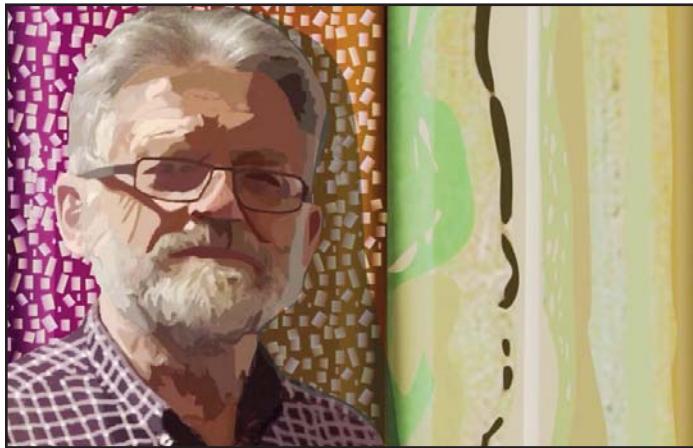


SERIES



Heritage Stone 6.

Gneiss for the Pharaoh: Geology of the Third Millennium BCE Chephren's Quarries in Southern Egypt*

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SUMMARY

A remarkable campaign of decorative stone quarrying took place in the southwestern Egyptian desert almost 5000 years

ago. The target for quarrying was Precambrian plagioclase–hornblende gneiss, from which several life-sized statues of King Chephren (or Khafra) and thousands of funerary vessels were produced. The former inspired George Murray in 1939 to name the ancient quarry site ‘Chephren’s Quarries.’ Almost 700 individual extraction pits are found in the area, in which free-standing boulders formed by spheroidal weathering were worked by stone tools made from local rocks and fashioned into rough-outs for the production of vessels and statues. These were transported over large distances across Egypt to Nile Valley workshops for finishing. Although some of these workshop locations remain unknown, there is evidence to suggest that, during the Predynastic to Early Dynastic period, the permanent settlement at Hierakonpolis (Upper Egypt) could have been one destination, and during the Old Kingdom, another may have been located at pyramid construction sites such as the Giza Plateau (Lower Egypt). Chephren’s Quarries remains one of the earliest examples of how the combined aesthetic appearance and supreme technical quality of a rock made humans go to extreme efforts to obtain and transport this raw material on an ‘industrial’ scale from a remote source. The quarries were abandoned about 4500 years ago, leaving a rare and well-preserved insight into ancient stone quarrying technologies.

RÉSUMÉ

Une remarquable campagne d’extraction de pierres décoratives a été menée dans le sud-ouest du désert égyptien il y a près de 5000 ans. La roche cible était un gneiss à plagioclase–hornblende, de laquelle ont été tiré plusieurs statues grandeur nature du roi Khéphren (ou Khâef Rê) et des milliers de vases funéraires. C’est pourquoi George Murray, en 1939, a donné au site de l’ancienne carrière le nom de ‘Chephren’s Quarries.’ On peut trouver près de 700 fosses d’extraction sur le site, renfermant des blocs de roches formés par altération sphéroïdale qui ont été dégrossis avec des outils de pierre pour la production de vases et de statues. Puis ils ont été transportés à travers l’Égypte jusqu’aux ateliers de finition de la vallée du Nil. Bien que la localisation de certains de ces ateliers demeure inconnue, certains indices permettent de penser que, de la période prédynastique jusqu’à la période dynastique précoce, l’établissement permanent à Hiérakonpolis (Haute Égypte) aurait pu être l’une de ces destinations; durant l’Ancien empire une autre destina-

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Figure 1. a) Statue of King Chephren (left) made from light-banded Chephren gneiss (Egyptian Museum, Cairo); b) at top, vessel made from speckled variety (Art and History Museum, Brussels), and at bottom, vessel made from a speckled, light variety (Egyptian Museum, Turin). Photo credits: Jon Bosworth (left) and Tom Heldal (right).

tion aurait pu être située aux sites de construction de pyramides comme le Plateau de Giza (Basse Égypte). Les Chephren's Quarries l'une des plus anciennes exemples montrant comment la combinaison des qualités esthétiques et techniques remarquables de la roche ont incité les humains à consentir de si grands efforts pour extraire et transporter ce matériau brute à une échelle industrielle d'un site éloigné. Les carrières ont été abandonnées il y a environ 4500 ans, nous laissant une fenêtre rare et bien conservé sur des technologies anciennes d' extraction de pierre de taille.

Traduit par le Traducteur

INTRODUCTION

Some of the greatest treasures of ancient Egypt were made from plagioclase–hornblende gneiss, including the life-sized sculptures of King Chephren (or Khafra; ca. 2500 BCE) and thousands of funerary vessels (Aston 1994; Fig. 1). The stone in question is a gneissic rock, essentially composed of varying proportions of bytownite plagioclase and hornblende, so that the appearance varies from almost white (anorthositic) to nearly black (gabbroic). The name '*Chephren gneiss*', covering all the exploited varieties of the gneiss, was introduced by Klemm and Klemm (1993, 2008), partly to avoid confusion arising from the numerous names given to these rocks through time

(Sultan et al. 1994; Harrell and Brown 1994). The only source of this stone had remained a mystery until a military patrol found it after getting lost in a sandstorm in 1932.

The quarries are located 12 km west of Gebel el-Asr in southern Egypt, 60 km northwest of Abu Simbel and just south of Wadi Toshka. Gebel el-Asr stands out as a natural landmark in the flat and hyper-arid desert, even though the sandstone hill is only 50 m higher than the surroundings. To the west of Gebel el-Asr, Precambrian basement rocks of the Gebel el-Asr Complex are exposed (Said 1962; Tawadros 2001; Fig. 2). Within this complex, almost all outcrops of hornblende–plagioclase gneiss were exploited by the ancient Egyptians (Fig. 3). The term '*Chephren's Quarries*' is used for an extensive area with numerous extraction pits.

Vessel production had already started in the Late Neolithic (5100–4700 BC), given its presence in elite burials 50 km to the west at Nabta Playa (Schild and Wendorf 2001). However, it was during the Predynastic Period (ca. 4000–3100 BCE) that highly-crafted vessel production began in earnest, reaching a peak between the Early Dynastic Period (3100–2686 BCE) and the Fourth Dynasty (2613–2494 BCE) of the Old Kingdom (2686–2134 BCE). Production for objects such as life-sized statues of the pharaoh marked a significant transition towards much larger-scale appropriation and transport of the material

