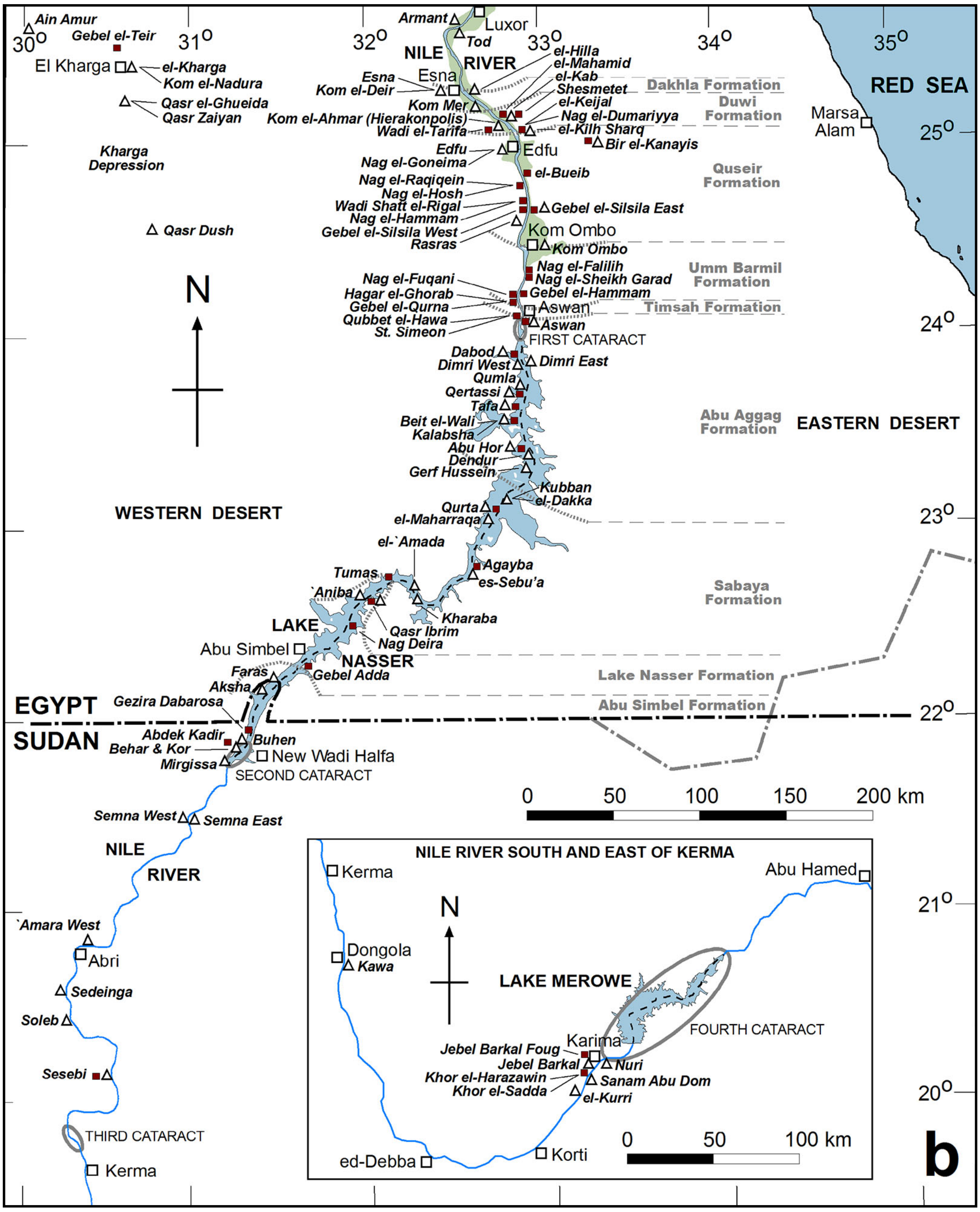
2 Harrell (2012a).

3 Quibell and Green (1902), pp. 3-7, 14, 51.

4 Marouard and Papazian (2012).


30°
31°
32°
33°
34°
35°
MEDITERRANEAN SEA
Alexandria
Damietta
Port Said
El Arish
31°
Tanta
Ismalia
0 50 100 150 200 km
N
LEGEND
SANDSTONE TEMPLE (△)
SANDSTONE QUARRY (■)
MODERN CITY (□)
CULTIVATED NILE FLOODPLAIN ( )
RIVER ( ), LAKE or SEA ( )
Cairo
Suez
30°
Qasr el-Sagha
Dimai
Faiyum Depression
El Faiyum
Medinet Madi
Beni Suef
Serabit el-Khadim
29°
NILE
RIVER
SINAI
15 km, Bahariya Depression
Ras Gharib
El Minya
28°
el-`Sheikh Ibada
el-`Amarna
WESTERN
DESERT
EASTERN DESERT
RED SEA
Hurghada
Assiut
el-Matmar
27°
Safaga
Sohag
el-`Araba el-Madfuna (Abydos)
Dendara
Qena
Quseir
Nag Hammadi
Qift
Qus
el-Muweih
26°
Luxor
Nag' el-Madamud
Luxor West Bank (Thebes)
Luxor East Bank (Thebes)
10 km, Dakhla Depression
a

1a.



1b.

Fig. 1a-b. Maps of Egypt and northern Sudan showing the locations of ancient sandstone temples and quarries.

The choice of sandstone

The preference for sandstone over limestone as a building material coincided with the transfer of religious and political authority from Memphis near Cairo to Thebes (Luxor) at the beginning of the 18th Dynasty. Thebes was closer to the sandstone sources and this probably was a factor, but more importantly the Egyptians at this time also recognized 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 and roofing slabs.[5] The hardness and strength of sandstone 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 (limonite and hematite), calcite, and clay minerals. When these cements are sparse, the rock is friable and so easily disaggregated, and when abundant and filling all the intergranular pore spaces, the rock is well-indurated and durable. Sandstone with abundant quartz cement is the hardest of all and is referred to as 'silicified sandstone,' one of ancient Egypt's most important ornamental and utilitarian stones. Silicified sandstone was not used as a building material for temples and so will not be further considered here.[6] It should be noted, however, that on at least one occasion this rock was employed for a small shrine, the so-called 'red chapel' of Hatshepsut in Karnak's Open-Air Museum.

Megascopic properties

Sandstone in temples can usually only be examined megascopically (i.e., with at most a magnifying lens) with the observable properties limited to grain size, bedding, and color. Additional information on texture and especially mineralogy is provided by microscopic (i.e., petrographic or thin section) analysis, and geochemistry can identify amounts of trace elements. Such analyses, however, are destructive and require samples that are not normally available to those studying sandstone monuments.

Throughout most of the world, grain size in sandstone and other clastic sedimentary rocks is specified according to the Udden-Wentworth grain size scale (table 1). In studies of Egyptian rocks by German geologists, however, the grain size terminology usually follows the DIN (Deutschen Instituts für Normung) 4022 scale.[7] This scale recognizes only three grain size divisions for sand: coarse (2.000-0.630 mm), medium (0.630-0.200 mm) and fine (0.200-0.063 mm). In the present paper, it is the Udden-Wentworth scale's five-fold division for sand that is employed throughout. The modal or average grain size of temple sandstones is easily determined through the use of a visual comparator. There are many such aids commercially available, but the author prefers the one shown in figure 2. This is placed against a sandstone surface and viewed along the right edge with a magnifying lens (5-10X) to match the sand grains in the rock with a size-calibrated image on the comparator.

---

5 Clarke and Engelbach (1930), pp. 12-13; Arnold (1991), pp. 183-184.

6 For more information on the varieties and sources of silicified sandstone see Klemm *et al.* (1984); Klemm and Klemm (1993), pp. 283-303; (2008), pp. 215-231; Heldal *et al.* (2005); Harrell and Madbouly (2006); Knox *et al.* (2009); and Harrell (2012b; 2012c).

7 For example, Klitzsch *et al.* (1987); Hermina *et al.* (1989); Klemm and Klemm (1993; 2008).

<table>
<tr><th colspan="2">SEDIMENT NAME</th><th>GRAIN SIZE RANGE</th><th colspan="2">ROCK NAME[8]</th></tr>
<tr><td rowspan="4">GRAVEL</td><td>boulder</td><td>over 256 mm</td><td colspan="2" rowspan="4">conglomerate
(if rounded clasts)
or
breccia
(if angular clasts)</td></tr>
<tr><td>cobble</td><td>64 to 256 mm</td></tr>
<tr><td>pebble</td><td>4 to 64 mm</td></tr>
<tr><td>granule</td><td>2.00 to 4.00 mm</td></tr>
<tr><td rowspan="5">SAND</td><td>very coarse grained</td><td>2.00 to 1.00 mm</td><td colspan="2" rowspan="5">sandstone</td></tr>
<tr><td>coarse grained</td><td>1.00 to 0.50 mm</td></tr>
<tr><td>medium grained</td><td>0.50 to 0.25 mm</td></tr>
<tr><td>fine grained</td><td>0.25 to 0.125 mm</td></tr>
<tr><td>very fine grained</td><td>0.125 to 0.062 mm</td></tr>
<tr><td rowspan="2">MUD</td><td>silt</td><td>0.004 to 0.062 mm</td><td>silty shale if fissile[9], otherwise siltstone</td><td rowspan="2">mudstone</td></tr>
<tr><td>clay</td><td>less than 0.004 mm</td><td>clayey shale if fissile[9], otherwise claystone</td></tr>
</table>

Table 1. The Udden-Wentworth grain size scale for clastic sedimentary rocks.

