QuarryScapes: ancient stone quarry landscapes in the Eastern Mediterranean

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Introduction

The spectacular monuments and cities of the ancient Near East are testament to an industrial past where large-scale stone procurement remains unequalled. Yet, stone quarries are often forgotten as key archaeological sites, even though they are rich in material remains and of crucial significance if we are to understand social and technological practices of the past. Sometimes invisible, often undocumented and largely unprotected, these ancient quarry landscapes are rapidly being destroyed from pervasive human activities such as urban expansion and modern quarrying.

Despite the difficulties in having stone quarries recognised as important sites for archaeological study, the acquisition of stone for tools, monuments and constructions, or objects of art has always been an important activity throughout the history of mankind. Moreover, traces of such exploitation are literally found all over the Mediterranean region. Campaigns to acquire stone in antiquity from thousands of local, regional and distant quarries were partly statements of an elite seeking the best places to extract prestigious stone. But mostly what was sought was raw material for construction and utilitarian products acquired at a local level by people skilled in stone-working over many generations.

Quarrying in antiquity has transformed large areas of land, sometimes reaching tens and even hundreds of square kilometres, and so reshaping the natural landscape considerably. Archaeological remains such as roads, settlements, workshops, inscriptions and other material culture, directly or indirectly linked to the stone extraction, can in varying degrees comprise these extensive cultural landscapes. Yet, it is the geology that forms the backdrop of any quarry landscape, in which the distribution of exploitable rock and the morphology of the terrain define the framework that gave rise to these man-made features. The confrontation of geology and geomorphology, technologies of extracting the stone and the social organisation behind these activities creates these unique landscapes. Hence, in addition to being 'geological resources' and 'archaeological sites', the resulting areas are 'industrial landscapes' that have certain features in common.

However, despite these common foundations, ancient quarry landscapes can vary quite considerably. For example, some may be closely associated to the building of a city, as representing a key local stone resource used in its construction . In such cases, the quarries are often gradually obliterated and hidden by the expanding city itself. Here, quarrying represents a particular stage within the continuous development of the urban landscape. Other quarry landscapes display one or few campaigns of exploiting prestigious stone in remote areas. Still others may have developed over thousands of years, displaying continuous extraction from prehistory into the present. There are many factors that can contribute to the transformation of a quarry landscape, although fundamentally these are linked to the quality and desirability of the stone resource at a given time. Such aspects and the role that changing extraction technologies played in quarrying these resources was crucial in the shaping of the landscape over time.

The inspiration for the QuarryScapes project came from the necessity to put such ancient industrial/cultural landscapes on the map before it is too late. It was aimed at raising the awareness of their importance across a broad spectrum of audiences, including researchers within archaeology, geology and conservation, decision makers and heritage authorities, various stakeholders and the lay audience. QuarryScapes, being a multidisciplinary project, drew together professionals from academic and other institutions in Egypt, Jordan, Turkey, the UK, Belgium, Italy and Norway, focussing specifically on documentation, conservation and heritage management of these fragile quarry landscapes within the first collaborative and innovative project of its kind.

The QuarryScapes project partly involved research in selected case studies throughout the region. In addition, the project included more practical activities related to the implementation of research into heritage management. Thus, the project aimed at creating a 'road towards conservation' for such landscapes, from the initial recognition of ancient quarries to conservation strategies. The case studies focussed on different segments of this 'road'. Some aimed at the initial recognition of ancient quarry landscapes and linking the quarries to the use of the stone extracted through provenance studies. Others involved detailed documentation and surveying of quarry landscapes and how to interpret different quarrying activities in the light of time, space and function. Yet others aimed at finding ways of assessing the significance of quarry landscapes and their importance to our common heritage. Since many quarry landscapes are poorly documented and protected, one case study focussed on the risks and threats to such landscapes, with special emphasis on Egypt. The innovation activities within the project included a work package on the construction and implementation of a quarry landscape database for the Egyptian heritage authorities and a work package on site management planning for a particular quarry landscape.

This volume contains ten papers that reflect these multidisciplinary approaches undertaken in the QuarryScapes project and their application to the different case study areas. Outcomes from these case studies and the fresh perspectives drawn are presented as the basis not only for future research, but as the first step towards conserving this endangered cultural heritage.

In summary, these contributions cover a range of important issues, as well as providing a background to research already undertaken in the documentation of ancient quarries. For instance, *Harrell and Storemyr* give an overview of ancient Egyptian quarry landscapes, highlighting how closely related these are to monuments, ornamental and utilitarian products of antiquity. The paper summarises many years of research carried out by Harrell, supplemented with new data from QuarryScapes.

The importance of scientific approaches to the study of ancient quarry landscapes, in terms of determining stone source, extraction techniques and how these are linked to the properties of the resource, is discussed by *Heldal et al.* and *Abu-Jaber et al*. These authors present examples of geological and archaeological case studies within particular quarry landscapes, one in Egypt and one in Jordan. The former involved exploitation of gypsum (alabaster) used for making funerary vessels in ancient Egypt, whilst the latter constitutes the landscape of the building stone quarries surrounding the Roman city of Gerasa in the northern part of Jordan. *Knox et al*. present a study that indirectly results from the QuarryScapes project, explaining the use of new methods in tracing the source of the silicified sandstone used in the famous 'Colossi of Memnon', placed on the west bank of the Nile at Luxor. Provenance studies are important in linking a particular stone, that may be widely distributed, to its original source. Such studies can provide us with important insights into ancient trade routes and the social dynamics that linked quarries with other places and people.

The granite outcrops at Aswan have been exploited continuously since at least the Early Dynastic into modern times. The famous 'Unfinished Obelisk quarry' is situated in these resources and for several years the Supreme Council of Antiquities (SCA) has conducted excavations and surveys of this and other ancient quarries in the area. Within the QuarryScapes project this work concentrated on delineating important areas around Aswan with ancient quarries from several periods. As this is an area exposed to rapid urbanisation and modern granite quarrying, the importance of such investigations cannot be underestimated in providing background information necessary for balancing modern development with conservation. *Kelany et al.* present some of the main results from these surveys.

An important case study in the project was the description of the quarries used for building the ancient city of Sagalassos in Anatolia, Turkey. *Degryse et al.* present some of the main results of this study, but with special emphasis on how the quarries can be presented to tourists visiting this monumental town.

In an essay by *Storemyr*, the fate of ancient Egyptian stone quarries over the last 50 years is described. The causes of destruction and neglect of such sites are brought forward, and key questions regarding future conservation are raised, as urban growth and quarrying are expected to remain the largest threat for the ancient quarries also in the future.

A key issue within QuarryScapes was to develop a methodology that can be applied cross-culturally for describing, characterising and interpreting ancient quarry landscapes. The paper by *Heldal* suggests a method for using empirical data in the 'construction' of a quarry landscape, to establish a base for building a 'case for conservation'. A complex quarry landscape at the Aswan West Bank is used as an example.