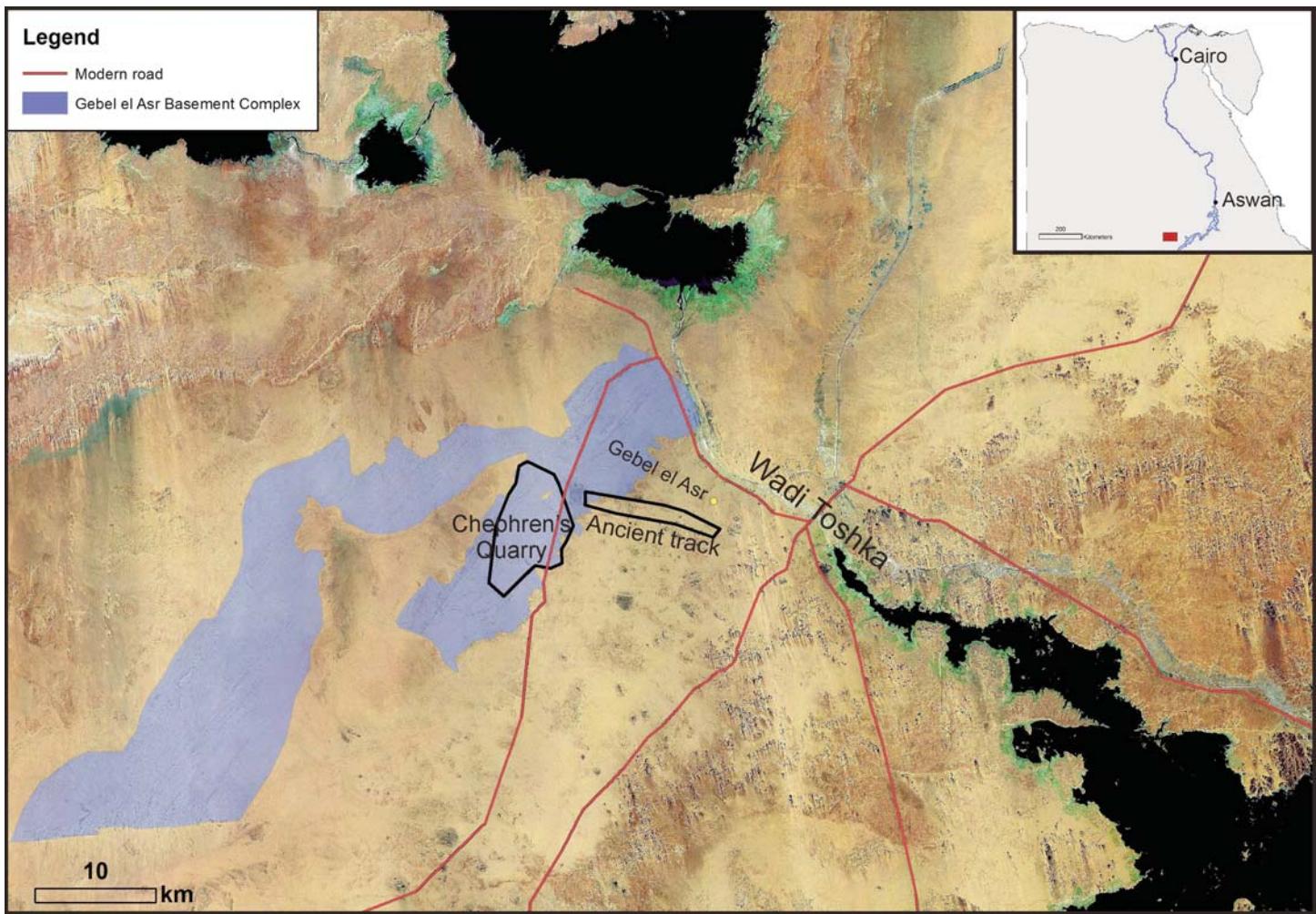


Figure 2. Map showing the location of the Gebel el-Asr basement inlier, Chephren's Quarry, and the ancient track to the Nile.

to sites over a thousand kilometres away (e.g. the Giza Plateau in Lower Egypt). We believe that appropriation of this particular rock is of global significance as it marks a turning-point in the large-scale production of a specific stone for purely ornamental purposes. Reginald Engelbach (1933) undertook the first survey at Chephren's Quarries, in the northern part of the area, discovering quarries, built structures and workshops at Quartz Ridge. Engelbach returned in 1938 with George Murray (Engelbach 1938; Murray 1939), discovering not only quarries, but also loading ramps, part of the transport route to the Nile, and several artefacts, such as inscribed stone stelae dating to the reigns of 4th, 5th and 12th Dynasty Egyptian rulers (including Khufu and Sahura). More recent geo-archaeological research was undertaken by Harrell and Brown (1994), and archaeological/geological surveys and excavations directed by Ian Shaw were carried out between 1997 and 2004 (Shaw and Bloxam 1999; Shaw 2000; Bloxam 2000, 2003, 2005, 2007; Shaw et al. 2001, 2010; Storemyr et al. 2002; Shaw and Heldal 2003; Heldal et al. 2009). This work revealed significant new information about the extent of quarrying, extraction technologies, and logistics, as well as settlement remains through which we could begin to understand the social organization and subsistence of a quarry work force operating 5000 years ago.

This paper presents a geological view of the quarries,

including the ways in which geological processes formed this unique stone resource so that it became exploitable by the ancient Egyptians, and even how these processes resulted in a readily available 'tool kit' for working the stone. It builds on several field campaigns between 2003 and 2007. Some of the data presented have previously been published (Storemyr et al. 2002; Shaw and Heldal 2003; Heldal and Storemyr 2003; Bloxam 2007, 2011; Heldal et al. 2009; Shaw et al. 2010). However, this paper presents unpublished data on the geology of the area and seeks to engage a stronger geological perspective on the quarries than in previous publications. In this way, we hope to communicate the significance of this unique geological resource, exploited for only a brief period of time.

OUTLINE OF THE GEOLOGY

Between Lake Nasser and the Libyan–Sudanese border at Gebel Uweinat are three outcrop areas of Precambrian basement rocks (Richter and Schandelmeyer 1990): the Bir Sufsaf Complex to the west, and the Gebel el-Asr Complex and Gebel Umm Shâghir Complex to the east (Huth and Franz 1988). These form part of a large east-west trending system of basement uplifts, surrounded by Upper Cretaceous sedimentary rocks (Hendriks et al. 1984).

In the Gebel el-Asr area, the old metamorphic complex consists mainly of granitic rocks and patches of the Chephren

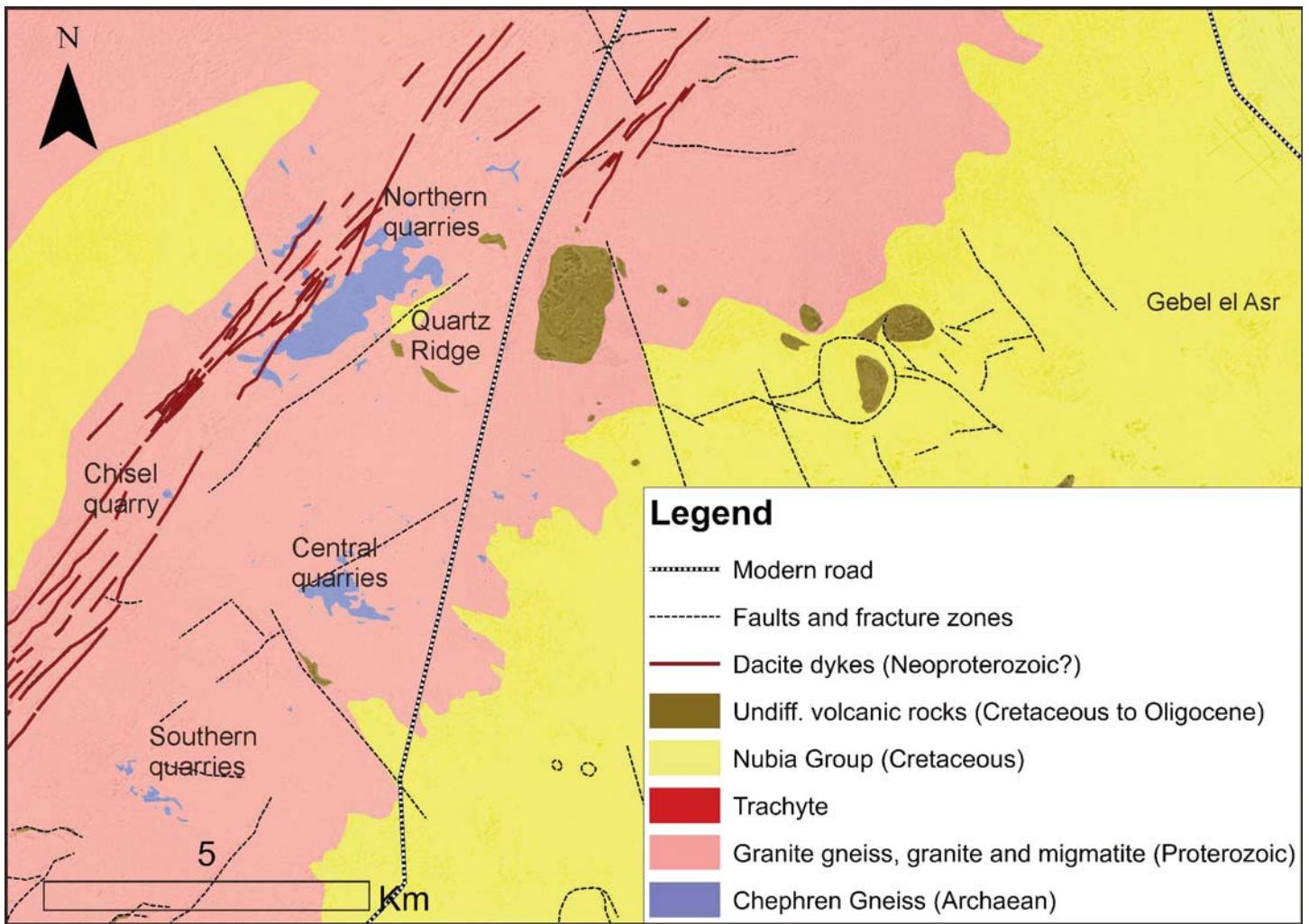


Figure 3. Geological map of the Chephren's Quarry area.

gneiss (Fig. 3). Hence, the outcrop pattern of the Chephren gneiss is highly irregular, displayed in numerous isolated outcrops of varying size. U–Pb zircon age-dating suggests that the gneiss is older than 1900–2100 Ma, and may well be Archean (Sultan et al. 1994). Schandlmeier et al. (1987) suggested that these rocks experienced granulite facies metamorphism around 2900 Ma, later retrogressive amphibolite facies metamorphism at 2650 Ma, and an anatectic event accompanied by granite formation around 1750 Ma. A new thermal event characterized by migmatization occurred by 680 Ma (Schandlmeier et al. 1987), corresponding to a metamorphic age of 690 Ma in the Chephren gneiss, and crystallization ages between 741 and 626 Ma in migmatites farther northeast (Sultan et al. 1994). Intrusive granitic bodies were linked to various stages of migmatitization.