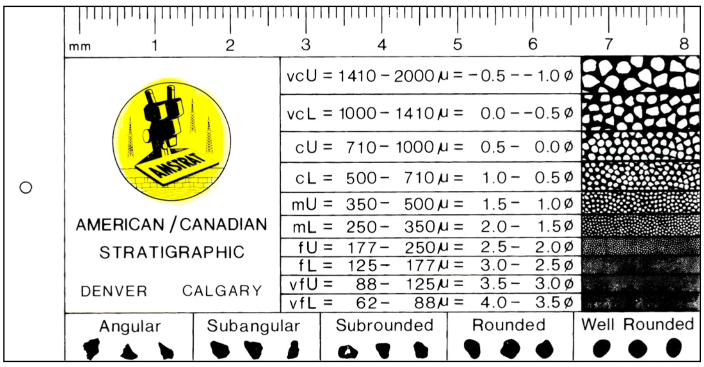


Fig. 2. Grain-size comparator of the American-Canadian Stratigraphic Company (Denver, Colorado, USA). The upper (U) and lower (L) halves of the five Udden-Wentworth sand-size classes (vf, f, m, c and vc) are shown with a grain-roundness comparator along the bottom edge. Grain sizes are given in µm and also in phi (Φ) notation, where [phi size] = $-\log_2$ [mm size]).

8 Rock names reflect the predominant grain size. Some coarser or finer grains can also be present in a given rock type.
9 Fissility is the property of a mudstone that causes it to break into thin, platy fragments up to a few millimeters thick.

When sandy sediment is deposited it can exhibit a number of bedding types depending on the environmental conditions. The principal ones and the easiest to recognize in temple sandstones are planar bedding, and tabular and trough cross-bedding. These structures are defined by the attitude of laminations between the major bedding planes (fig. 3). The laminations can be difficult to see, however, on dirty or weathered rock surfaces. When no laminations are present, the rock is said to exhibit massive bedding. Sometimes the laminations are merely indistinct and thus give the false impression of massive bedding. All bedding types are encountered in Egyptian sandstones, but by far the most common is tabular cross-bedding (fig. 4).

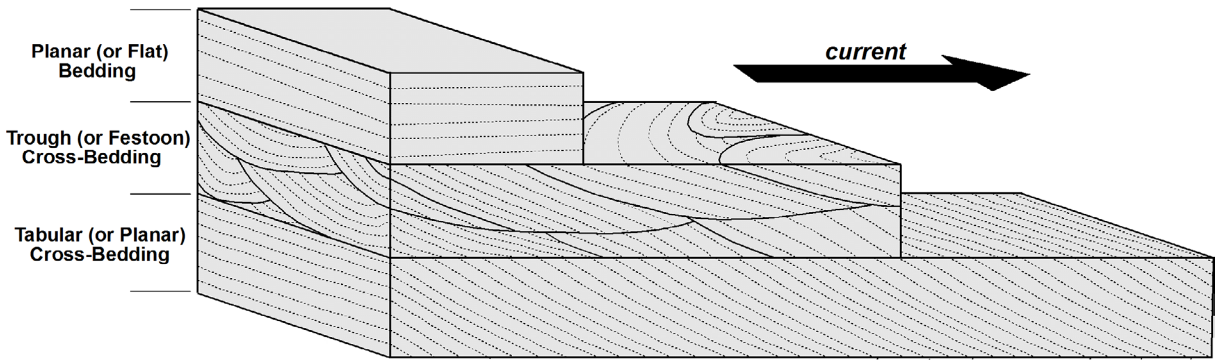


Fig. 3. Diagram illustrating planar bedding, and trough and tabular cross-bedding. The heavier lines represent major bedding planes and the lighter ones are the internal laminations.

Fig. 4. Tabular cross-bedding in sandstone at the Nag el-Hammam quarry. Smallest scale division is 1 cm. The scale rests on a major bedding plane separating two cross-bed sets.

Fig. 5. Typical drab-colored sandstone (very fine-grained) from the el-Mahamid quarry.

Fig. 6. Typical drab-colored sandstone (fine-grained) from the Gebel el-Silsila quarry.

With few exceptions, the sandstone quarried in Ancient Egypt has an internal coloration that varies from light shades of gray, yellow, orange, brown or pink, or mixtures thereof (figs. 5-6). Yellowish-brown is the most common hue. Such normally colored sandstones, which vary from very fine- to coarse-grained, can be collectively referred to as drab-colored. Nearly white sandstones are occasionally encountered and these constitute another distinct color variety.

A very different-looking sandstone was employed only during the 12th and especially the 11th Dynasties and this is medium-grained with a uniform, moderately dark reddish- to mainly purplish-brown color (fig. 7). It was used for several temples in the Abydos-Thebes region, including the Osiris-Khentyimentyu temple at Kom el-Sultan in Abydos,[10] the north temple of Min and Isis in Qift,[11] the Senwosret I temple within the Amun temple complex at Karnak in Luxor,[12] and on the Luxor West Bank in the Amun temple at Medinet Habu,[13] and the Mentuhotep II mortuary temple at Deir el-Bahri.[14] It is probably not a coincidence that the 11th Dynasty saw both the first use of purplish sandstone in Egypt and also the opening of the first mine for amethyst, a purplish gemstone, near Wadi el-Hudi, 25 km southeast of Aswan.[15] Also in the Middle Kingdom, there was a surge in the popularity of purplish-red garnet for jewelry. It is thus apparent that the color purple was especially favored during this period but the reason for this is unknown.

Fig. 7. Purplish sandstone column fragment in the Mentuhotep II temple at Deir el-Bahri. Smallest scale division is 10 cm.

10 Petrie (1903, vol. 2), pp. 14-16, 33; Petrie (1938), pp. 24-25.
11 Petrie (1938), pp. 24-25.
12 François Larché, pers. comm. (2015).
13 Hölscher (1939), pp. 4-5.
14 Clarke (1910), pp. 13-14; Arnold (1979), p. 31.
15 Shaw and Jameson (1993).

A final color variety is the light green sandstone employed in Karnak temple's 5th pylon (fig. 8), which dates to the reign of Thutmose I.[16] This rock, which is fine-grained with tabular cross-bedding, is only known from this example. It may have been chosen for the symbology represented by its color, with green signifying rebirth in the afterlife (as represented by Osiris, whose figure is typically depicted in green) as well as fertility and joy. Challenging this suggestion, however, is the fact that the 5th pylon was originally covered by a limestone casing with the green sandstone hidden from view.

Fig. 8. Greenish sandstone block in the 5th pylon at Karnak temple. Note the chisel marks.

Determining sandstone's color can be problematical because its appearance on dirty, weathered exterior surfaces can be very different from what is seen internally on fresh breaks. On quarry and temples walls and especially on natural outcrops, the sandstone usually has a fairly uniform light brown color. Where long exposed to the elements, the rock will develop a patina known as 'desert varnish'. This has a variable composition but normally consists of iron and manganese oxides plus clay minerals.[17] It thickens and darkens with age, eventually becoming nearly black and completely obscuring a rock's internal color. Color determination is further complicated when working with archaeological objects because, of course, these cannot be broken to reveal their true (internal) color. The best one can do is look for relatively fresh breaks in the external surfaces that occurred during excavation or subsequent handling. These are not always present or recognizable, however. And finally, color perception varies from person to person and under different lighting conditions, and so it is often helpful to use a standard color guide, such as the Geological Society of America's 'Rock-Color Chart' (Boulder, Colorado, USA).

16 Larché (2009), p. 151.
17 Lucas (1905); Potter and Rossman (1977; 1979).

Internal sandstone colors in shades of yellow and brown are caused by the presence of hydrated iron oxides (i.e., iron hydrates). These are collectively referred to as 'limonite' and represent a number of poorly crystallized phases with the generalized formula of $FeO{\bullet}OH{\bullet}nH_2O$ or $Fe_2O_3{\bullet}nH_2O$. Goethite ($FeO[OH]$ or $HFeO_2$) is a common, well-crystallized phase within the iron hydrate group. Shades of pink, red and purple are the result of anhydrous iron oxide (i.e., hematite; Fe_2O_3). Some Egyptian sandstones have an orangey coloration. Orange is a blend of red and yellow and so in rocks this probably represents a mixture of hematite and limonite. When iron oxides are absent, the rock has a light grayish to nearly white color which is the natural hue of the quartz sand grains. The green sandstone in Karnak's 5th pylon gets its color from the presence of sand-size grains of dark green glauconite, a type of clay mineral.

A final megascopic attribute of temple sandstones is the tool marks commonly left on their surfaces when blocks were dressed to adjust their size and shape (e.g., fig. 8). Indications of when the dressing was done can be gleaned from the different forms taken by the marks and the metal residues of the tools that made them.[18]

Formations

The various sandstones used in Egyptian temples were collectively referred to in the past as the Nubian Sandstone. Stratigraphical difficulties with this designation caused geologists to later redefine the sandstones into numerous, and at times conflicting, formations. A sedimentary formation is a sequence of strata distinct from the rock layers both above and below by virtue of its lithology or paleontology, and thus is a mappable stratigraphic unit. The formations described in table 2 for Egypt are the most widely accepted ones,[19] and these are defined primarily by their fossil content. Despite the new terminology, these rocks are still informally referred to as the Nubian Sandstone or Nubian Group. More formally in Sudan, the correlative stratigraphic units are usually identified simply as the Nubian Sandstone Formation. From the table it can be seen that the petrology of a sandstone will vary somewhat according to the formation supplying it. The geologic ages of sedimentary strata (and consequently also formations) decrease from south to north in the Nile Valley due to their slight (approximately 2 degree) northerly inclination, and this means that the sandstone properties also change in a downriver direction. The boundaries between the formations in the Nile Valley are shown in figure 1.