Research on quarries and quarry landscapes is of little value unless the information obtained can be used by cultural heritage authorities to secure sustainable management of such sites. *Shawarby et al.* show how data from basic research have been compiled in national databases that are available to regional and national heritage authorities. They conclude with the belief that the project has succeeded in drawing the attention of the Egyptian administration to an important element of Egypt's cultural heritage that had previously been overlooked.

Finally, *Bloxam* addresses the problem of assessing the overall significance and value of ancient quarry landscapes by developing a methodology that can be transferred across a range of archaeological contexts. By introducing 'four concepts of landscape', she shows that it is possible to identify significance and value in several different ways, depending on the historical contexts in which the quarry landscapes are situated.

The objective of the QuarryScapes project has been to draw attention to this understudied and endangered cultural heritage as the foundation not only for future research, but as a first step towards their recognition and conservation. All contributors to the project hope that the outcomes from these case studies, as complied in this volume, and the perspectives drawn will from an important addition to research agendas concerned with the study of ancient production sites.

Apart from this Special Publication, outcomes from the QuarryScapes project are also contained in other published journal articles, or have been accepted for publication in various professional outlets. An updated list of these will be kept on the project website at http://www.quarryscapes.no. Although the QuarryScapes project has officially ended, it is hoped that interest in the subject will grow and that the website will provide an avenue of communication between the project participants as well as anybody interested in the subject.

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Ancient Egyptian quarries – an illustrated overview

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The surviving remains of ancient Egyptian material culture are dominated by the stones used for building, ornamental, gem, and utilitarian applications. These came mainly from the Nile Valley and Eastern Desert (with some also from the Western Desert), where over 200 quarries have been discovered spanning about 3500 years from the Late Predynastic Period to the Late Roman Period. The harder stones (nearly all the igneous and metamorphic rocks plus silicified sandstone and chert) were quarried using stone tools aided by fire setting and wood levers up until the Late Period, when the stone tools were replaced by iron ones. The softer stones (mainly limestone, sandstone, and travertine) were extracted with copper and, later, bronze picks and chisels during the Dynastic Period, with iron tools again replacing the earlier ones by the end of the Late Period. Until the advent of suitable roadways and wagons rugged enough to transport them in the Greco–Roman Period, the larger pieces of quarried stone were carried on sledges, often along prepared roads, and probably pulled by teams of men to the building sites or to the Nile River for shipping. Ancient quarries are more than just sources of stones, but are also rich archeological sites with ruins and other cultural remains. Their study and preservation is necessary because they provide a unique perspective on life in ancient Egypt.

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Introduction

Much of what remains of ancient Egypt consists of stone. There are building stones for temples, pyramids, and tombs; ornamental stones for vessels, sarcophagi, shrines, stelae, statues, and other sculptures; gemstones for jewelry and the decorative arts; and utilitarian stones for tools, weapons, grinding stones, and other applications. It is with the sources and varieties of these stones that this paper is concerned. We have excluded those rocks supplying precious metals, such as gold and copper, but for these see Ogden (2000) and Klemm et al. (2001, 2002). The term 'quarry' is used here for all extraction sites, although those for gemstones (and precious metals) are more commonly referred to as 'mines.' In the sections that follow, the geology of Egypt is first summarized in order to provide a general idea of the stones available to the ancient Egyptians. A database of known ancient quarries is then presented and this is followed by a discussion of the various uses to which the quarried stones were put. The paper continues with a description of the quarrying technologies employed, and concludes with a review of the typical archeological remains found at quarry sites. This overview is intended for the general reader and so reference citations are largely omitted from the text but are included in the bibliography.

Overview of Egyptian geology

Egypt's oldest rocks date to the late Precambrian and early Phanerozoic eons, approximately 500 to 2600 million years ago (Ma), with most forming during the Pan-African Orogeny of 500 to 1200 Ma (see Table 1 for the geologic time scale and the geologic ages of the quarry stones, and attached, fold-out map for the generalized geology of Egypt and the quarry locations). These include both igneous and metamorphic rocks, collectively referred to as Egypt's 'crystalline basement complex'. The basement rocks are mostly buried beneath layered sequences of younger Phanerozoic sedimentary rocks. Overlying most of the latter are geologically recent (Quaternary period) deposits of unconsolidated sediments, including fluvial siliciclastic gravel, sand, and mud in the Nile Valley and desert wadis, and aeolian sand in the Eastern Desert and especially in the Western Desert with its vast Saharan 'sand sea'. During the Quaternary, biogenic deposits accumulated along Egypt's coasts, with carbonate dunes forming behind the Mediterranean beaches and carbonate reefs forming off the Red Sea shore.

Outcrops of Precambrian basement rocks are restricted to the southern Sinai Peninsula, the southeast and southwest corners of the Western Desert, and the Red Sea Hills of the Eastern Desert. The latter outcrops broaden westward at the latitude of Aswan and extend all the way to the Nile, where they form this river's 'First Cataract'. Another five cataracts interrupt the Nile River in northern Sudan. Outcrops of sedimentary rocks, mainly sandstone in southern (Upper) Egypt and limestone to the north in Middle and Lower Egypt, form the 'walls' of the Nile Valley and the surfaces of the adjacent plateaus of the Western and Eastern deserts.

During the Paleozoic and Mesozoic eras of the Phanerozoic eon, Egypt was alternately elevated above sea level and inundated by shallow seas with mostly

Table 1. Geologic time scale. Dates are from USGS (2007).

Eon	Era	Period	Epoch	Million years before present	Egyptian quarries
Phanerozoic	Cenozoic	Quaternary	Holocene	present–0.0115	
			Pleistocene	0.0115–1.8	all limestone along the Mediterranean coast
		Tertiary	Pliocene	1.8–5.3	limestone at Dahshur and Gebel el-Gir
			Miocene	5.3–23	all anhydrite and gypsum along the Red Sea coast
			Oligocene	23–33.9	Gebel Ahmar silicified sandstone and all basalt
			Eocene	33.9–55.8	all limestone in the Nile Valley, except at Dahshur, Gebel el-Gir and el-Dibabiya; all travertine and chert; and the Umm el-Sawan gypsum
			Paleocene	58.8–65.5	limestone at el-Dibabiya
	Meso-zoic	Cretaceous		65.5–145.5	all sandstone, including the silicified variety except at Gebel Ahmar
		Jurassic		145.5–199.6	all turquoise and some malachite
		Triassic		199.6–251	
	Paleozoic	Permian		251–299	
		Carboniferous		299–359.2	
		Devonian		359.2–416	
		Silurian		416–443.7	
		Ordovician		443.7–488.3	
		Cambrian		488.3–542	
Pre-cambrian				542–4,000+	all igneous and metamorphic rock varieties, except basalt; and all gemstones except turquoise and some malachite

siliciclastic sedimentary rocks forming (conglomerate, sandstone, and mudrock) plus some limestone. The thickest and most areally extensive of these deposits is the Nubia Group (or Sandstone), which dates to the latter part of the Cretaceous period and was deposited in shallow-marine to mainly fluvial environments. From the Late Cretaceous through the Eocene epoch of the Tertiary period, most of Egypt was under a shallow sea and accumulating carbonate sediments that are best represented today by the various Eocene limestone formations. Beginning in the Oligocene epoch and continuing through the Quaternary period, most of Egypt was above sea level and once again receiving predominantly siliciclastic sediments.