The youngest rocks within the basement inliers are dykes of varying composition, but are predominantly dacitic. They probably relate to Late Proterozoic–Early Paleozoic extensional tectonics in the latter stages of subduction, and are commonly referred to as ‘dyke swarms’ and ‘ring complexes’ of felsic to mafic and locally alkaline composition (Richter and Schandlmeier 1990; Pudlo and Franz 1994; Tawadros 2001). Mylonite zones are common in the basement inliers (Bernau et al. 1987), associated with Late Proterozoic retrogressive greenschist facies metamorphism that partly overprinted the previ-

ous high-grade fabrics of the basement rocks (Huth and Franz 1988). During the Late Cretaceous, the Precambrian rocks were exposed to weathering, and the Nubia Group (Whiteman 1970), consisting predominantly of fluvial and shallow marine sandstone and mudstone, was deposited on top of the then rather flat paleo-terrain. Shortly after (from around 80 Ma according to Bernau et al. (1987), and perhaps up to the Oligocene), the area experienced intense subvolcanic activity, corresponding to the Late Cretaceous volcanism described from other parts of Egypt, such as Wadi Natash (Mohamed 2001). Numerous volcanic plugs and dykes (basalt, trachyte and rhyolite) intruded the older rocks. The volcanic activity caused brecciation and deformation of the sandstone strata, as well as hydrothermal alteration (silicification). The hardening of the sandstone along faults, dykes, and above and around volcanic plugs made them resistant to weathering, resulting in a peculiar landscape of crater-like structures, fault ridges and sandstone hills. The origin of the crater-like structures has been subject to several studies in recent years, mainly because it was suggested that they were impact features (Paillou et al. 2004). More recently, however, doubts have been raised about such an origin; instead, it has been suggested that they represent an extensive, eroded hydrothermal vent complex (Orti et al. 2008).

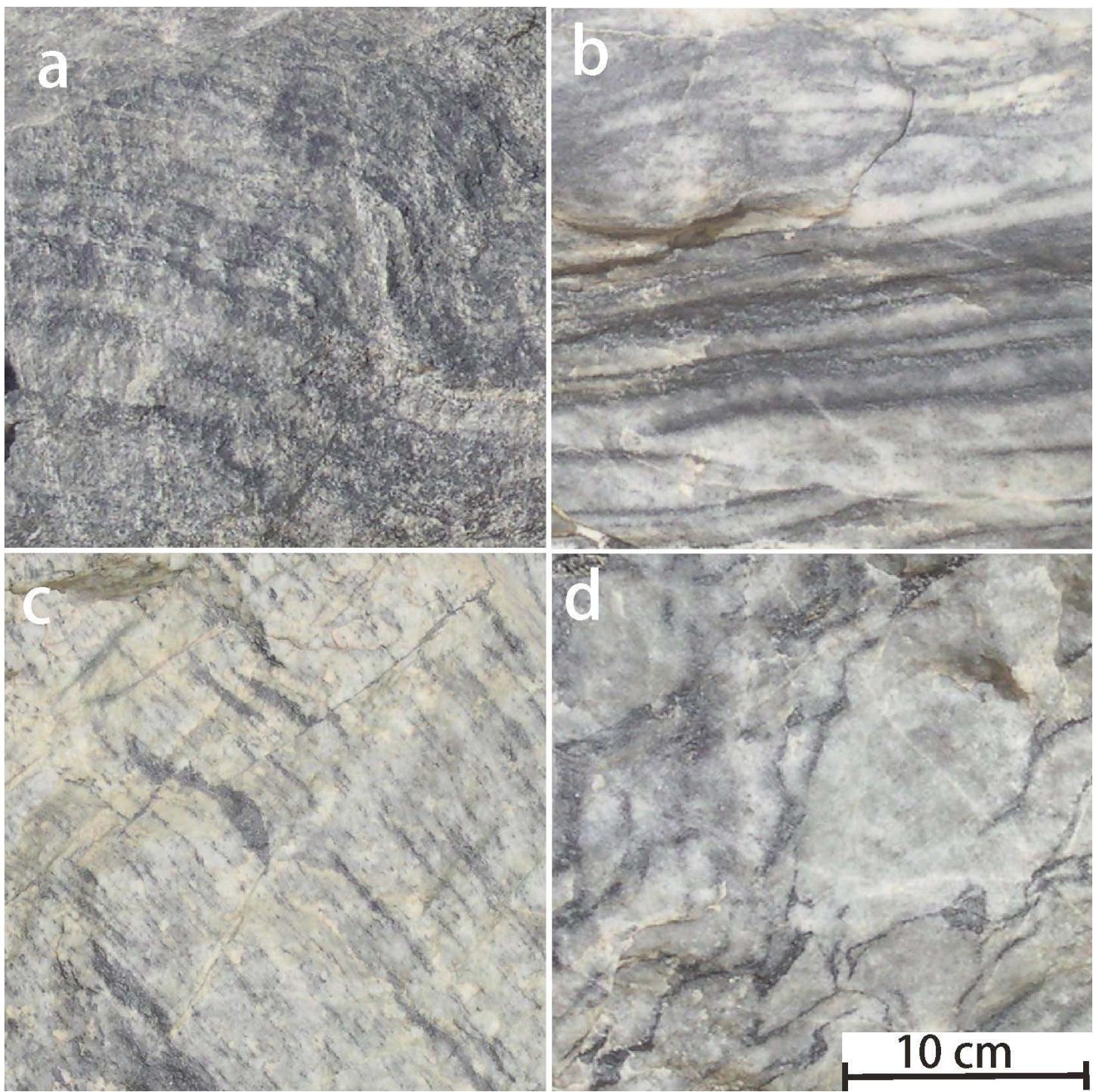


Figure 4. Varieties of the Chephren gneiss. a) Dark banded; b) light banded ("statue type"); c) light speckled ("vessel type"); d) light flame-structured.

PETROGRAPHY AND FABRIC OF THE ROCKS

High-An plagioclase (bytownite; An^{78-83}) and hornblende are the diagnostic and dominating minerals in the Chephren gneiss (Figs. 4 and 5a, b), and their proportions determine the subtypes described below. In addition, there are minor (less than one percent) quantities of quartz and zircon, and (in zones) minerals formed by retrograde metamorphism such as chlorite, sericite and uralite (Fig. 5c, d). The feldspar grain size varies between 0.1 and 1 mm. A characteristic aspect of the Chephren gneiss is its granoblastic texture (Fig. 5a, b), which is inherited from Archean to Palaeoproterozoic high-grade meta-

morphism ('granoblastite'). The granoblastic texture is one of the 'secrets' of the Chephren gneiss, since it makes the rock dense and strong, with extremely low porosity. This, in addition to the lack of quartz (resulting in less difference in hardness between minerals), may have been an important reason for the selection of the rock for funerary vessels and statues.

A field classification of four varieties of Chephren gneiss, based on its visual appearance, has been established, as follows (Heldal et al. 2009; Fig. 4a–d): light-speckled Chephren gneiss (main subtype for funerary vessels; Fig. 4c), light-banded Chephren gneiss ('statue' subtype, Fig. 4b), dark-banded Chep-