Quarries and provenance determinations

Appendix 2 lists the 44 known ancient sandstone quarries in Egypt and northern Sudan, and figure 1 shows their locations. A locality name and coordinates are provided for each quarry along with its period of activity, size, current status, and, in some cases, a general petrological description. Although the list is long, it is far from complete. There are undoubtedly more quarries awaiting discovery, as well as others that are forever lost because they have been destroyed through urban growth or especially as a result of modern quarrying for rough construction stone. Although not destroyed, numerous sandstone quarries are no longer accessible because they are now under Lake Nasser.

18 Arnold (1991), pp. 41-47, 257-259; Harrell and Storemyr (2013), pp. 21-28.
19 These are the formations introduced by Klitzsch *et al.* (1987) and Hermina *et al.* (1989).

Dakhla Formation (Upper Cretaceous – Late Campanian and Maastrichtian stages to Paleocene; ~74-60 mya): interbedded sandstone, silty and clayey mudstones, and limestone.
Duwi Formation (Upper Cretaceous – Middle Campanian to Early Maastrichtian stages; ~78-70 mya): very fine- to medium-grained sandstone with mainly massive to planar bedding and occasional tabular cross-bedding plus interbedded silty and clayey mudstones, limestone, and phosphorite.
Quseir Formation (Upper Cretaceous – Early to Late Campanian stage; ~82-74 mya): very fine- to mainly fine- to medium-grained sandstone with planar bedding to mainly tabular cross-bedding plus interbedded silty and clayey mudstones, and phosphorite.
Umm Barmil Formation (Upper Cretaceous – Santonian to Early Campanian stages; ~85-82 mya): in the upper part, mainly fine- to medium-grained sandstone with tabular cross-bedding and interbedded silty and clayey mudstones and oolitic iron ore; and in the lower part, medium- to coarse-grained sandstone with tabular cross-bedding.
Timsah Formation (Upper Cretacous – Coniacian to Santonian stages; ~90-85 mya): medium- and coarse-grained to mainly fine-grained sandstone with planar-bedding to mainly tabular and trough cross-bedding plus interbedded silty and clayey mudstones, and oolitic iron ore.
Abu Aggag Formation (Upper Cretaceous – Turonian stage; ~94-90 mya): medium- to coarse-grained sandstone, occasionally pebbly, kaolinitic and often ferruginous, with mainly trough cross-bedding plus interbedded pebble-cobble conglomerate
Taref Formation (Upper Cretaceous – Turonian stage; ~94-90 mya): mainly fine- to coarse-grained sandstone with tabular cross-bedding and, near the base, interbedded conglomerate.
Bahariya Formation (Upper Cretaceous – Cenomanian stage; ~100-94 mya): interbedded sandstone and silty and clayey mudstone.
Sabaya Formation (Lower to Upper Cretaceous – Albian to Early Cenomanian stages; ~113-98 mya): fine-grained (upper part) and medium- to coarse-grained (lower part) sandstone with abundant trough to mainly tabular cross-bedding plus interbedded conglomerate and silty mudstone.
Lake Nasser Formation (Lower Cretaceous – Aptian stage; ~125-113 mya): interbedded fine- to coarse-grained sandstone with tabular to trough cross-bedding and planar bedding, and silty and clayey mudstones.
Abu Simbel Formation (Upper Jurassic to Lower Cretaceous – Oxfordian to Barremian stages; ~163-125 mya): interbedded tabular to trough cross-bedded sandstone and mudstone.

Table 2. Egyptian Sandstone Formations.[20]

As a practical matter, the building stones used at ancient construction sites usually came from a quarry in the immediate neighborhood. This quarry was probably on the upriver side of a site because it was easier to float a heavily loaded boat down the Nile than to sail it upriver against the current, even with the prevailing northerly wind. A notable exception to the local derivation of building stones is the high-quality sandstone from Gebel el-Silsila. This quarry, the most extensive in Egypt for sandstone, provided large, fracture-free blocks of uniform color and texture. It was

20 Formation names and chronologies are those of Hermina *et al.* (1989) as used on the geologic maps of Klitzsch *et al.* (1987). The years before present (mya – millions of years ago) for the stratigraphic stages are taken from the International Chronostratigraphic Chart, version 2016/04 (International Commission on Stratigraphy). Petrological descriptions are a synthesis of multiple sources, including Attia (1955), Van Houten and Bhattacharyya (1979), Ward and McDonald (1979), Hermina *et al.* (1989), Ahmed *et al.* (1993), Klemm and Klemm (1993, 2008), Issawi *et al.* (1999), and fieldwork by the present author. The information is incomplete for some formations.

the principal building material for temples in the Theban region, over 100 km to the north, as documented by ancient inscriptions.[21] It was no doubt used for many other distant structures, especially those in a downriver direction. The second largest sandstone quarry is at the now drowned site of Qertassi and although it apparently did not supply rock of as high a quality as that coming from Gebel el-Silsila, it was mainly used outside its immediate area. Inscriptions tell us, for example, that it was employed for the Philae temple complex 35 km to the north,[22] and it was probably also used for other structures in the Aswan area. For most temples, however, the quarry supplying the stone will be found close at hand. It is expected, therefore, that more quarries remain to be discovered, especially near the Nubian temples along the Nile in southern Egypt and northern Sudan.

It is not yet possible to identify by analytical means the specific quarry supplying a particular sandstone, but the formation, and hence the general location in the Nile Valley, can sometimes be established. For example, very fine-grained sandstone with planar bedding almost certainly comes from the Duwi or Quseir Formation whereas coarse-grained sandstone with trough cross-bedding probably comes from one of the formations near Aswan or to the south of it. Fine- to medium-grained, tabular cross-bedded sandstones – the predominant lithology – can come from any formation. Further distinctions require petrographic microscopy. There are just a few published sources of petrographic information on Egyptian sandstones in the Nile Valley: two for natural outcrops in the Aswan[23] and el-Mahamid[24] areas, another for ancient quarries throughout Egypt but only providing incomplete qualitative data,[25] and the last for the ancient Gebel el-Silsila quarry.[26] The present author has also done petrographic analyses of samples from several quarries between Esna and Aswan as well as from two sandstone temples closely associated with quarries south of Aswan. With one exception, all the aforementioned data combined still represent too few samples to say anything definitive about the mineralogical differences among quarries or formations. The exception is total feldspar content (i.e., orthoclase + microcline + plagioclase). This ranges between 5 and 15% for the el-Mahamid, el-Keijal, el-Bueib and Nag el-Raqiqein quarries – all within 20 km of Edfu – with the first two in the Duwi Formation and the last two in the upper part of the underlying Quseir Formation. All other tested quarries south of Nag el-Raqiqein have a total feldspar content of less than 5%. These percentages, all from the author's petrographic analyses, are provided in appendix 2. The feldspar-rich sandstones are what petrologists call 'arkose', 'subarkose' or 'arkosic arenite', depending on the classification scheme followed, with all the other sandstones, except the glauconite-rich ones, termed 'quartz arenite'. Other minerals in Egyptian sandstones show no consistent differences among quarries and formations, at least based on the currently available sample data.

The finding for feldspar content is supported by the trace element analyses of samples from four quarries: el-Mahamid, Nag el-Falilih, Nag el-Sheikh Garad and Gebel el-Silsila.[27] It was found that rubidium is significantly higher for el-Mahamid than for the other three quarries. Rubidium is a trace element associated with feldspar and so it is to be expected that it will be high in sandstones rich in this mineral. Because feldspar grains are more easily broken and abraded than quartz grains,

21 Breasted (1906, vol. 4), pp. 10-12; Weigall (1910), pp. 358-359; Kitchen (1991); Kramer (2009).
22 Weigall (1907), pp. 62-63; Clarke and Engelbach (1930), p. 15.
23 Shukri and Ayouti (1953).
24 Ahmed and Hussein (1983).
25 Klemm and Klemm (1993), pp. 225-281; (2008), pp. 167-213.
26 Fitzner *et al.* (2003).
27 Klemm and Klemm (1993), pp. 279-281, figs. 328-329; (2008), pp. 212-213, figs. 328-329. El-Mahamid is the Klemms' El Kab quarry, and Nag el-Falilih and Nag el-Sheikh Garad together are their El Gaaphra quarry.

which are the main constituent of sandstone, the amount of feldspar in sand tends to increase with decreasing grain size. It is this relationship that probably accounts for the differences in feldspar content among quarries, although it is also possible the feldspar content reflects different geologic sources for the sand.

The source of the Middle Kingdom's purplish sandstone is unknown. The quarries at Qubbet el-Hawa, Nag el-Hammam and Wadi Shatt el-Rigal are previously suggested possibilities,[28] but all can be excluded. None possesses beds of medium-grained sandstone of the requisite color that are at least 1 m thick, the minimum dimension required for the largest architectural elements and statues cut from the purplish sandstone. The most likely source at present appears to be the Gebel el-Silsila quarry but more fieldwork is needed to evaluate this possibility. This quarry is also the only known source of a white sandstone, which was used to a minor extent in the Karnak temple.