The mid-Tertiary uplift of Egypt, which initiated the return of siliciclastic sedimentation, was caused by the opening of the Red Sea, a plate tectonic rifting event that separated the Arabian Peninsula from the African landmass, beginning about 30 Ma. As a consequence of this rifting, the crystalline basement complex was pushed up to form the Red Sea Hills, a south-to-north flowing paleo-Nile river developed along a fracture zone west of the Red Sea Hills, magmatic activity produced dolerite dikes that intruded all earlier rocks, and volcanic eruptions extruded basaltic lava flows. The paleo-Nile was fed by tributaries draining the lands to the west and east of its course in Egypt, but the modern Nile River, with its water sources in the Ethiopian and Ugandan highlands, dates to the late Quaternary. For additional information on the geology of Egypt see Said (1990) and Tawadros (2001), and for a non-technical introduction see Sampsell (2003).

Ancient Egyptian quarries database

Just over 200 ancient quarries are known from Egypt, and these range in age from the Late Predynastic to the Late Roman Period, a span of about 3500 years (see Table 2 for the chronology of ancient Egypt). The attached map shows their distribution and provides, on the back, the names and coordinates of the quarry localities as well as their stone types and general ages. Detailed plans of several of the larger, more important quarries (and the associated quarry landscapes) are provided in Figures 7–8, 19, 21–22, 26, 28 and 32. Nearly all quarries, except those now under Lake Nasser, were located in the field by the authors. Their latitudes and longitudes, as reported here, are those determined from Google Earth satellite images (www.GoogleEarth.com). The workings for most of the quarries are visible on these images, but they are seldom obvious. This database also includes several quarries of medieval Islamic date in Egypt's Eastern Desert. Although it is the most comprehensive list of ancient Egyptian quarries yet published, this database is still incomplete. There are undoubtedly many more quarries awaiting discovery as well as others that will remain unknown because they have been destroyed by urban growth, modern quarrying, or natural weathering and erosion. Moreover, the database does not include quarries earlier than the Late Predynastic Period, such as those of Paleolithic and Neolithic age for tools made from chert (flint) and silicified sandstone (quartzite).

The authors' publications and other selected sources on specific Egyptian quarries and their stones are provided in the bibliography. Other useful sources of information include Lucas (1962, p. 50–74, 386–428), De Putter and Karlshausen (1992), and Klemm and Klemm (1993, 2008). See Figures 10 and 11 for images of selected ancient quarry stones.

Sources and uses of stone in ancient Egypt

Building stones

Limestone and sandstone were the main building stones of ancient Egypt (Figures 1–10). From Early Dynastic times onward, limestone was the material of choice within the limestone region for pyramids, mastaba tombs, and temples. Beginning in the late Middle Kingdom, sandstone was used for all temples within the sandstone region as well as many of those in the southern part of the limestone region. Both limestone and sandstone were also employed for statuary and other non-architectural applications when harder and more attractive orna-

Table 2. Ancient Egyptian chronology. Dates are from Baines and Malek (2000, p. 36–37).

Late Predynastic Period		ca. 3100–2950 BCE	
Dynastic Period	Early Dynastic Period	2950–2575 BCE	Dynasties 1–3
	Old Kingdom	2575–2150 BCE	Dynasties 4–8
	First Intermediate Period	2125–1975 BCE	Dynasties 9–11
	Middle Kingdom	1975–1630 BCE	Dynasties 11–14
	Second Intermediate Period	1630–1540 BCE	Dynasties 15–17
	New Kingdom	1540–1075 BCE	Dynasties 18–20
	Third Intermediate Period	1075–715 BCE	Dynasties 21–early 25
	Late Period	715–332	Dynasties late 25–30
Greco–Roman Period	Ptolemaic Period	332–30 BCE	
	Roman Period	30 BCE–395 CE	
	Byzantine (or Late Roman) Period	395–640 CE	
Islamic Period		640 CE–present	

Figure 1. Limestone quarries near Cairo. Top: open-cut workings at Giza (L2, 4th Dynasty–Old Kingdom) with king Khafre's (or Chephren's) pyramid behind. Bottom: open-cut and gallery workings at Zawyet Nasr on Gebel Mokattam (L5, Old and/or Middle Kingdom to New Kingdom) close to Cairo's Citadel. The latter quarry also provided stone for mosques and other buildings of medieval Islamic Cairo (insert). Photos by Per Storemyr.