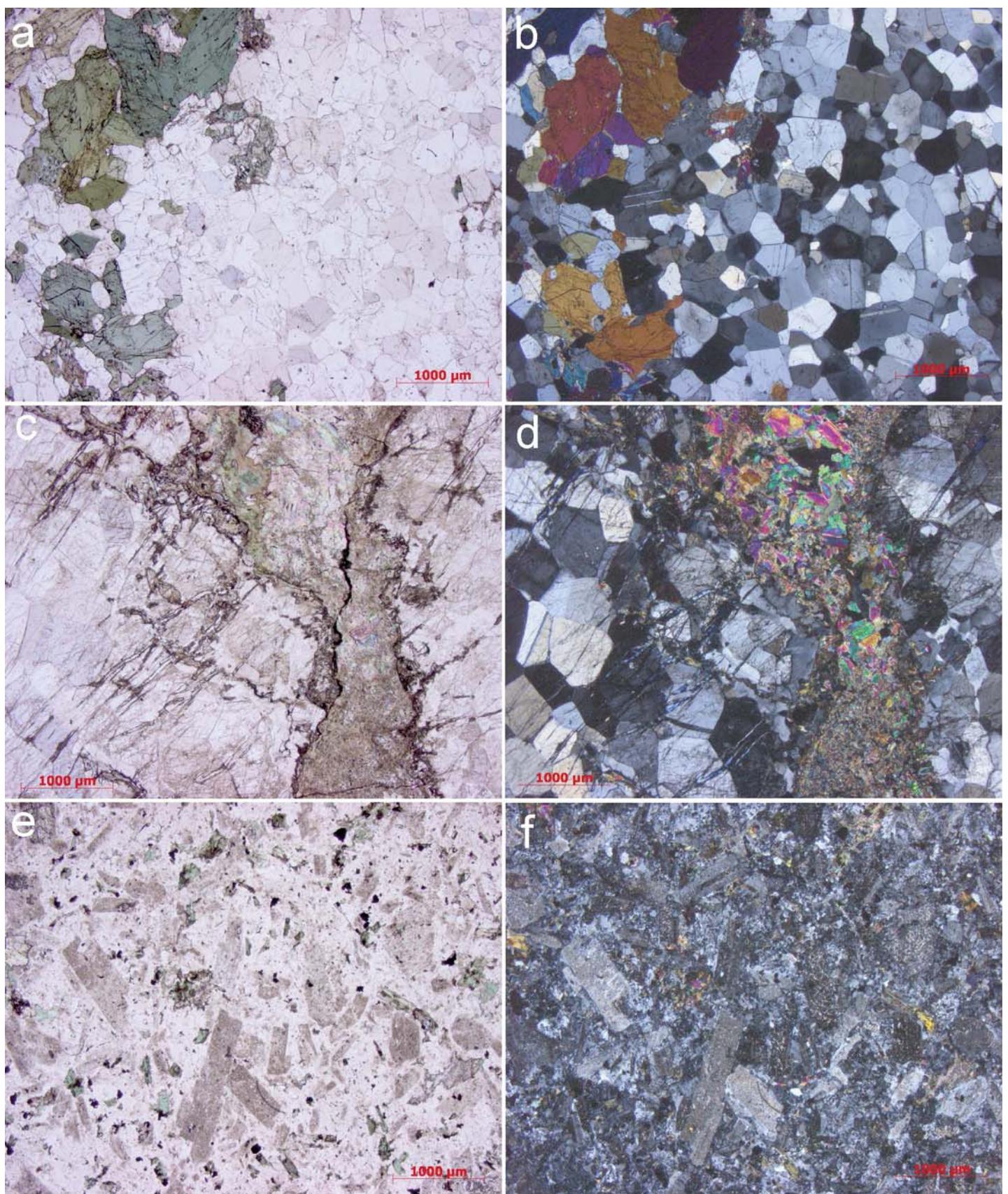


Figure 5. Photomicrographs of the Chephren gneiss and dacite. a) Typical speckled variety (plane-polarized light); green to bluish-green hornblende grains are seen on the left side, and the light coloured grains on the right side are predominantly bytownite and minor quartz; b) same image as a) with crossed Nicols; c) light-banded subtype displaying shear zones and microcracks (some filled with chlorite) related to Late Proterozoic mylonitization, which has a negative impact on the quality of the gneiss; d) same image as c) with crossed Nicols, also showing grain-reduction and uralitization of hornblende on the right side; e) porphyritic dacite showing plagioclase phenocrysts in a meshy groundmass of feldspar and quartz, locally forming a granophytic intergrowth, and alteration products; f) same image as e) with crossed Nicols.

hren gneiss (Fig. 4a), and light flame-structured Chephren gneiss (Fig. 4d); the latter two types were apparently not used.

Along shear zones, the granoblastic texture has been modified to display a more foliated to proto-mylonitic fabric; uralitization of hornblende, saussuritization of plagioclase, and chlorite-filling of extensional and shear fractures are commonly seen (Fig. 5c, d). Thus, the more foliated and sheared varieties have been subject to more alteration of the original granoblastic texture. The vessel-makers' preference for the less foliated varieties (light-speckled subtype) may perhaps be explained by the fact that it was simply better suited for the purpose than the other subtypes, although it is also possible that aesthetics and colour symbolism played a role (e.g. Grzymski 1999; Spence 1999). The composition of the feldspars and low density of microcracks may also be responsible for the translucency of the Chephren gneiss, and may have been another 'factor of preference' regarding its use for vessels. Moreover, the Chephren gneiss exhibits a blue glow in the bright desert sunlight and in the minds of the ancient Egyptians this may have imbued it with a magical quality.

The granitic rocks display a range of compositional and structural variations. The most common type is fine-grained, gneissic, microcline granite having a distinct biotite foliation, containing 'schlieren' and veins of more coarse-grained to pegmatitic granite, and aplitic veins. Also, non-foliated microcline granite and porphyritic granodiorite occur. The more fine-grained and aplitic varieties of granite were much used as tools (pounders) in the quarrying.

The dacite dykes are porphyritic and have a fine-grained groundmass (Fig. 5e, f). The plagioclase phenocrysts are partly zoned and rich in inclusions. The groundmass is composed of quartz, feldspars and pyroxene, but the low-grade metamorphic alteration has caused chloritization and uralitization of mafic minerals and sericitization of plagioclase, resulting in a meshy, dense texture (Fig. 5f). The dacite was also much used for tools (particularly pounders), possibly because metamorphic modification of the igneous texture made it a 'tougher' rock.

LANDSCAPE AND WEATHERING

The most striking aspects of the landscape in the Gebel el-Asr area are features related to the volcanic vents described above. In the area covered by the Nubia Group, hydrothermal hardening of the sedimentary rocks made them particularly resistant to weathering (compared to the poorly cemented surrounding rocks), leaving a pattern of linear, ring-shaped and circular hills and ridges. The volcanic rocks generally have low weathering resistance, and mostly occur in depressions in the terrain.

The outcrop area of the basement rocks does not display similar contrasts in weathering and is characterized by low relief. A characteristic feature of the weathering of hard, siliceous and feldspathic rocks in such an arid climate is the formation of rounded, *in situ* boulders. These boulders are produced by what has been called 'woolsack' or 'spheroidal' weathering (Fig. 6), the former term relating to the resulting boulder landscape, the latter to the process of weathering itself. Boulder-weathering can be described as a dynamic process involving chemical weathering of silicate rocks combined with mechanical fracturing caused by volume changes

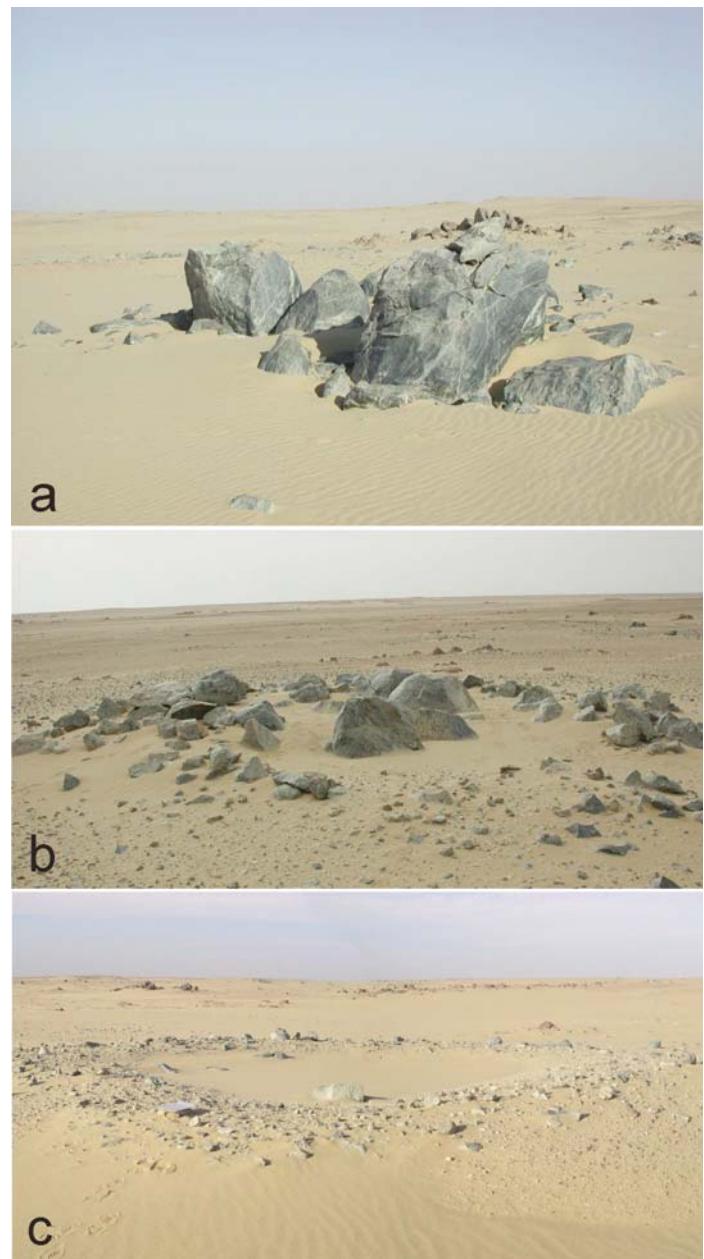


Figure 6. a) Cluster of gneiss boulders, shaped by weathering processes, not exploited; b) cluster of gneiss boulders that has been partly quarried; c) small quarry where the boulders once located in the center have been completely worked, forming a 'crater'-like structure enveloped by a circular spoil heap.