There is no known quarry that could have supplied the green glauconitic sandstone at Karnak. This rock is closely associated with phosphatic deposits (phosphorite) in the upper part of the Quseir Formation and also especially in the overlying Duwi Formation (table 2).[29] There are numerous, thick glauconitic sandstone beds in both formations, but only in the Western Desert's Bahariya, Dakhla and Kharga Depressions. Rare, thin-bedded occurrences of this rock have been reported from the Nile Valley, but with no specific localities identified.[30] If beds of glauconitic sandstone are to be found along the Nile, it is most likely to be near Edfu, where there are outcrops of phosphatic rocks in the Quseir and Duwi Formations. This is further indicated by a sample of glauconitic sandstone from Karnak's 5th pylon that was analyzed by the author and found to contain 6.3% total feldspar, which is consistent with a derivation from one of these formations. If an 18th Dynasty quarry for glauconitic sandstone once existed near Edfu, it may have been destroyed by the extensive phosphate mining that occurred in this region beginning in the early 1900's.

Although the megascopic properties of sandstone may not allow the identification of a specific formation or quarry, they are still useful for recognizing that multiple sources of building materials were used in different temples or in different construction phases of a single temple. What is needed, therefore, is a systematic study of sandstone used in Egyptian temples for purposes of both basic documentation and source characterization. More research is also needed on the sandstone quarries, including further megascopic and petrographic descriptions as well as an analysis of pottery to be better establish their ages.

Conclusions

Sandstone was the principal building stone used in Upper Egypt and Nubia from the Middle Kingdom onward. It came from forty-four known quarries (and others yet undiscovered) that were excavated in eleven geologic formations, all informally referred to as the Nubian Sandstone. This rock can be quite variable in its grain size, bedding type, color, and mineralogy. These properties can sometimes identify the formation – and, hence, the general geographic location of the source – for a sandstone used in a temple. For example, a quarry in the Duwi Formation or upper part of the Quseir Formation, and thus in the Edfu region, is indicated by either a greenish (glauconitic) sandstone, a sandstone of any color containing over 5% total feldspar, or a very fine-grained sandstone with planar bedding. It is not currently possible to recognize specific quarries for these or any other variety of sandstone used in temples, except where these associations are indicated in ancient inscriptions.

28 Arnold (1979), p. 31; Klemm and Klemm (1993), pp. 238-240; (2008), pp. 177-178.

29 Hermina *et al.* (1989), p. 126; Glenn (1990); Glenn and Arthur (1990); Baioumy (2007); Baioumy and Boulis (2012a; 2012b).

30 Ghanem *et al.* (1968), stratigraphic column; Baioumy (2007), fig. 2; Craig Glenn, pers. comm. (2016).

Appendix 1. Ancient Egyptian sandstone temples[31]

LOCATION[32]	MONUMENT and DATE[33]	OTHER MATERIALS and STATUS
Nile Valley		
el-Sheikh `Ibada [Gr. Antinoopolis]: on EB at 27° 48.455' N, 30° 52.373' E	temple of Ramesses II [NK19]	minor limestone; largely destroyed
el-`Amarna [Eg. Akhetaten]: on EB at 27° 38.720' N, 30° 53.760' E	small Aten temple of Akhenaten [NK18]	mostly limestone; largely destroyed
Matmar: on EB at 27° 6.388' N, 31° 19.832' E	combined Aten and Seth temples of Akhenaten and Ramesses II [NK18-19]	mostly limestone?; destroyed
el-`Araba el-Madfuna [Eg. Abedju; Gr. Abydos]: on WB at (1) 26° 11.516' N, 31° 54.671' E; (2) 26° 11.507' N, 31° 54.603' E; (3) 26° 11.188' N, 31° 54.982' E; (4) 26° 11.090' N, 31° 55.140' E	(1) Osiris temple [NK18 & LP30]	mostly limestone?; largely destroyed
	(2) Osiris-Khentyimentyu temple at Kom el-Sultan [OK-LP30]	mostly mud brick; largely destroyed
	(3) cenotaph temple of Ramesses II [NK19]	mostly limestone; largely destroyed
	(4) Osiris temple of Seti I [NK19]	mostly limestone; largely intact
Dendara [Eg. Iunet and Tantere; Gr. Tentyris]: on WB at 26° 8.520' N, 32° 40.210' E	Hathor temple [Pt-R; minor LP30]	intact
Qift [Eg. Gebtu; Gr. Coptos]: on EB at (1) 25° 59.804' N, 32° 48.973' E; (2) 25° 59.773' N, 32° 48.991' E; (3) 25° 59.741' N, 32° 48.996' E	(1) north temple of Min & Isis [Pt-R; minor MK12, NK18 & LP26]	largely destroyed
	(2) middle temple [Pt-R; minor MK12, 3IP22 & NK18]	largely destroyed
	(3) south temple of Geb [Pt; minor LP30]	largely destroyed
Qus [Eg. Gesa or Gesy; Gr. Apollinopolis Parva]: on EB at 25° 54.954' N, 32° 45.847' E	Haroeris and Heqet temple [Pt]	largely destroyed
Nag' el-Madamud [Eg. Madu]: on EB at 25° 44.051' N, 32° 42.606' E	Montu temple [Pt-R; minor MK12, NK18 & LP?]	minor limestone; largely destroyed
Luxor East Bank [Eg. Waset and Ipet-Resyt; Gr. Thebes and Diospolis Magna]: at (1) 25° 43.111' N, 32° 39.487' E; (2) 25° 42.005' N, 32° 38.367' E; (3) connecting (1) and (2)	(1) Karnak Amun temple complex [NK18-20; minor MK12, 3IP21-23, LP25-26, LP29-30, Ma, & Pt-R]	moderately intact
	(2) Luxor Amun temple [NK18-19; minor NK20, LP25, LP30, & Pt-R]	largely intact
	(3) Avenue of sphinxes [LP30]	moderately intact

31 Includes all free-standing temples and attached courts of rock-cut temples (and also pyramids and fortresses) that are either entirely or partly built with sandstone. The principal sources of information are: *Description de l'Égypte* (1809-29), Wilkinson (1847), Weigall (1907; 1910), Baedeker (1929), Survey of Egypt – 1:100,000 topographic maps (1920's and 1930's), Fakhry (1973-74), Seton-Williams and Stocks (1988), Murnane (1996), Gohary (1998), Baines and Malek (2000), and Wilkinson (2000) as well as field observations by the author and the 'Temple Explorer' website: http://temple.egyptien.egyptos.net/temples/temples.php. Ancient Egyptian (Eg.), Greco-Roman (Gr.) and Kushite (Ku) names are given where known.

32 Temples and other structures are listed from north to south.

33 Construction dates are given in brackets using the following abbreviations: ED = Early Dynastic, OK = Old Kingdom, MK = Middle Kingdom, NK = New Kingdom, LP = Late Period, Nap = Napatan period, Mer = Meroitic period, Ma = Macedonian period, Pt = Ptolemaic period, R = Roman period, and B = Byzantine period. Numbers after abbreviations are dynasties. Note that LP26-R in Egypt is contemporary with Nap-Mer in Sudan.

Luxor West Bank: at (1) 25º 44.287' N, 32º 36.415' E; (2) 25º 44.274' N, 32º 36.357' E; (3) 25º 44.241' N, 32º 36.370' E; (4) ~25º 43.98' N, 32º 37.01' E; (5) 25º 43.965' N, 32º 37.684' E; (6) 25º 43.815' N, 32º 36.782' E; (7) 25º 43.738' N, 32º 36.128' E; (8) 25º 43.728' N, 32º 36.685' E; (9) 25º 43.656' N, 32º 36.629' E; (10) 25º 43.621' N, 32º 36.513' E; (11) 25º 43.615' N, 32º 36.471' E; (12) 25º 43.501' N, 32º 36.386' E; (13) 25º 43.327' N, 32º 36.221' E; (14) 25º 43.309' N, 32º 36.066' E; (15) 25º 43.293' N, 32º 36.226' E; (16) 25º 43.261' N, 32º 36.580' E; (17) 25º 43.193' N, 32º 36.044' E; (18) 25º 43.139' N, 32º 36.121' E; (19) 25º 43.023' N, 32º 36.037' E; (20) 25º 41.716' N, 32º 34.706' E	(1) Hatshepsut mortuary temple at Deir el-Bahri [NK18]	mostly limestone; moderately intact
	(2) Tuthmose III mortuary temple at Deir el-Bahri [NK18]	minor limestone; largely destroyed
	(3) Mentuhotep II mortuary temple at Deir el-Bahri [MK11]	minor limestone; largely destroyed
	(4) Ramesses IV mortuary temple [NK20]	destroyed with building stone unknown but probably including sandstone
	(5) Seti I mortuary temple at Qurna [NK19]	largely intact
	(6) Tuthmose III valley temple at Qurna [NK18]	largely destroyed
	(7) Hathor temple at Deir el-Medina [Pt]	largely intact
	(8) Amenhotep II mortuary temple at Qurna [NK18]	largely destroyed
	(9) Ramesses II mortuary temple, the Ramesseum [NK19]	minor limestone; moderately intact
	(10) Tuthmose IV mortuary temple [NK18]	largely destroyed
	(11) Wezmose mortuary temple [NK 18]	destroyed with building stone unknown but probably including sandstone
	(12) Merenptah mortuary temple [NK19]	common limestone; largely destroyed
	(13) Amenophis, son of Hapu, mortuary temple [NK18]	mostly mud brick; largely destroyed
	(14) Ay and Horemheb mortuary temple [NK18]	mostly mud brick; largely destroyed
	(15) Thutmose II mortuary temple [NK18]	destroyed with building stone unknown but probably including sandstone
	(16) Amenhotep III mortuary temple at Kom el-Hetan [NK18]	minor limestone; largely destroyed
	(17) Ramesses III mortuary temple at Medinet Habu [NK20]	largely intact
	(18) Amun temple at Medinet Habu [NK18; minor MK11, NK20, LP25-26, LP29-30, Ma, Pt & R]	largely intact
	(19) Toth temple, the Qasr el-Aguz, at Medinet Habu [Pt]	largely intact
	(20) Isis temple, the Deir el-Shalwit [R]	intact
Armant [Eg. Iuny; Gr. Hermonthis]: on WB at 25º 37.328' N, 32º 32.664' E	Montu temple [NK18; minor MK11-12, Pt & R]	minor limestone; largely destroyed