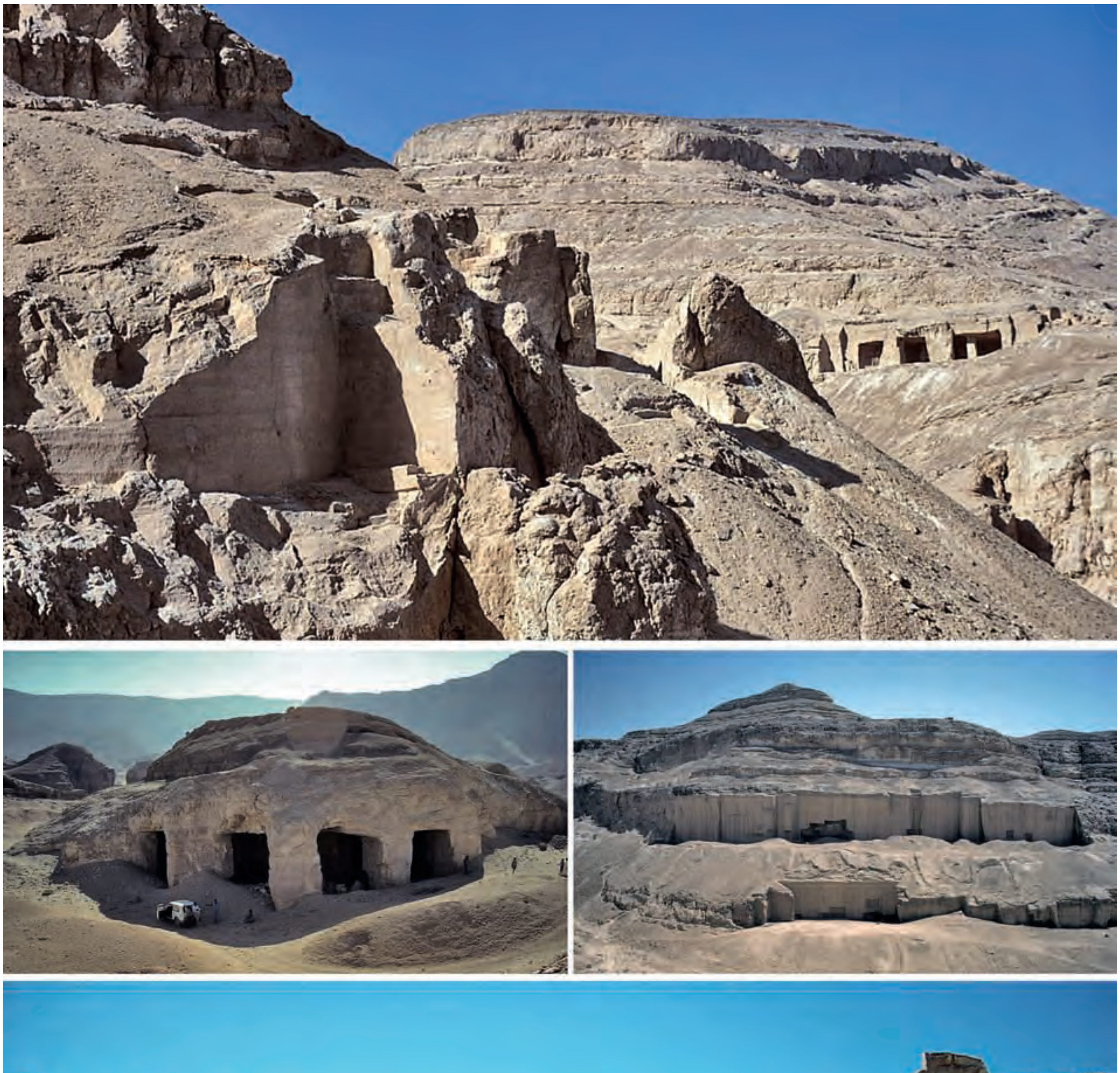

Figure 2. Limestone quarries in the Nile Valley. Top: open-cut (left) and gallery (right) workings at Qaw el-Kebir (L75, Old and/or Middle Kingdom to New Kingdom, and Ptolemaic to Roman) near ancient Antaeopolis. Middle left: gallery workings at El-Dibabiya (L91, 19th Dynasty–New Kingdom, 21st Dynasty–3rd Intermediate Period, and Roman). Middle right: open-cut workings at Beni Hasan (L21, Old and/or Middle Kingdom to New Kingdom, and Roman) near the famous Beni Hasan tombs. Bottom: open-cut workings at Zawyet el-Amwat (L16, New Kingdom to Roman) in the Zawyet Sultan district. Photos by James Harrell.

Figure 3. Limestone quarry in western Thebes, near Luxor. Top: aerial view of western Thebes with the Wadi el-Muluk quarry (L85, 18th Dynasty–New Kingdom, 26th Dynasty–Late Period, and Roman) at the arrow. Bottom and middle right insert: open-cut and gallery workings in the Wadi el-Muluk quarry. Note the red lines on the gallery ceiling in the insert, which mark the progress of the ancient quarrymen. Middle left insert: queen Hatshepsut's temple at Deir el-Bahri, which was built with limestone from the Wadi el-Muluk quarry. Photos by Per Storemyr.

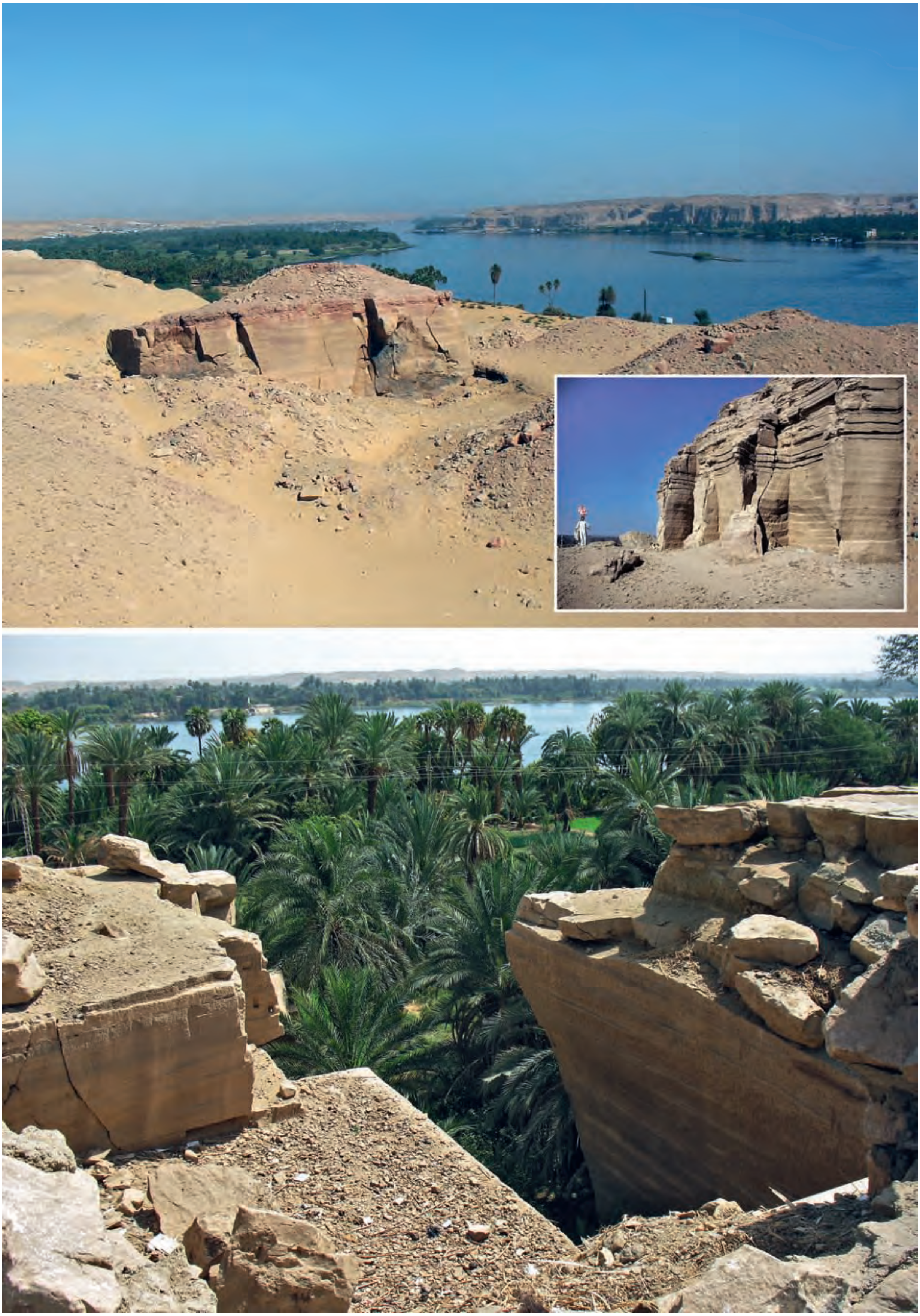

Figure 4. Sandstone quarries in the Nile Valley. Top: open-cut workings at Naq el-Fugani (S12, Ptolemaic), just north of Aswan. Bottom: open-cut workings at Nag el-Hosh (S6, Ptolemaic to Roman) just north of Kom Ombo. Insert: open-cut workings at El-Mahamid (S2, Old and/or Middle Kingdom, and Ptolemaic), near ancient El-Kab. Photos by Per Storemyr except the insert, which is by James Harrell.