(thermal expansion and contraction) of the weathered rocks (Røyne et al. 2008). The chemical disintegration of the rock causes formation of a clay-rich mineral soil (saprolite). The chemical weathering initiates along pre-existing fractures, propagating outward from the fractures into the sound bedrock. Since the weathering occurs most rapidly at corners, the remaining parts of sound bedrock (corestones) take on a spherical shape. A zone of cm-scale rinds commonly occurs between the sound rock and the saprolite. Finally, the loose saprolite is eroded and the corestones exposed.

The landscape resulting from boulder-weathering typically consists of clusters of boulders formed where the density of natural fractures is low. Such is the case in the Gebel el-Asr area, where clusters of boulders from the basement rocks lay

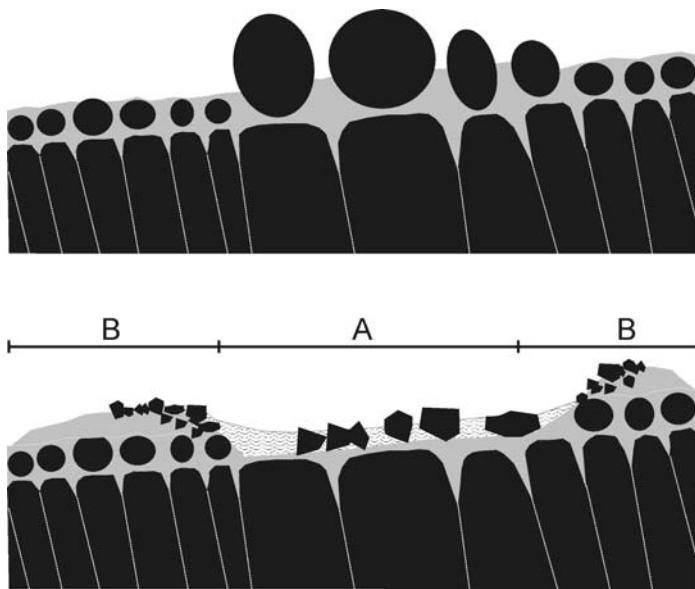


Figure 7. Before and after sketch of the quarrying of a cluster of gneiss boulders. A shows the extraction area, and B is where spoils from the working of blocks (work area) were deposited. Black = corestone or, if smaller and angular, work debris, and light grey = saprolite.

scattered on the surface within the outcrop area. It is interesting to note, though, that there is a clear difference in weathering between the granitic rocks and the gneiss: the former predominantly display thin-layered ‘onion-skin’ spalling, but the latter rarely does so, although the blocks are similarly rounded. The surface of the gneiss boulders is usually sound, eroded and polished by windblown sand. Because of the granoblastic texture described above, the gneiss is more resistant to weathering than the granitic rocks. In other words, the weathering process resulted in large and sound blocks, left ready for exploitation. Similarly, sound cobbles and boulders of dacite are found on the surface along the paths of the dykes. Such cobbles could be picked up and used directly as tools for working the gneiss boulders.

QUARRYING TECHNOLOGY

Before quarrying started, outcrops of the Chephren gneiss typically were seen as scattered, single boulders or clusters of boulders. Most of these had their upper part exposed, whereas the lower part was buried in the hard, clayey soil formed by *in situ* weathering of the rock (Fig. 7). During quarrying, the boulders were divided into smaller pieces of rock, which were worked into rough-outs for vessels or statues. The debris from the working was deposited concentrically around the boulders. Thus, the clusters of boulders were gradually transformed into concentric, ‘crater-like’ spoil heaps (Fig. 6). Large clusters of boulders resulted in large quarry pits with tall spoil heaps that had been worked for a long time; the smallest quarries reflect the work on a single boulder.

The Chephren gneiss was worked with stone tools, essentially pounders of varying size, as well as elongated hand-axes. All these tools came from local sources, the most apparent of which is the dacitic dyke rock (Fig. 8). The weathered cobbles and smaller boulders made perfect pounders and could be picked up from the ground and used without any reduction (Fig. 9). The dacite was also applied for making votive stelae,

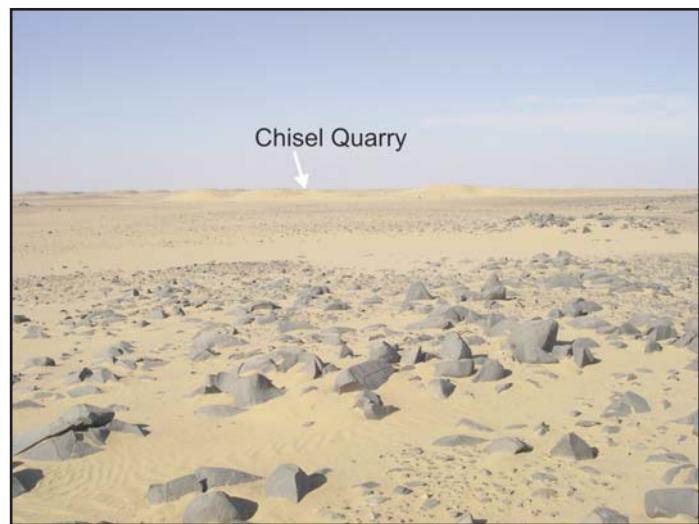


Figure 8. Outcrops of dacite dykes; the Chisel Quarry is seen in the background. Rounded cobbles suitable for tools can easily be found.

including the most famous one, the Khufu Stele (now displayed at the Cairo Museum, JE68572).

Cobbles of the Chephren gneiss itself were also used as pounders (Fig. 9), and, on the basis of a single find, it seems that the stone was also crafted into axe-heads. It is, however, difficult to quantify this use, since the tools (or fragments of tools) cannot be readily distinguished from spoil fragments. Pounders were also made from the granitic rocks. Since the granitic rocks are more porous than the gneiss and the dacite, they are not naturally found as rounded and sound cobbles, so these had to be manufactured (Fig. 10). Granite pieces were roughly hewn to irregular semi-spheres, which quickly became more spherical during use. Hand-axes were made from dacite and basalt, the latter from the volcanic plugs (Fig. 9).

Stone quarrying may generally be viewed as a four-step process (Heldal 2009): extraction from bedrock resulting in a rough block; reduction of the block to a core; semi-finishing of the core to a rough-out (or ‘blank’); and finally, finishing to the final product. In Chephren’s Quarries, quarrying started with the second step, since the boulders were already detached from the bedrock (see Figs. 6, 7 and 11). First, the soil and weathered rock fragments surrounding the boulders were removed. This is reflected in the lower part of the spoil heap stratigraphy, containing soil and deeply weathered rock fragments coated with white clay from the alteration of feldspar.

The second step was reduction of the blocks. In the case of vessel quarrying, the blocks were reduced to rough, squared fragments (cores) large enough to contain the shape of a vessel blank (Fig. 12). This part of the process seems to have been carried out mostly with large pounders up to 40 cm in diameter by first stripping off the weathered crust, then dividing the blocks into smaller pieces. Each piece was then worked with smaller tools, either small pounders or hand-axes, by splitting off small pieces (trimming) along the perimeter of the core until the vessel blank was finished.