Tod [Eg. Djerty; Gr. Tuphium]: EB at 25° 34.985' N, 32° 32.012' E	Montu temple [NK18 & Pt; minor MK11-12, NK19-20 & R]	largely destroyed
Esna [Eg. Iunyt, Senet and Tasenet; Gr. Latopolis]: on WB at 25° 17.609' N, 32° 33.371' E	Khnum temple [Pt-R]	intact
near Esna: (1) on WB at ~25° 19.3' N, 32° 31.6' E; (2) on EB at ~ 25° 17.1' N, 32° 34.9' E; (3) on WB at ~ 25° 12.8' N, 32° 38.0' E; (4-5) on WB but not located	(1) Khunum temple at Kom el-Deir [Pt-R]; (2) el-Hilla or Contralatopolis temple [Pt-R]; (3) Kom Mer temple [R]; (4) Osiris and Isis temple at Kom Senum [age?]; and (5) Sahure temple [OK5]	all destroyed and now lost with the building stone unknown, except for the el-Hilla temple, but probably sandstone
el-Kab [Eg. Nekheb; Gr. Eileithyiaspolis]: on EB at 25° 7.130' N, 32° 47.870' E	Nekhbet and Thoth temples [NK18-19, LP25-27, LP29-30 & R]	largely destroyed
near el-Kab: on EB at (1) 25° 8.313' N, 32° 49.718' E; (2) 25° 8.062' N, 32° 49.060' E; (3) 25° 8.021' N, 32° 49.089' E; (4) 25° 7.672' N, 32° 47.633' E; (5) 25° 7.318' N, 32° 48.054' E	(1) Hathor and Nekhbet shrine [NK18]	intact
	(2) Shesmetet shrine [Pt; minor NK19]	partly rock-cut; moderately intact
	(3) el-Hammam shrine [NK19; minor Pt]	intact
	(4) Thutmose III shrine [NK18]	destroyed
	(5) Nectanebo I or II shrine [LP30]	largely destroyed
Kom el-Ahmar [Eg. Nekhen; Gr. Hierakonpolis]: on WB at ~25° 5.86' N, 32° 46.84' E	temple [NK18; minor Pt]	minor limestone ?; destroyed
near el-Kilh Sharq: on EB, not located but near 25° 3.6' N, 32° 52.4' E	two temples [Pt or R like the nearby Nag el-Dumariyya quarry?]	both destroyed and now lost with the building stone unknown but probably sandstone
Edfu [Eg. Djeba or Mesen; Gr. Apollinopolis]: on WB at 24° 58.680' N, 32° 52.410' E	Horus temple [Pt; minor NK19-20]	intact
Nag el-Goneima: on WB at 24° 56.619' N, 32° 50.515' E	pyramid [ED3]	largely intact
Gebel el-Silsila [Eg. Kheny or Khenu]: on EB at 24° 38.991' N, 32° 56.045' E	Kheny temple [NK18-19]	minor limestone; destroyed
Rasras or **Faris**: on WB at 24° 35.205' N, 32° 54.086' E	temple [R]	destroyed
Kom Ombo [Eg. Nubt; Gr. Ombos]: on EB at 24° 27.120' N, 32° 55.690' E	Sobek and Haroeris temple [Pt; minor NK18 & R]	largely intact

Aswan area [Eg. Swenet; Gr. Syene]: on Elephantine Island (1) at 24° 5.095' N, 32° 53.177' E; (2) at 24° 5.086' N, 32° 53.199' E; (3) at 24° 5.054' N, 32° 53.187' E; in Aswan city (4) at 24° 5.042' N, 32° 53.601' E; on Philae Island (5) originally at 24° 1.300' N, 32° 53.336' E and moved to Agilkia Island at 24° 1.519' N, 32° 53.054' E; on Biga Island (6) at ~24° 1.25' N, 32° 53.16' E	(1) Hekaib shrine [MK11-12]	largely intact
	(2) Satet or Satis temple [MK11 & NK18]	moderately intact
	(3) Khnum temple [LP30]	largely destroyed
	(4) Isis temple [Pt]	intact
	(5) Isis temple complex [Pt-R; minor LP30]	intact
	(6) Osiris temple [Pt]	largely destroyed
Dabod: originally on WB at ~23° 53.7' N, 32° 51.7' E and moved to the Museo Arqueologico Nacional, Madrid, Spain	Isis temple [Mer & Pt-R]	largely intact
Dimri: on both WB and EB close to ~ 23° 51.2' N, 32° 53.5' E	temples [R]	largely destroyed and now under Lake Nasser
Qumla: on EB at ~23° 42.9' N, 32° 54.0' E	temple [Pt]	destroyed and now under Lake Nasser
Qertassi [Gr. Tzitzis]: originally on WB at ~23° 41.8' N, 32° 53.4' E and moved to New Kalabasha on WB at 23° 57.610' N, 32° 52.053' E	Hathor shrine [R]	largely intact
Tafa [Gr. Taphis]: originally on WB at ~23° 38.2' N, 32° 52.3' E and moved to Rijksmuseum van Oudheden, Leiden, Netherlands	north temple [R]	intact; there is also reportedly a south temple that is largely destroyed and now under Lake Nasser
Beit el-Wali: originally on WB at ~23° 33.7' N, 32° 51.8' E and moved to New Kalabsha on WB at 23° 57.710' N, 32° 51.976' E	Amun temple [NK19]	partly rock-cut; largely intact
Kalabsha [Gr. Talmis]: originally on WB at ~23° 33.6' N, 32° 51.8' E and moved to (1) New Kalabsha on WB at 23° 57.651' N, 32° 52.044' E; (2) 23° 57.646' N, 32° 52.002' E; (3) Elephantine Island at 24° 5.028' N, 32° 53.095' E; (4) Ägyptisches Museum, Berlin, Germany	(1) Horus-Mandulis temple [R]	largely intact
	(2) Dedwen shrine and birthhouse [Pt]	partly rock-cut; largely intact
	(3) Ptolemy IX shrine [Pt; minor R]	partly intact
	(4) gateway for Kalabsha temple enclosure [Pt-R]	largely intact
Abu Hor or **Kobash**?: on EB at ~ 23° 26.5' N, 32° 54.8' E	temple [Pt-R]	largely destroyed and now under Lake Nasser
Dendur [Gr. Tutzis]: originally on WB at ~ 23° 23.2' N, 32° 56.1' E and moved to Metropolitan Museum of Art, New York, USA	Pediset and Pihor temple [R]	intact
Gerf Hussein: originally on WB at ~23° 16.7' N, 32° 53.6' E with the free-standing courtyard moved to New Kalabsha on WB at 23° 57.617' N, 32° 52.017' E and portions of the rock-cut reliefs moved to the Aswan Museum	Ptah, Ptah-Tenen and Hathor temple [NK19]	partly rock-cut; largely intact with rock-cut portion now under Lake Nasser

el-Dakka [Eg. Pselqet; Gr. Pselchis]: originally on WB at ~23° 10.4' N, 32° 45.3' E and moved to New Sebu'a on WB at 22° 48.066' N, 32° 32.749' E	Thoth and Pnubs temple [Mer, Pt-R; some reused blocks from a MK-NK temple from other side of river]	intact
Kubban or **Quban** [Eg. Baki; Contra Pselchis]: on EB near ~23° 9.5' N, 32° 45.6' E	three temples [MK]	destroyed and now under Lake Nasser
Qurta: on WB at ~23° 6.6' N, 32° 43.1' E	Isis temple [R; minor NK18]	largely destroyed and now under Lake Nasser
el-Maharraqa or **Offeduniya** [Gr. Hierasykaminos]: originally on WB at ~23° 3.5' N, 32° 41.6' E and moved to New Sebu'a on WB at 22° 48.037' N, 32° 32.857' E	Serapis temple [R]	largely intact
es-Sebu'a: originally on WB at ~22° 46.0' N, 32° 33.5' E and moved to New Sebu'a on WB at 22° 47.579' N, 32° 32.723' E	Amun and Re-Horakhti temple [NK19; minor NK18]	partially rock-cut; largely intact
el-`Amada: originally on WB at ~22° 43.4' N, 32° 14.3' E and moved to New Amada on WB at 22° 43.863' N, 32° 15.758' E	Amun and Re-Horakhti temple [NK18-19]	intact
`Aniba [Eg. Mi'an]: on WB at ~ 22° 42.8' N, 32° 4.2' E	Horus or Karanub temple [NK18; minor MK12 & NK19-20]	largely destroyed and now under Lake Nasser
Kharaba: on EB near Nag Shaqqa at ~22° 38.9' N, 32° 16.1' E	temple [age?]	destroyed and now under Lake Nasser
Qasr Ibrim [Gr. Primis]: on EB at 22° 38.977' N, 31° 59.554' E	temple [LP25]	largely destroyed and now on an island in Lake Nasser
Faras [Gr. Pakhoras]: on WB at ~ 22° 13.0' N, 31° 29.0' E	Hathor temple [NK18]	largely destroyed and now under Lake Nasser
Aksha or **Serra West**: on WB at ~ 22° 9.6' N, 31° 25.0' E with some reliefs moved to the National Museum, Khartoum, Sudan	Amun-Re temple [NK19]	largely destroyed and now under Lake Nasser
Buhen: on WB at ~ 21° 54.4' N, 31° 17.2' E and moved to the National Museum, Khartoum, Sudan	Isis and Min temple [NK18] and Horus temple [NK18 & LP25]	largely intact
Behar & **Kor**: on WB at ~ 21° 52.6' N, 31° 15.6' E	Behar temple and Kor fortress walls [MK12-13]	largely destroyed and now under Lake Nasser
Mirgissa [Eg. Iken]: on WB at ~21° 49.5' N, 31° 11.7' E	Hathor temple [NK]	largely intact? and now under Lake Nasser
Semna West: originally on WB at ~21° 29.6' N, 30° 57.5' E and moved to the National Museum, Khartoum, Sudan	Dedwen temple [NK18 & LP25; minor MK12]	largely intact
Semna East or **Kumma**: originally on EB at ~21° 29.5' N, 30° 57.9' E and moved to the National Museum, Khartoum, Sudan	Khnum temple [NK18]	largely intact
`Amara West: on WB at 20° 49.299' N, 30° 23.071' E	Amun temple [NK19]	largely destroyed