Figure 5. Stone temples. Top: Philae sandstone temple (Ptolemaic–Roman) near Aswan as seen in the early 1900s before its removal to higher ground on a nearby island following the completion of the Aswan High Dam in 1971. Stone for this temple came from the Qertassi quarry (S20), now under Lake Nasser. Bottom right: Hibis sandstone temple (Late Period) in Kharga Oasis, with the stone probably coming from the Gebel el-Teir quarry (S32). Bottom left: calcareous-sandstone temple at Qasr el-Sagha in northern Faiyum (Middle Kingdom), with the stone coming from a quarry probably nearby but not yet identified. Photos by Per Storemyr except the top one, which is from American Colony Jerusalem Collection (1900–1920, PPOC, digital ID: http://hdl.loc.gov/loc.pnp/matpc.01580).

Figure 6. Softstone quarrying technology: Top: vertical trenches and undercuts for sandstone blocks in the Gebel el-Silsila quarry (S9b, Middle to New Kingdom, and Ptolemaic to Roman). Bottom: dressed (chiseled) quarry face in sandstone at the Nag el-Hosh quarry (S6, Ptolemaic to Roman). Lower right insert: bedrock surface after removal of limestone blocks by trenching and undercutting in the Giza quarry beside the king Khafre (or Chephren) pyramid (L2, 4th Dynasty–Old Kingdom). Photos by Per Storemyr.

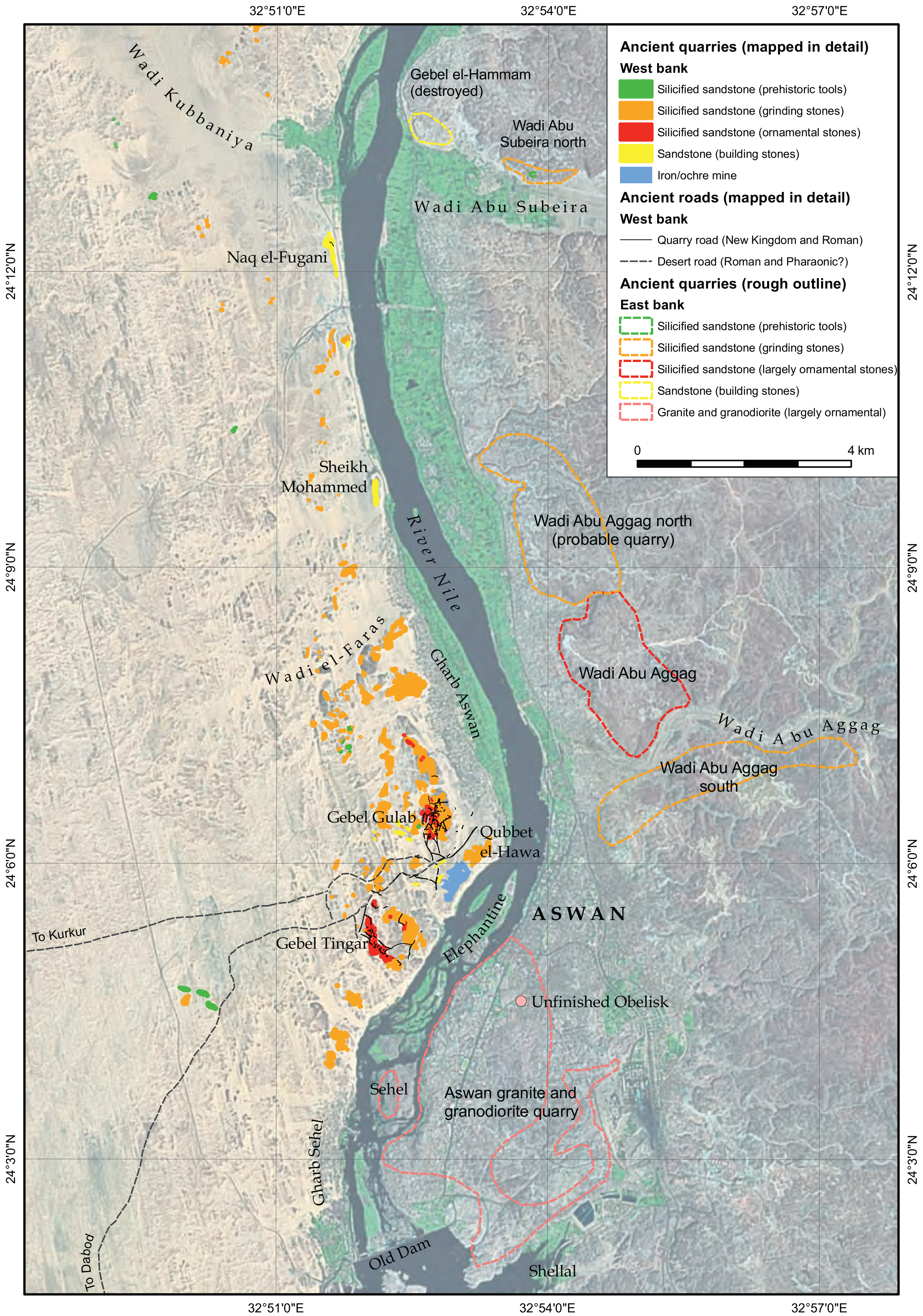

Figure 7. Map showing an ancient quarry landscape covering about 100 km² in the Aswan area, with quarries for granite and granodiorite in Aswan (H6); dolerite in Aswan (H37–38); silicified sandstone at Wadi Abu Aggag (H4), Gebels Gulab and Tingar (H5), and Wadi Abu Subeira (H36); and normal (non-silicified) sandstone at numerous localities (S12–13, S16–18, and S38). Map by Per Storemyr based on a survey by the QuarryScapes project as well as on Harrell and Madbouly (2006) for Wadi Abu Aggag and Klemm and Klemm (1993) for the Aswan granite/granodiorite quarries. A Landsat satellite image (ca. 2000) is used as background.