The blocks destined for statues were worked differently. It is likely that fire-setting was involved in the first stages of ‘peeling’ layers from the block and, simultaneously, testing their soundness. There are two observed features that indicate the use of fire in quarrying: the sand and gravel beneath four

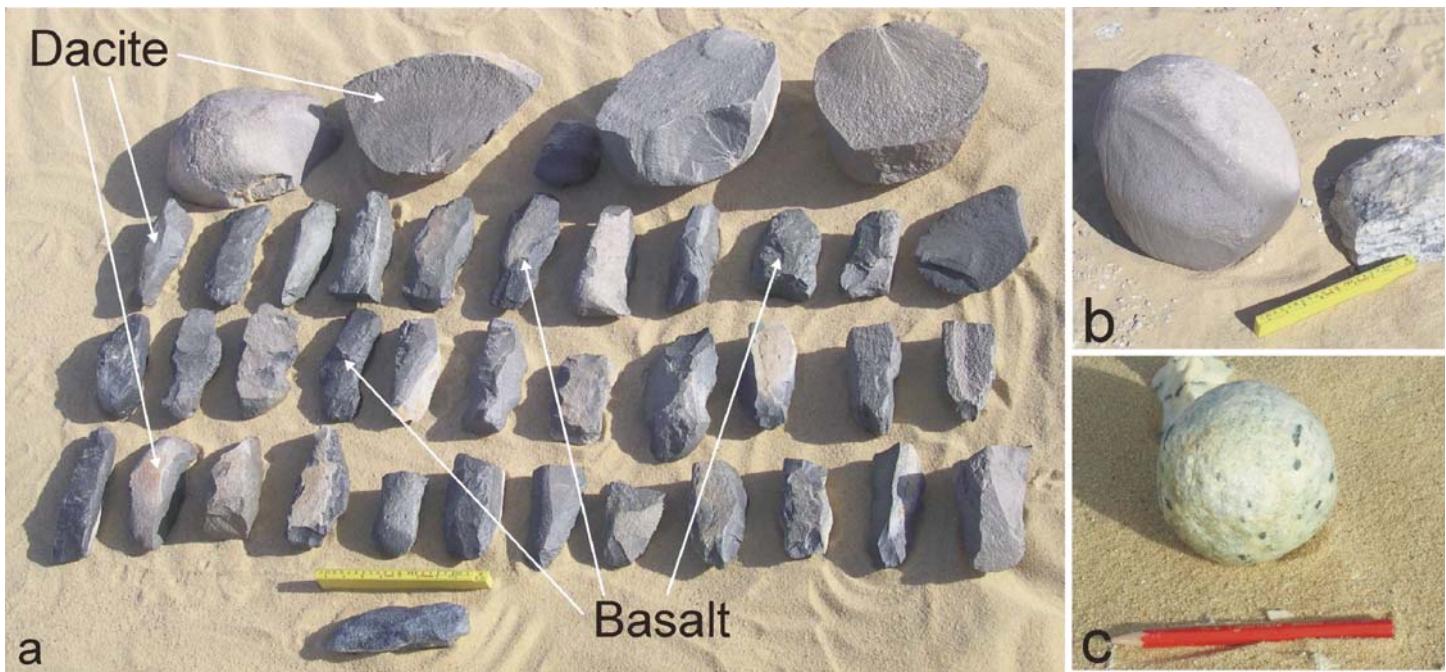


Figure 9. a) Tool collection, comprising discarded (split) pounds and hand axes; b) large dacite pounder for splitting blocks; c) well-used small pounder made from the Chephren gneiss itself. Scale: ruler = 21 cm; pencil ≈ 14 cm.



Figure 10. Manufactured granite pounds. These were made in the same way as vessel blanks, trimmed to a rough spherical shape.

of the blocks (including one of the dressed statue blocks) contain fragments of charcoal. Flaky ‘potlid’ rock fragments are seen beside one block (Fig. 13b), where they spalled off from the surface of the block following the application of heat. Such features are good indications of the use of fire (Heldal and Storemyr 2014). Fire-setting technology has also been recently observed in the large-scale quarrying of greywacke in the Wadi Hammamat, in Egypt’s Eastern Desert (Bloxam 2015).

During production of vessels, the blocks were reduced by splitting. However, for making statue blocks, it would be necessary to remove thin flakes parallel to the surface rather than splitting off large pieces, both for reducing the block size and for changing its shape. Fire-induced spalling could have been the most efficient way of doing this, for this particular rock. Finally, dressing of the block surfaces (particularly the ones

parallel to the gneissic banding) was carried out with pounders (Fig. 13d). Four discovered blocks of gneiss are leftovers from statue production. Two of these seem to be finished to the stage of transport readiness; they are wider at one end than the other, having a straight ‘back’ and a slightly curved ‘front’ (Fig. 14) – their shape would be perfect for some of the smaller statues of King Chephren. Other large blocks are found in many different shapes, and it is difficult to interpret their final purpose. Some may have been selected for statues and later discarded because of cracks or other flaws. Others may have been split up and worked to large vessels (e.g. a large vase in the Cairo Museum dating to the 5th dynasty reign of Unas).

LOGISTICS AND THE SOCIAL ASPECTS OF QUARRYING

As already mentioned, the only source of Chephren gneiss was 60 km away from the Nile Valley in the southwestern Egyptian desert, which, although seemingly remote to us today, was only 50 km east of the major Neolithic settlement of Nabta Playa and also close to later Old Kingdom habitations at Tushka. As we know from earlier evidence for the use of Chephren gneiss in Late Neolithic burial contexts at Nabta Playa, it is clear that the resource was well-known by local people for a long period. The exploitation and transport of this material on a much larger scale by the Early Dynastic and Old Kingdom was likely to be connected with intricate social networks involving local and regional specialists, such as stonemasons, who had knowledge of this resource and the ability to exploit it. Therefore, rather than scenarios that suggest large deployments of state-organized (unskilled?) labour to quarry the stone, we can argue for a much more nuanced picture in which the key contribution of central/state mechanisms involved the logistics of transporting the stone. Investments in logistical infrastructure such as constructing roads and ramps, as argued in the context of other quarry landscapes that witnessed similar transformations to larger-scale procurement, clearly present themselves in the

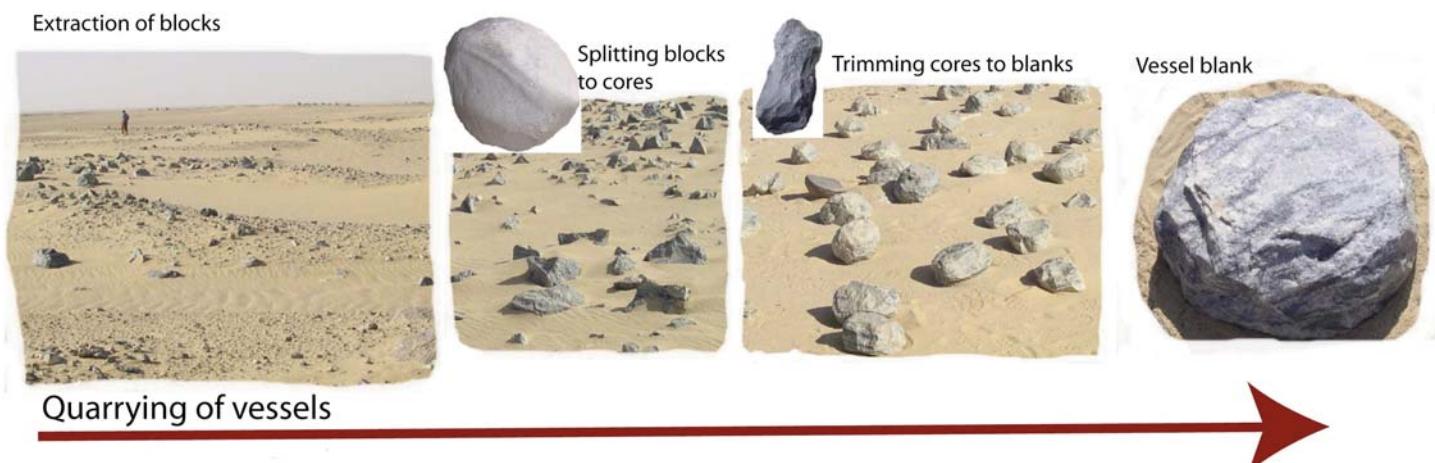


Figure 11. Overview of work process for vessel production.



Figure 12. Selection of vessel blanks showing the range of sizes and shapes.

archaeological record (Bloxam and Heldal 2007; Bloxam 2015; Bevan and Bloxam 2015). Significantly, it is along the transport route out of Chephren's Quarries that most of the settlement and subsistence evidence is found. This is in the form of two well-preserved small camps, a number of shallow groundwater wells, pottery and other domestic elements, and also the location of a single rock-cut inscription identifying an 'overseer of the craftsmen' (Bloxam 2003; Shaw et al. 2010).

The logistics of loading and transporting statue rough-outs weighing upwards of two tons from Chephren's Quarries is

one of the most intriguing aspects of the whole quarrying operation. Tantalizing clues about the ways in which this may have been done remain well-preserved in the archaeological record. For example, three similar stone-built loading ramps associated with the large-block quarries were excavated, revealing two deep tracks in front that were artificially cut to accommodate the runners of a large vehicle (Fig 15). The height and dimensions of the vehicle implied by these tracks suggest something more substantial than a low-lying sledge, although nothing of this type has yet been found in the archaeological record (Bloxam 2000, 2003, 2007). Contrary to other quarries, where no large blocks seem to have been quarried, loading ramps are apparently unique to the quarries where one or several large blocks were ready for transportation.