Sedeinga: on WB at 20° 33.181' N, 30° 17.623' E	Hathor temple [NK18]	destroyed
Soleb: on WB at 20° 26.179' N, 30° 20.043' E	Amun-Re temple [NK18]	largely destroyed
Sesebi: on WB at 20° 6.575' N, 30° 32.585' E	Aten temple [NK18] rebuilt as Amun, Mut and Khonsu temple [NK19]	largely destroyed
Tabo: on EB at 19° 23.141' N, 30° 28.161' E	Amun temple [LP25; minor Mer]	largely destroyed
Kawa [Eg. Gematon]: on EB at 19° 7.390' N, 30° 29.817' E	Amun temples [NK18, LP25 & Nap-Mer]	largely destroyed
Nuri: on WB at 18° 33.894' N, 31° 54.946' E	pyramids [LP25 & Nap-Mer]	largely intact
Jebel Barkal [Ku. Napata]: on EB at 18° 32.094' N, 31° 49.817' E	Amun temple complex [NK18-19, LP25 & Nap-Mer] and pyramids [Mer]	temples partly intact and pyramids intact
Sanam Abu Dom: on WB at 18° 29.004' N, 31° 49.139' E	Amun-Re temple [LP25]	largely destroyed
el-Kurru: on EB at 18° 24.546' N, 31° 46.243' E	pyramids [LP25]	largely destroyed
	Western Desert	
Faiyum Depression: (1) Qasr el-Sagha at 29° 35.708' N, 30° 40.671' E; (2) Dimai [Gr. Soknopaiou Nesos] at 29° 32.150' N, 30° 40.115' E; (3) Medinet Madi [Gr. Narmouthis] at 29° 11.620' N, 30° 38.520' E	(1) temple [MK12]	intact
	(2) Soknopaios temple [Pt-R]	mostly mud brick and limestone; largely intact
	(3) Renenutet temple [MK12; minor Pt-R]	possibly sandy limestone; largely intact
Bahariyya Depression: in Bawiti area (1) at 28° 21.416' N, 28° 50.787' E; (2) at ~ 28° 21.25' N, 28° 51.50' E; (3) el-Qasr or `Ain el-Muftalla at 28° 20.870' N, 28° 51.502' E; (4) Qasr el-Migysbah at 28° 20.510' N, 28° 49.326' E; south of Bawiti (5) Qasr Allam at 28° 15.575' N, 28° 47.045' E	(1) Apries Shrines [LP26]	largely intact
	(2) Roman arch	destroyed
	(3) Amasis and Apries temple [LP26]	largely destroyed
	(4) Alexander the Great temple [Pt]	largely intact
	(5) Alexander the Great temple [Pt]	mostly mud brick; largely destroyed
Kharga Depression: (1) Ain Amur at 25° 39.112' N, 29° 59.460' E; (2) el-Kharga at 25° 28.587' N, 30° 33.316' E; (3) Kom el-Nadura at 25° 28.140' N, 30° 33.840' E; (4) Qasr el-Ghueida at 25° 17.200' N, 30° 33.470' E; (5) Qasr Zaiyan at 25° 15.085' N, 30° 34.254' E; (6) Qasr Dush at 24° 34.800' N, 30° 43.030' E	(1) temple [R]	partly limestone; largely destroyed
	(2) Hibis temple [LP27, LP30 & Pt]	minor limestone; largely intact
	(3) temple [R]	largely destroyed
	(4) Amun temple [LP26 & Pt]	largely intact
	(5) Amun, Mut and Khonsu temple [Pt-R]	largely intact
	(6) Isis and Serapis temple [R]	largely intact

Dakhla Depression: (1) el-Qasr el-Dakhla at ~25° 41.79’ N, 28° 53.01’ E; (2) Amheida at ~ 25° 40.13’ N, 28° 52.25’ E; (3) Deir el-Hagar at 25° 39.882’ N, 28° 48.800’ E; (4) Balat at 25° 33.433’ N, 29° 16.788’ E; (5) Ain Birbiya at 25° 31.363’ N, 29° 19.173’ E; (6) Ismant el-Kharab [Gr. Kellis] at 25° 30.964’ N, 29° 5.643’ E; (7) Mut el-Kharab at ~25° 29.02’ N, 28° 58.42’ E	(1) Thoth temple [Pt-R]	destroyed or buried under houses
	(2) Toth temple [Pt-R]	largely destroyed
	(3) Amun, Mut and Khonsu temple [R]	largely intact
	(4) Mut temple [NK]	largely destroyed
	(5) Amennakht temple [R]	possibly limestone; largely intact
	(6) Tutu and Neith temples [R]	possibly limestone; largely destroyed
	(7) Seth temple [R; minor NK18, 3IP, LP26 & Pt]	destroyed
Eastern Desert and Sinai		
Serabit el-Khadim, Sinai at 29° 2.213’ N, 33° 27.560’ E	Hathor temple [MK12 & NK18]	mostly limestone; largely intact
Bir el-Kanayis, Eastern Desert at 25° 0.358’ N, 33° 18.018’ E	Amun-Re temple [NK19]	mostly rock-cut

Appendix 2. Ancient Egyptian sandstone quarries[34]

LOCATION[35]	AGE[36], SIZE[37] and STATUS	SANDSTONE PETROLOGY[38]
Nile Valley		
Duwi Formation		
el-Mahamid on EB at 25° 8.15' N, 32° 46.92' E	Pt; medium; intact and not protected?	very fine- to fine-grained; massive to indistinct planar bedding with minor tabular cross-bedding; light yellowish-brown (total feldspar = 9.4-11.2% [2])
Shesmetet on EB at 25° 8.065' N, 32° 49.034' E	NK19 & Pt like the nearby Shesmetet temple?; small; intact and protected	fine-grained; massive to indistinct planar bedding with minor tabular cross-bedding; light brown?
Wadi el-Tarifa on WB at 25° 4.70' N, 32° 44.62' E	NK18 & Pt like the nearby Kom el-Ahmar temple?; medium; destroyed	very fine- to medium-grained; massive bedding to tabular cross-bedding; light brown to mainly light brownish gray or light gray (has a "high proportion of feldspar" according to Klemm and Klemm 2008: 173)
el-Keijal on EB at 25° 4.09' N, 32° 51.78' E	Pt or R, at least in part; small; intact and not protected	very fine- to fine-grained; massive bedding; medium brown or light pinkish to purplish brown (total feldspar = 8.7% [1])
Quseir Formation – upper part		
Nag el-Dumariyya on EB at 25° 2.96' N, 32° 53.33' E	Pt-R; small, intact and not protected	very fine- to fine-grained; planar bedding with minor trough cross-bedding; light pinkish gray or brown
el-Bueib on EB at 24° 48.61' N, 32° 54.84' E	MK12, NK18 & B?; medium; moderately intact and not protected	very fine- to medium-grained; massive to planar bedding and tabular cross-bedding; light brown (total feldspar = 6.1% [1])
Nag el-Raqiqein WB at 24° 44.76' N, 32° 55.24' E	age?; small; largely intact and now threatened	very fine- to mainly fine-grained; tabular cross-bedding with minor planar bedding; light to medium brown (total feldspar = 14.2% [1])
Quseir Formation – lower part		
Nag el-Hosh on WB at 24° 44.31' N, 32° 55.28' E	Pt-R; medium; largely intact and now threatened	fine- to mainly medium-grained; tabular cross-bedding; light brown to light pinkish-brown (total feldspar = 1.4% [1])

34 This data comes primarily from the author's unpublished field and laboratory studies. Additional information is provided by (1) Klemm and Klemm (1993), pp. 225-281; (2008), pp. 167-213 for quarries in the Nile Valley north of Aswan and in the Western Desert's depressions; and (2) Spence *et al.* (2009), pp. 44-45 and Mohamed (2012) for quarries in the Nile Valley south of Wadi Halfa in Sudan.

35 Coordinates are for quarry centers. Where there is uncertainty in a location, this is indicated by the approximate symbol (~) and a reduced precision in the reported coordinates.

36 See footnote 33 in Appendix 1.

37 Quarry size corresponds to the maximum dimension of an area of workings or the cumulative maximum dimensions for multiple isolated areas of workings. Three size classes are recognized: small (< 100 m), medium (100-1000 m), and large (> 1000 m).

38 The Udden-Wentworth scale is used for grain size, and colors are for internal (fresh) surfaces. The number of samples analyzed is indicated within brackets for total feldspar content.