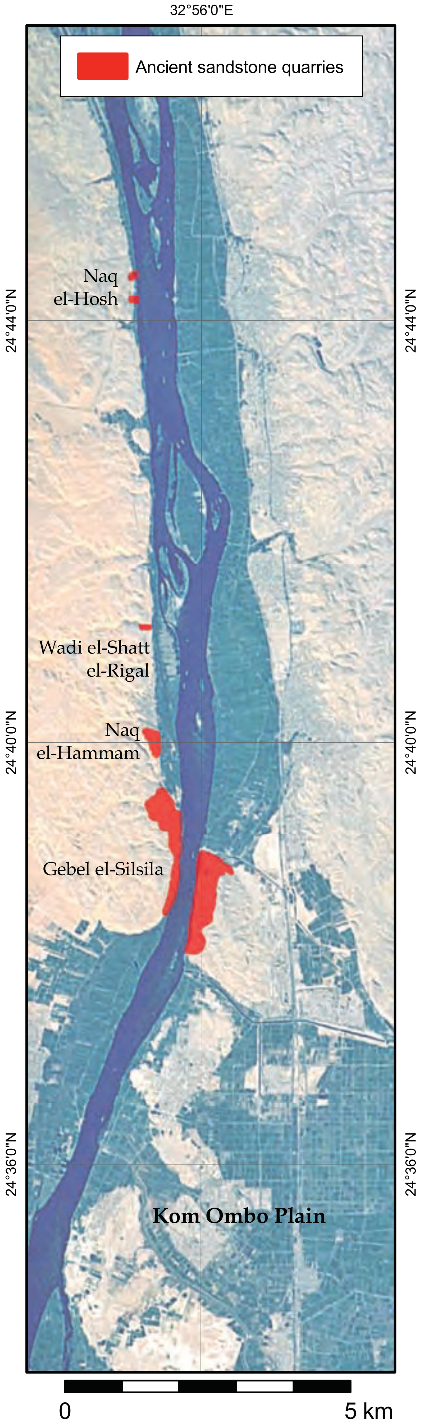

Figure 8. Map of the Kom Ombo area showing the sandstone quarries at Gebel el-Silsila (S9a, b, Middle to New Kingdom, Ptolemaic to Roman), Nag el-Hammam (S8, S35, Middle and/or New Kingdom), Wadi el-Shatt el-Rigal (S7, Middle to New Kingdom), and Naq el-Hosh (S6, Ptolemaic to Roman). The unique location of Gebel el-Silsila, on both sides of the Nile in a narrow 'semi-cataract' zone, is undoubtedly the reason why this area was developed into ancient Egypt's largest sandstone quarry. Map by Per Storemyr based on an outline of quarries in Klemm and Klemm (1993) with the background image from Image Science and Analysis Laboratory, NASA–Johnson Space Center ('The Gateway to Astronaut Photography of Earth,' http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=ISS018&roll=E&frame=15496).

mental stones were not available. Along the Red Sea coast, the temples and other important buildings of the Ptolemaic and Roman Periods were built with blocks of anhydrite and gypsum.

Nearly all the limestone came from Tertiary formations (mainly Eocene but also Paleocene and Pliocene) with the ancient quarries located in the hills and cliffs bordering the Nile Valley between Cairo in the north and Isna in the south. Some limestone, of Quaternary age, was also quarried along the Nile Delta's Mediterranean coast west of Alexandria. Quarries in the Nile Valley from Isna southward into northern Sudan supplied the sandstone, which came from the Cretaceous Nubia Group. Anhydrite and gypsum were obtained from Egypt's Red Sea coast, where they occur in various Miocene formations, and gypsum also came from Eocene outcrops in the Faiyum region of the Western Desert.

Ornamental stones

In contrast to the plain-looking building stones, those employed for ornamental purposes have attractive colors and patterns, and also take a good polish due to their greater hardness or, in the case of travertine and gypsum, their coarsely crystalline character (Figures 7, 10–29). The principal applications of these stones and their periods of use are as follows: (1) External veneer on pyramids: Old Kingdom—granite, and granodiorite. (2) Pyramid capstones: Old and Middle Kingdoms—granodiorite, and possibly basalt. (3) Linings of burial chambers and passages in pyramids and mastaba tombs: Early Dynastic Period through Middle Kingdom—granite, granodiorite, and silicified sandstone. (4) Door lintels, jambs, and thresholds of temples: Early Dynastic through Roman Periods—granite, granodiorite, and silicified sandstone. (5) Temple pavements: Old Kingdom—basalt and travertine. (6) Temple columns: Old and Middle Kingdoms—granite. (7) Internal wall veneer, pavement, and columns for temples and other buildings: Roman Period—andesite–dacite porphyry, granite, granodiorite, metaconglomerate, metagabbro, metagraywacke, pegmatitic diorite, quartz diorite, rhyolite porphyry, tonalite gneiss, and trachyandesite porphyry. (8) Basins: Roman Period—granite, andesite–dacite porphyry, and tonalite gneiss. (9) Barque shrines: Middle and New Kingdoms—granite, silicified sandstone, and travertine. (10) Small statue shrines (naoi): Old Kingdom through Roman Period—granite, granodiorite, metagraywacke, and silicified sandstone; and Late Period only—dolerite porphyry. (11) Obelisks: New Kingdom and Roman Period—granite; and New Kingdom only—metagraywacke, and silicified sandstone. (12) Offering tables: Old Kingdom through Roman Period—granite, granodiorite, metagraywacke, silicified sandstone, and travertine. (13) Small vessels and figurines: Late Predynastic Period through Old Kingdom—andesite porphyry, anorthosite–gabbro gneiss, basalt, granite, metagraywacke, obsidian, pegmatitic diorite, quartz rock crystal, red-and-white limestone breccia, gypsum, serpentinite, silicified (petrified) wood, travertine (the most commonly used stone), tuff, and tuffaceous limestone; and Middle Kingdom and Second Intermediate Period only—blue anhydrite (a stone different from the white anhydrite used in construction). (14) Canopic jars: Old Kingdom through Roman Period—travertine. (15) Sarcophagi: Old Kingdom through Roman Period—granite, granodiorite, metagraywacke, and silicified sandstone; Old through New Kingdoms only—travertine; New Kingdom through Late Period only—metaconglomerate; and Late Period only—basalt. (16) Small to colossal statues and other sculptures: Early Dynastic through Roman Periods—granite, granodiorite, metagraywacke, red-and-white limestone breccia, silicified sandstone, and travertine; Old and Middle Kingdoms only—anorthosite-gabbro gneiss; early New Kingdom only—marble, and pyroxenite; Late Period only—dolerite porphyry; Late through Roman Periods only—basalt, and metaconglomerate; and Roman Period only—andesite–dacite porphyry. (17) Scarab and shabti figures: New Kingdom through Roman

Period—metagraywacke, serpentinite, soapstone (steatite), and travertine. (18) Stelae: Old Kingdom through Roman Period—granite, granodiorite, metagraywacke, and silicified sandstone; and Late Period only—metaconglomerate. (19) Cosmetic and ceremonial palettes: Late Predynastic and Early Dynastic Periods: metagraywacke. Note that many of the above objects were also carved from non-ornamental limestone and sandstone.