As for small rough-outs intended for vessels, they would have been transported to workshops in the Nile Valley for finishing. Although tracing the precise locations of such workshops remains problematic, we can make some indirect suggestions because of the discovery of stone-vessel workshops at Elephantine and Hierakonpolis, as well as the recent discovery of Chephren gneiss debris associated with a workshop area on the Giza Plateau (Hoffman 1991; Kaiser et al. 1999).

DISTRIBUTION AND SIZE OF THE QUARRIES

In total, 667 individual gneiss quarries have been recorded (Fig. 16a), varying significantly in size (Table 1). The smallest ones, exploiting a single boulder only, measure approximately 2 metres in diameter, including the circular spoil heap. The largest quarries (up to 280 m along the longest axis) exploited either a large group of boulders or several in a row, resulting in tall, circular to elongated spoil heaps. In total, the quarries cover an area equal to 174,000 m². Most quarries range between 10 and 100 m² (542 quarries), 87 can be described as very small (less than 10 m²), and 38 as large (more than 1000 m²).

The northern area has the largest number of quarries (452) and also the largest quarried area (90,000 m²) (Table 2). Although the central area hosts fewer quarries (180), the quarried area is almost as large as in the north (80,000 m²) (Table 3), because most of the quarrying was concentrated in a few large quarries. Elsewhere, 'Chisel Quarry,' located northwest of the central quarries, is a single quarry covering almost 2000 m².



Figure 13. Overview of work process for statue blocks. a) Digging into the soil around a removed block; b) spalled surface on a gneiss block probably induced by heating; c) split rock pieces (made by pounding) around a partially worked block; d) dressed statue block (note the shape) ready for transport. Scale: ruler measures 80 cm.

Table 1. Number of quarries and their size.

m ²	Quarries
<10	87
10–50	259
50–100	186
100–500	85
500–1000	12
1000–1500	4
1500–2000	10
2000–3000	10
3000–10000	10
10000–20000	3
20000–30000	1
Total	667

(Figs. 16, 17), whereas the southern quarries, approximately the same area, comprise 34 very small quarries (Table 2).

Vessel blanks are found in many quarries. These are spherical to disc-shaped, trimmed rough-outs varying in size from 15 to 50 cm across. In some quarries, stockpiles of vessel

Table 2. Quarry areas, size and number of individual quarries.

	Area (m ²)	# of quarries
Northern quarries	90,000	452
Central quarries	80,000	180
Chisel quarry	2000	1
Southern quarries	2000	34

Table 3. Type of stone tools found in Chephren's Quarry.

Rock type	Cobble pounders	Manufactured pounders	Hand axes	Pounders with hafted necks
Dacite	X		X	X
Granitic rocks	X		X	X
Chephren gneiss	X			
Basalt				X

blanks have been observed. The stockpiles have been recorded and, as shown in Fig. 16c, they are common in all the quarry areas. None, however, are found in the eastern part of the central quarries, and they are also less common in the central quar-

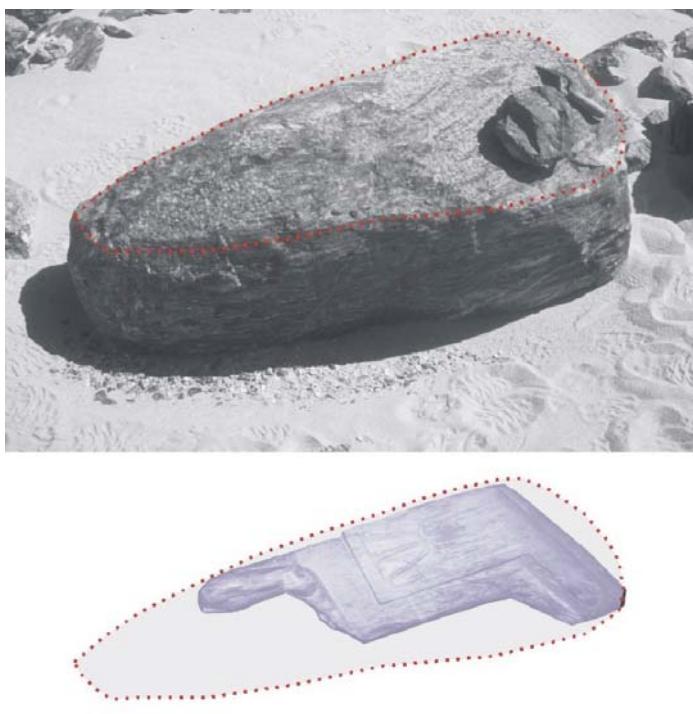


Figure 14. Statue block dressed to a shape suitable for making statues of a seated king (the block is approximately 150 cm long).

ries than in the northern ones. This pattern coincides with the distribution of gneiss subtypes: the evidence of vessel production is most commonly found within the occurrences of light-speckled Chephren gneiss.

The distribution of large blocks and loading ramps indicates that only small parts of the total quarry area were used for production of statues and, perhaps, very large vessels (Fig. 16d). There are few places with worked blocks and only one loading ramp in the northern quarries. In the central quarries, there are several statue-blocks and ramps, especially in the large so-called Khufu Stele Quarry and its vicinity. It seems that these quarries mainly produced large blocks, since no or few small vessel blanks have been found. The focus of large-block production in the central quarries coincides, interestingly, with the main occurrences of the light-banded subtype of gneiss.

Judging from evidence in the quarries, as well as from the archaeological records at pyramids and tombs, production of vessel blanks was virtually the only activity at the Chephren Quarries from the Predynastic Period through to the 3rd Dynasty. The number of produced vessels would have been very high. Given that the spoil deposition area is roughly the same size as the actual block extraction area, if each square metre within the extraction area produced one vessel, the number of vessels would be close to 90,000. This is not surprising, given the enormous numbers of stone vessels that have been found across Egypt. In the subterranean storerooms of Djoser's step pyramid, no less than 30,000 vessels have been found, of which 892 are made from Chephren gneiss (Firth and Quibell 1935).

Quarrying targeted the assumed best-quality rock for vessels, namely the speckled variety of the gneiss. Available blocks of this subtype may have been depleted when campaigns for



Figure 15. Loading ramp with dug linear depressions for fitting to a yet unknown type of transport vehicle.

larger statue blocks began during Chephren's reign in the Old Kingdom. Hence, the light-banded type was targeted. While this subtype is of poorer quality, it is still good enough for the production of large statues.

Regarding the resources used for tools, there are some interesting patterns (Fig. 16b). Although the dacite seems to be the preferred tool rock, its use decreased away from the dykes. At a distance from the dykes, manufactured granite pounders and pounders from the Chephren gneiss were used. This strongly suggests that although dacite seemed to be the ideal pounder rock, it could be easily replaced by alternatives that did the job sufficiently well.

CONCLUSIONS

The landscape in the Gebel el-Asr area is remarkable, shaped by geological processes from the Archean to the present day. The geological landscape bears witness to repeated geological cycles: formation of layered igneous complexes; deep burial in the earth's crust; partial melting and high grade metamorphism; uplift and erosion; deposition of marine and fluvial sediments; volcanic eruptions; and finally uplift and erosion once more. All these events played a part in shaping a natural resource of such importance to the ancient Egyptians that they went to great lengths to exploit it. The Chephren gneiss is unique because its complex geological history and preservation of its high-grade metamorphic fabric through billions of years was the direct cause of its suitability for the production of beautiful vessels and sculptures.