Wadi Shatt el-Rigal on WB at 24° 41.11' N, 32° 55.39' E	MK11-12 & NK18?; medium; intact and partially protected	very fine- to mainly fine- to medium-grained; tabular cross-bedding; light gray to light yellowish gray or brown (total feldspar = <1% [1])
Nag el-Hammam on WB at 24° 40.36' N, 32° 55.47' E	MK-NK?; medium; intact and not protected	very fine- to mainly fine- to medium-grained: tabular cross-bedding; light brown (northern part) to brownish-yellow (southern part) with occasional thin purplish-brown planar zones (total feldspar = <1% [4])
Gebel el-Silsila on WB at 24° 39.05' N, 32° 55.75' E, and on EB at 24° 38.48' N, 32° 56.04' E	MK-R; large; largely intact and protected	mainly fine- to medium-grained and occasionally pebbly medium- to coarse-grained; tabular cross-bedding but planar bedding when coarse-grained; light to medium brown or yellowish- to orangy-brown with common minute reddish-brown spots, or yellowish-white to white (total feldspar = <1.3% [6])
Umm Barmil Formation		
Nag el-Falilih on EB at 24° 20.04' N, 32° 55.27' E	Pt & R?; medium; partially destroyed and not protected	very fine- to mainly fine-grained; massive to indistinct tabular cross-bedding; light yellowish- to pinkish-brown (total feldspar = 3.5% [1])
Nag el-Sheikh Garad on EB at 24° 18.45' N, 32° 54.72' E	Pt & R?; large; largely destroyed	very fine- to mainly fine- to medium-grained; tabular cross-bedding; light yellowish- to pinkish-brown (total feldspar = 1.5-4.6% [3])
Gebel el-Hammam on EB at ~24° 13.5' N, 32° 52.5' E	NK18; small?; destroyed	very fine- to mainly fine- to medium-grained; tabular cross-bedding; light yellowish- to pinkish-gray (total feldspar = 1.7% [1])
Nag el-Fuqani on WB at 24° 12.24' N, 32° 51.60' E	Pt; medium; largely intact and now threatened	fine- to medium-grained; tabular cross-bedding with minor planar to wavy bedding; yellowish- or pinkish-gray to mainly light gray
Hagar el-Ghorab on WB at 24° 11.33' N, 32° 51.79' E	Pt-R?; small; intact and now threatened	no information
Gebel el-Qurna WB at 24° 9.75' N, 32° 52.10' E	R and earlier?; medium; intact and not protected	fine- to mainly medium- to coarse-grained; tabular cross-bedding; light gray or light yellowish- to pinkish-gray (total feldspar = <1% [2])
Timsah Formation		
Qubbet el-Hawa on WB at 24° 6.11' N, 32° 53.26' E (possible quarry)	from exteriors of OK6 & MK12 tombs; small; intact and protected	medium- to mainly fine-grained; planar bedding with thin mudstone interbeds; light gray or multi-hued in shades of gray, yellow, brown, red and purple
Abu Aggag Formation		

St. Simeon on WB at 24° 5.69’ N, 32° 52.55’ E	either OK-MK like the nearby Qubbet el-Hawa tombs or B like the St. Simeon monastery; small; largely intact and protected	medium- to coarse-grained; planar bedding; light brown?
Aswan on EB at 24° 3.29’ N, 32° 54.46’ E	NK & R?, medium?; largely destroyed	no information
Dabod on WB at ~23° 53.7’ N, 32° 51.7’ E	Pt, R & Mer like the nearby Dabod and Dimri temples?; small?; under Lake Nasser	
Qertassi on WB at ~23° 41.8’ N, 32° 53.4’ E	Pt & R; large; under Lake Nasser	
Tafa on WB at ~23° 38.2’ N, 32° 52.3’ E	R like the nearby Tafa temple?; small or medium?; under Lake Nasser	
Kalabsha on WB at ~23° 33.6 ’ N, 32° 51.8’ E	Pt-R like the nearby Kalabsha temples; small or medium?; under Lake Nasser	fine-grained; light yellowish-brown – based on samples from the Kalabsha temple (total feldspar = <1 % [2])
Abu Hor on WB ~23° 26.5’ N, 32° 54.8’ E	Pt & R like the nearby Abu Hor temple?; small or medium?; under Lake Nasser	no information
Sabaya Formation		
Qurta on WB at ~23° 6.6’ N, 32° 44.1’ E	MK, NK18, Pt & R like the nearby Kubban, el-Dakka, Qurta and el-Maharraqa temples?; small or medium?; under Lake Nasser	fine-grained; light brown to yellowish-brown – based on samples from the el-Maharraqa temple (total feldspar = <1% [4])
Agayba on WB at ~22° 51.0’ N, 32° 34.0’ E	NK18-19 like the nearby es-Sebu’a temple; small?; under Lake Nasser	no information
Sabaya or Lake Nasser Formation		
Tumas on WB at ~22° 45.4’ N, 32° 7.0’ E	MK12 & NK18-19 like the nearby el-`Amada and `Aniba temples?; small or medium?; under Lake Nasser	no information
Lake Nasser Formation		
Qasr Ibrim on EB at ~ 22° 39.0’ N, 31° 59.5’ E	LP25 like the nearby Qasr Ibrim temple?; small?; under Lake Nasser	no information
Nag Deira on EB at ~22° 30.4’ N, 31° 53.5’ E	NK like the nearby rock-cut tombs?; small; under Lake Nasser	
Gebel Adda on EB at ~ 22° 17.7’ N, 31° 36.5’ E	Mer; small; under Lake Nasser	pink and white sandstones; no other information
Abu Simbel Formation		
Gezira Dabarosa on WB at ~21° 55.8’ N, 31° 18.7’ E	MK12-13, NK18 & LP25 like the nearby Buhen and Kor fortresses?; small; under Lake Nasser	no information
Abdel Kadir on WB at 21° 52.41’ N, 31° 9.13’ E	MK11; small; intact and above Lake Nasser	

Nubian Sandstone Formation undifferentiated		
Sesebi on WB at 20° 6.70' N, 30° 32.57' E	NK18-19 like the nearby Sesebi temple?; small; intact and unprotected?	cross-bedded; light gray to nearly white with occasional orange bands; no other information
Jebel Barkal Foug on EB at 18° 32.66' N, 31° 49.86' E	NK18-19, LP25, Nap & Mer like the nearby Gebel Barkal temples?; small to medium; largely intact and not protected	no information
Khor el-Hawazawin on EB at 18° 30.59' N, 31° 48.58' E		
Khor el-Sadda on EB at 18° 30.05' N, 31° 48.08' E		
Eastern Desert		
el-Muweih at 25° 56.70' N, 33° 23.91' E	R; medium; intact and not protected	Taref Formation: no other information
Bir el-Kanayis at 25° 0.24' N, 33° 18.52' E	NK19 & R like the nearby temple and praesidium?; small; intact and protected	Quseir Formation: no other information
Western Desert		
Qaret el-Farangi, Bahariya Depression at ~28° 20.69' N, 28° 51.92' E	LP26, Pt & R like the nearby temples in el-Bawati?; small?; largely destroyed?	Bahariya Formation: no other information
el-Muzawqa, Dakhla Depression at 25° 40.91' N, 28° 50.31' E	Pt & R like the nearby Amheida and Deir el-Hagar temples?; small; intact and protected?	Quseir or Duwi Formation: no other information
south of Masara, Dakhla Depression at ~25° 28.7' N, 29° 3.4' E	NK18, 3IP, LP26, Pt & especially R like the nearby Ismant el-Kharab and Mut el-Kharab temples?; medium?; largely intact and not protected	Quseir or Taref Formation: no other information
Gebel el-Teir, Kharga Depression at ~25° 32.4' N, 30° 33.1' E	LP27, LP30, Pt & R like the nearby el-Kharga and Kom el-Nadura temples?; small?; largely intact?	Quseir or Dakhla Formation: no other information
Sinai Peninsula		
Serabit el-Khadim at 29° 2.20' N, 33° 23.90' E	MK12-NK20 like the nearby Hathor temple	Abu Durba Formation of Lower Carboniferous age

Bibliography

Ahmed, S. M., Al-Sheikh, H. A. and Osman, R. A. (1993), 'Facies and depositional environments of the pre-Maastrichtian clastic rocks of west and southwest Aswan, Egypt', *Egyptian Journal of Geology* 37/2, pp. 69-96.

Ahmed, M. I. S. and Hussein, S. A. (1983), 'Petrophysical properties of some sandstones facies from EL-Mahamid, Eastern Desert, Egypt', *Egyptian Journal of Geology* 27/1-2, pp. 21-26.

Arnold, D. (1979), *The Temple of Mentuhotep at Deir El-Bahari*, New York: Metropolitan Museum of Art, Egyptian Expedition.

Arnold, D. (1991), *Building in Egypt: Pharaonic Stone Masonry*, Oxford: Oxford University Press.

Attia, M. I. (1955), *Topography, Geology and Iron-Ore Deposits of the District East of Aswan*, Cairo: Egyptian Geological Survey.

Baedeker, K. (1929), *Egypt and the Sudan – Handbook for Travelers* (8th ed.), Leipzig: Karl Baedeker Publisher.

Baines, J. and Malek, J. (2000), *Cultural Atlas of Ancient Egypt*, Oxford: Andromeda/Checkmark Books.

Baioumy, H. M. (2007), 'Iron-phosphorus relationship in the iron and phosphorite ores of Egypt', *Chemie der Erde* 67, pp. 229-239.

Baioumy, H. M. and Boulis, S. N. (2012a), 'Glauconites from the Bahariya Oasis: an evidence for Cenomanian marine transgression in Egypt', *Journal of African Earth Sciences* 70, pp. 1-7.