During the Dynastic and Ptolemaic Periods, most of the ornamental stone was quarried in the Aswan region (granite, granodiorite, and silicified sandstone) with other smaller quarries located near Cairo (silicified sandstone), in the Western Desert's Faiyum (basalt) and Abu Simbel/Toshka area (anorthosite–gabbro gneiss), and in the Eastern Desert's Red Sea Hills (marble, metaconglomerate, metagraywacke, and dolerite porphyry). The travertine came from quarries just east of the Nile Valley and from the same Eocene limestone formations supplying building stones, where it occurs as cave and fissure fillings. The red-and-white limestone breccia also came from these same formations, where it occurs along faults, but no definite quarries have yet been found. Similarly, no quarries are known for the pyroxenite, serpentinite, and soapstone used in pre-Roman times. The many varieties of hardstones employed for vessels came mainly from the Red Sea Hills, where only a few of the quarries have so far been discovered. The basalt and gypsum also used for vessels came from the Faiyum–Cairo region, and the blue anhydrite, which is not known to occur in Egypt, may have been imported. Many of the same quarries for ornamental stones continued to be worked during the Roman Period, but most of the activity at this time involved new quarries producing a wide variety of attractive igneous and metamorphic rocks in the Red Sea Hills.

Gemstones

The ancient Egyptians used gemstones for beads, pendants, amulets, inlays, and seals (Figure 30). The materials most commonly employed during the Dynastic Period include: amazonite, carnelian (the most popular stone) and the closely related sard, red jasper, red garnet, lapis lazuli (the most valuable stone and imported from Afghanistan), colorless (rock crystal) quartz, and turquoise. Others occasionally used in this period were banded and sardonyx agate, amethyst (especially during the Middle Kingdom), bluish-white chalcedony, black hematite, yellow jasper (New Kingdom only), malachite, obsidian (imported from an unknown southern Red Sea or Ethiopian source), and white (milky) quartz. During the Greco–Roman Period the same gemstones were used, but there were also new ones, including emerald (green beryl), peridot (olivine) and, imported from India, aquamarine (bluish-green beryl), onyx agate, and sapphire (blue corundum). With the exceptions noted above, all these gemstones are thought to come from Egyptian sources, but the only known quarries are for amazonite, amethyst, carnelian, emerald, peridot, and turquoise. All the native gemstones come from the Precambrian basement rocks with the exceptions of turquoise and some malachite, which are found in sandstone of Jurassic age.

Utilitarian stones

Perhaps the most heavily used of all the Egyptian stones is chert (or flint, Figure 31). From Predynastic times onward it was employed for tools (awls, adzes, knife and sickle blades, axe and pick heads, choppers, drill bits, and scrapers) and weapons (dagger blades, and spear and arrow points). Even when metals (copper, bronze, and later iron) became commonplace for these applications, chert was still a popular low-cost alternative. For tools and weapons requiring the sharpest edges, imported obsidian was employed. A wide variety of stones, especially hard ones (including many of the aforementioned ornamental varieties), were used for the heads of maces, a club-like weapon.

From Late Predynastic times into the Late Period, the quarrying and much of the carving of hard ornamental stones was done with tools fashioned from tough, fracture-resistant rocks such as dolerite and others as discussed in a later section (Figure 16). These same rocks were also employed as grinding stones for smoothing rough, carved stone surfaces. The actual polishing of these surfaces was probably done with ordinary, quartz-rich sand of which Egypt abounds. For the softer sandstone and limestone, picks of chert (as well as metal tools) were employed. Grinding stones for grain have been used throughout Egyptian history and were usually carved from the same granite, granodiorite, and silicified sandstone employed for ornamental applications (Figure 31). During the Ptolemaic and Roman Periods, grinding stones made from imported vesicular basalt were popular.

In medieval Islamic times, Egypt had numerous quarries in the Eastern Desert for soapstone (steatite), which was carved into oil lamps and especially cooking vessels (Figures 32–33). Some of these quarries were also worked during the Roman Period. Eye shadow made from finely ground galena (dark gray) and malachite (green) was used by both Egyptian men and women. The grinding was done on cosmetic palettes carved mainly from metagraywacke. Egyptian temples and tombs were richly painted with bright primary colors often made from ground minerals: azurite and lapis lazuli (blue), goethite ochre and orpiment (yellow), gypsum and calcite (white), hematite ochre and realgar (red), and malachite (green). With the exceptions of chert (occurring as nodules in the Eocene limestones) and silicified sandstone (coming from the Cretaceous Nubia Group), essentially all the utilitarian stones were derived from the Precambrian basement rocks.

Ancient Egyptian quarrying technology

In considering the quarrying methods employed by the ancient Egyptians, it is useful to first distinguish between the 'hardstones' (essentially all the igneous