In exploiting these resources, the ancient Egyptians created a unique cultural landscape that is testament to the ingenuity used not only in methods to extract it, but also in transportation over large distances. As a ghost-town of antiquity, we also get a sense of the people who worked there from the remains of their camps, food left on the hearth, pottery and other domestic artefacts that still remain. These all reveal to us the ways in which local knowledge of the subsistence resources, as well as stone resources of the region were key: from where to dig wells to access groundwater, to locating the best secondary resources to make tools. The quarrying activity is also a display of simplicity, a skilled and efficient production of a 'difficult'

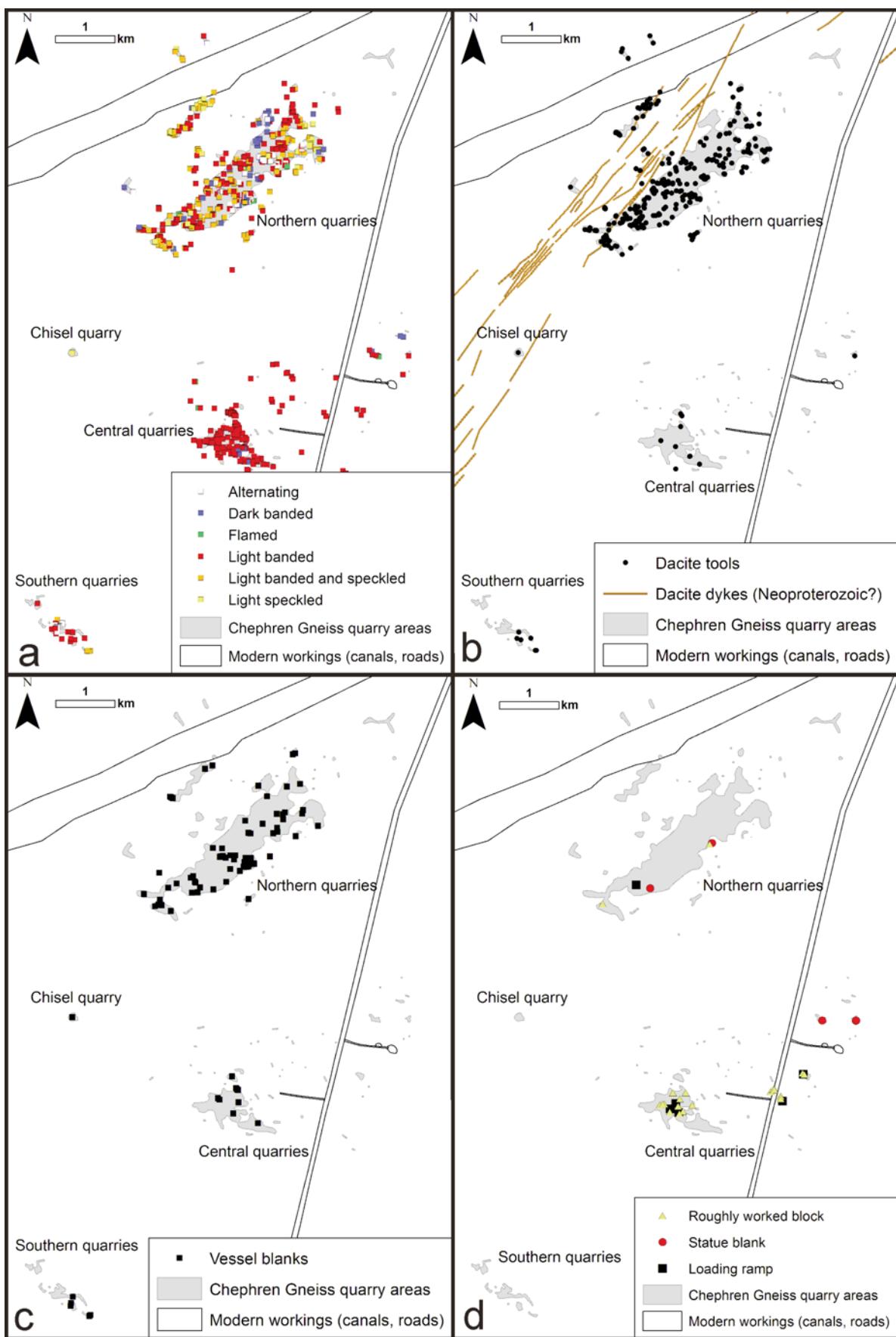


Figure 16. Spatial distribution of features in Chephren's Quarry. a) Recorded quarries and subtypes of gneiss; b) observations of dacite pounders and location of dacite dykes (source for the pounders); c) recorded collections of vessel blanks; d) observations of statue blocks and loading ramps.

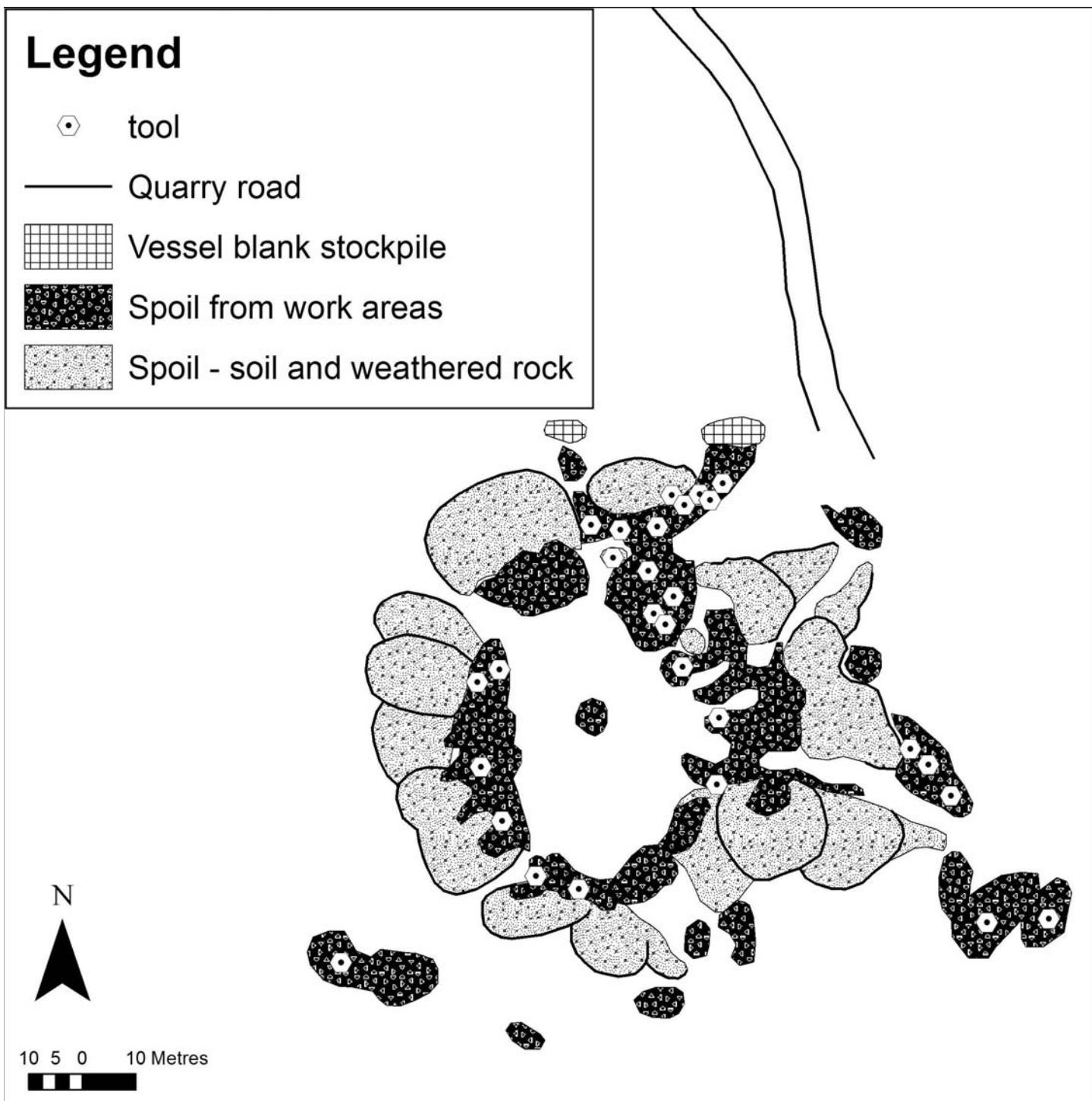


Figure 17. Map of Chisel Quarry, clearly showing the concentric layout and large spoil heaps.

rock with simple methods conducted by expert craftspeople. Although early vessels and statues were made from many stone types in ancient Egypt, Chephren's Quarries is an example of early industrial-scale excavation not only in Egypt, but globally. The beauty of the stone, combined with its unique physical properties, made it possible to make bowls and vases of extreme delicacy, and statues that are regarded as masterpieces of the ancient world. The quarries were abandoned more than 4500 years ago and, except for some limited use in the 12th Dynasty (about 500 years later), the stone never reappeared for

large-scale use. Probably, the resource was considered depleted. Hence, the remains from quarrying display a frozen image of the vogue for beautiful stone during a rich period in human history. Moreover, it is the most remote cultural-natural landscape connected to the pyramid builders of the Old Kingdom, or in other words, an extended part of the pyramid landscapes almost 1300 km away, therefore adding more value to its significance. Modern development and irrigation mega-projects in this part of the Egyptian desert remain a constant threat and may easily destroy this unique site, as it already has in some

parts (Storemyr 2009). But, if well managed and formally recognized as a heritage site of global significance, there will still be enough left to be enjoyed by future generations.

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