Baioumy, H. M. and Boulis, S. N. (2012b), 'Non-pelletal glauconite from the Campanian Qusseir Formation, Egypt: implications for glauconitization', *Sedimentary Geology* 249/250, pp. 1-9.

Breasted, J. H. (1906), *Ancient Records of Egypt – Historical Documents*, Vol. 4, *The Twentieth to the Twenty-Sixth Dynasties*, Chicago: University of Chicago Press.

Clarke, S. (1910), 'Architectural descriptions', in E. Naville (ed.), *The XIth Dynasty Temple at Deir El-Bahari* (pt. 2), London: Egypt Exploration Fund, pp. 13-19.

Clarke, S. and Engelbach, R. (1930), *Ancient Egyptian Masonry – The Building Craft*, London: Oxford University Press.

Description de l'Égypte. (1809-1829), *Description de l'Égypte, ou Recueil de observations et des recherches qui ont été faites en Égypte pendant l'éxpédition de l'armée française*, Paris: C. L. F. Panckoucke.

Fakhry, A. (1973-74), *The Oases of Egypt*, Vol. 2, *Bahriyah and Farafra Oases*, Cairo: American University in Cairo Press.

Fitzner, B., Heinricks, K. and La Bouchardiere. D. (2003), 'Weathering damage on pharaonic sandstone monuments in Luxor, Egypt', *Building and Environment* 38/9-10, pp. 1089-1103.

Ghanem, M., Zalata, A., Abd El Razik, T., Mikhailov, I., Mirtov, J., Razvaliaev, A. and Touliankin, V. (1968), *Geological Map of Idfu-Qena Area* (1:200,000; with accompanying stratigraphic column and cross-sections), Cairo: United Arabic Republic General Organization for Geological Researches and Mining Geological Survey.

Glenn, C. R. (1990), 'Depositional sequences of the Duwi, Sibaiya and Phosphate Formations, Egypt: phosphogenesis and glauconitization in a Late Cretaceous Sea', in A. J. G. Notholt and I. Jarvis (eds.), *Phosphorite Research and Development*, London: Geological Society (Special Publication No. 52), pp. 205-222.

Glenn, C. R. and Arthur, M. A. (1990), 'Anatomy and origin of a Cretaceous phosphorite-greensand giant, Egypt', *Sedimentology* 37, pp. 123-154.

Gohary, J. (1998), *Guide to Nubian Monuments on Lake Nasser*, Cairo: American University in Cairo Press.

Harrell, J. A. (2012a), 'Building stones', in W. Wendrich (ed.), *UCLA Encyclopedia of Egyptology*, Los Angeles: University of California at Los Angeles. [online at http://digital2.library.ucla.edu/viewItem.do?ark=21198/zz002c10gb]

Harrell, J. A. (2012b), 'Ornamental stones', in W. Wendrich (ed.), *UCLA Encyclopedia of Egyptology*, Los Angeles: University of California at Los Angeles. [online at http://digital2.library.ucla.edu/viewItem.do?ark=21198/zz002dwzs4]

Harrell, J. A. (2012c), 'Utilitarian stones', in W. Wendrich (ed.), *UCLA Encyclopedia of Egyptology*, Los Angeles: University of California at Los Angeles. [online at http://digital2.library.ucla.edu/viewItem.

do?ark=21198/zz002bqsfg]

Harrell, J. A., and Madbouly, M. I. (2006), 'An ancient quarry for siliceous sandstone at Wadi Abu Aggag, Egypt', *Sahara* 17, pp. 51-58.

Harrell, J. A., and Storemyr, P. (2013), 'Limestone and sandstone quarrying in ancient Egypt: tools, methods, and analogues', *Marmora* 9, pp. 19-43.

Heldal, T., Bloxam, E., Storemyr, P. and Kelany, A. (2005), 'The geology and archaeology of the ancient silicified sandstone quarries at Gebel Gulab and Gebel Tingar, Aswan (Egypt)', *Marmora* 1, pp. 11-35.

Hermina, M., Klitzsch, E. and List, F. K. (1989), *Stratigraphic Lexicon and Explanatory Notes to the Geological Map of Egypt* (1:500,000, 20 sheets), Cairo: Egyptian General Petroleum Corporation and Conoco Coral.

Hölscher, U. (1939), *The Excavation of Medinet Habu*, Vol. 2, *The Temples of the Eighteenth Dynasty*, Chicago: University of Chicago Press.

Issawi, B., El Hinnawi, M., Francis, M. and Mazhar, A. (1999), *The Phanerozoic Geology of Egypt – A Geodynamic Approach*, Cairo: Egyptian Geological Survey (Special Publication No. 76).

Kitchen, K. A. (1991), 'Building the Ramesseum', *Cahiers de Recherches de l'Institut de Papyrologie et d'égyptologie de Lille* 13, pp. 85-93.

Klemm, R. and Klemm, D. D. (1993), *Steine und Steinbrüche im Alten Ägypten*, Berlin: Springer-Verlag.

Klemm, R. and Klemm, D. D. (2008), *Stones and Quarries in Ancient Egypt*, London: British Museum Press.

Klemm, D. D., Klemm, R. and Steclaci, L. (1984), 'Die pharaonischen steinbrüche des silifizierten sandsteins in Ägypten und die herkunft der Memnon-Kolosse,' *Mitteilungun des Deutschen Archäologischen Instituts Abteilung Kairo* 40, pp. 207-220.

Klitzsch, E., List, F. K. and Pöhlmann, G. (eds.) (1987), *Geological Map of Egypt* (1:500,000; 20 sheets), Cairo: Egyptian General Petroleum Corporation and Conoco Coral.

Knox, W. O., Stadelmann, R., Harrell, J. A., Heldal, T. and Sourouzian, H. (2009), 'Mineral fingerprinting of Egyptian siliceous sandstones and the quarry source of the Colossi of Memnon', in N. Abu Jaber, E. G. Bloxam, P. Degryse and T. Heldal (eds.), *QuarryScapes: Ancient Stone Quarry Landscapes in the Eastern Mediterranean*, Bergen: Geological Survey of Norway (Special Publication no. 12), pp. 75-83.

Kramer, A. H. (2009), 'Talatat shipping from Gebel el-Silsileh to Karnak – a literature survey', *Bibliotheca Orientalis* 66/1-2, pp. 6-20.

Larché, F. (2009), 'A reconstruction of Senwosret I's portico and of some structures of Amenhotep I at Karnak', in P. J. Brand and L. Cooper (eds.), *Causing His Name to Live – Studies in Egyptian Epigraphy and History in Memory of William J. Murnane*, Leiden: Brill, pp. 137-173.

Lucas, A. (1905), *The Blackened Rocks of the Nile Cataracts and of the Egyptian Deserts*, Cairo: Ministry of Finance.

Marouard, G. and Papazian, H. (2012), 'The Edfu Pyramid Project: recent investigation at the last provincial step pyramid', *The Oriental Institute News and Notes* 213, pp. 3-9.

Mohamed, A. A. (2012), 'Quarrying for the king – the sources of stone for Kushite royal monuments', *Sudan & Nubia* 16, pp. 2-7.

Murnane, W. J. (1996), *The Penguin Guide to Ancient Egypt*, New York: Penguin Books.

Petrie, W. M. F. (1903), *Abydos* (Pt. 2), London: Egypt Exploration Fund.

Petrie, W. M. F. (1938), *Egyptian Architecture*, London: British School of Archaeology in Egypt.

Potter, R. and Rossman, G. (1977), 'Desert varnish: the importance of clay minerals', *Science* 196, pp. 1446-1448.

Potter, R. and Rossman, G. (1979), 'The manganese- and iron-oxide mineralogy of desert varnish', *Chemical Geology* 25, pp. 79-94.

Quibell, J. E. and Green, F. W. (1902), *Hierakonpolis* II, London: Bernard Quaritch.

Seton-Williams, V. and Stocks, P. (1988), *Blue Guide – Egypt*, London: A. & C. Black.

Shaw, I. and Jameson, R. (1993), 'Amethyst mining in the Eastern Desert: a preliminary survey at Wadi el-Hudi', *Journal of Egyptian Archaeology* 79, pp. 81-97.

Shukri, N. M. and Ayouti, M. K. (1953), 'The mineralogy of the Nubian Sandstone in Aswan', *Bulletin de l'Institut Désert de Égypt* 3/2, pp. 65-88.

Spence, K., Rose, P., Bunbury, J., Clapham, A., Collet, P., Smith, G. and Soderbery, N. (2009), 'Fieldwork at Sesebi, 2009', *Sudan & Nubia* 13, pp. 38-46.

Van Houten, F. B. and Bhattacharyya, D. P. (1979), 'Late Cretaceous Nubia Formation at Aswan, Southeastern Desert, Egypt', *Annals of the Geological Survey of Egypt* 9, pp. 408-419.

Ward, W. C. and McDonald, K. C. (1979), 'Nubia formation of central Eastern Desert, Egypt: major subdivisions and depositional setting', *American Association of Petroleum Geologists Bulletin* 63, pp. 975-983.

Weigall, A. E. P. (1907), *A Report on the Antiquities of Lower Nubia (the First Cataract to the Sudan Border) and Their Condition in 1906-1907*, Oxford: Oxford University Press.

Weigall, A. E. P. (1910), *A Guide to the Antiquities of Upper Egypt, from Abydos to the Sudan Frontier*, New York: Macmillan Co.

Wilkinson, J. G. (1847), *Hand-book for Travellers in Egypt*, London: John Murray.

Wilkinson, R. H. (2000), *The Complete Temples of Ancient Egypt*, London: Thames and Thames.