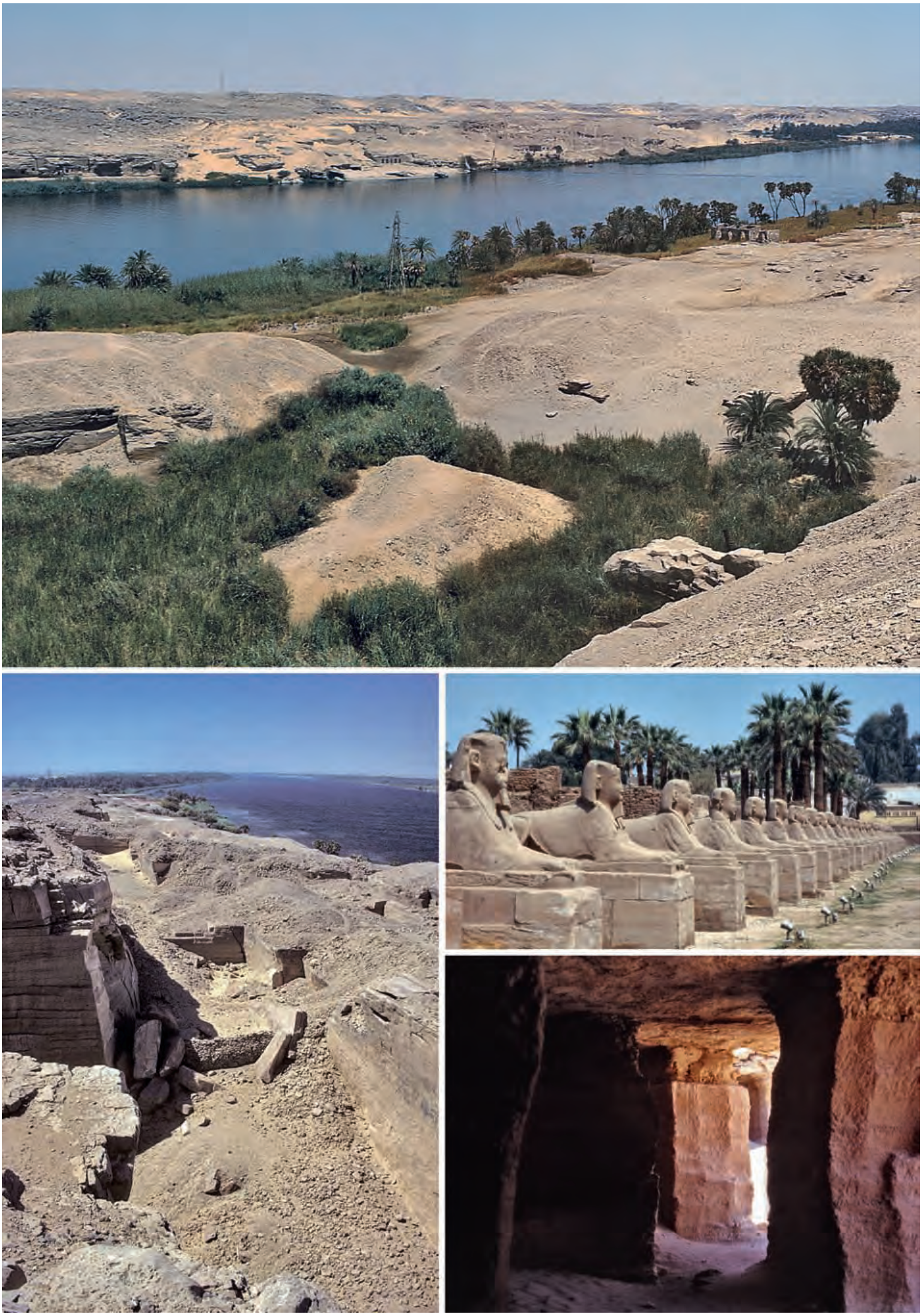

Figure 9. Gebel el-Silsila sandstone quarry (S9a, b, Middle to New Kingdom, Ptolemaic to Roman) and its products. Top: view from the east bank across part of the quarry with the west bank workings visible on the other side of the Nile River and the New Kingdom harbor (now filled with vegetation) in the foreground. Bottom left: Ptolemaic to Roman open-cut workings on the east bank. Bottom lower right: Middle Kingdom gallery workings on the east bank. Bottom upper right: sphinxes carved from Gebel el-Silsila sandstone on the avenue joining the Luxor and Karnak temples in Luxor. Photos by Per Storemyr except the bottom left one, which is by James Harrell.

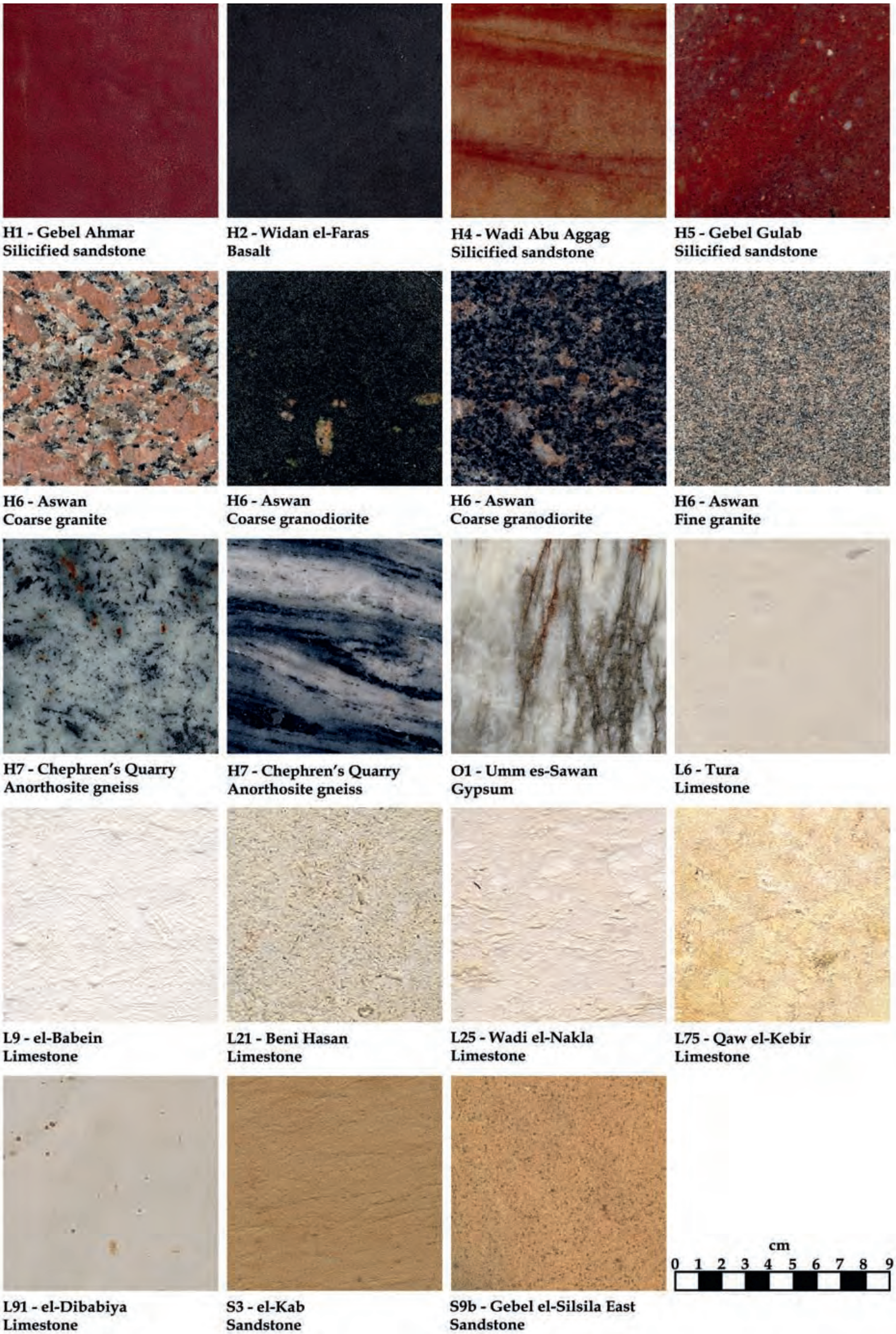

Figure 10. Selected stones from ancient quarries in the Nile Valley and Western Desert. The numbering and sequence of the images follow the list of quarries on the reverse side of the attached, fold-out map. Not all quarries and rock varieties are represented. Photos by James Harrell.

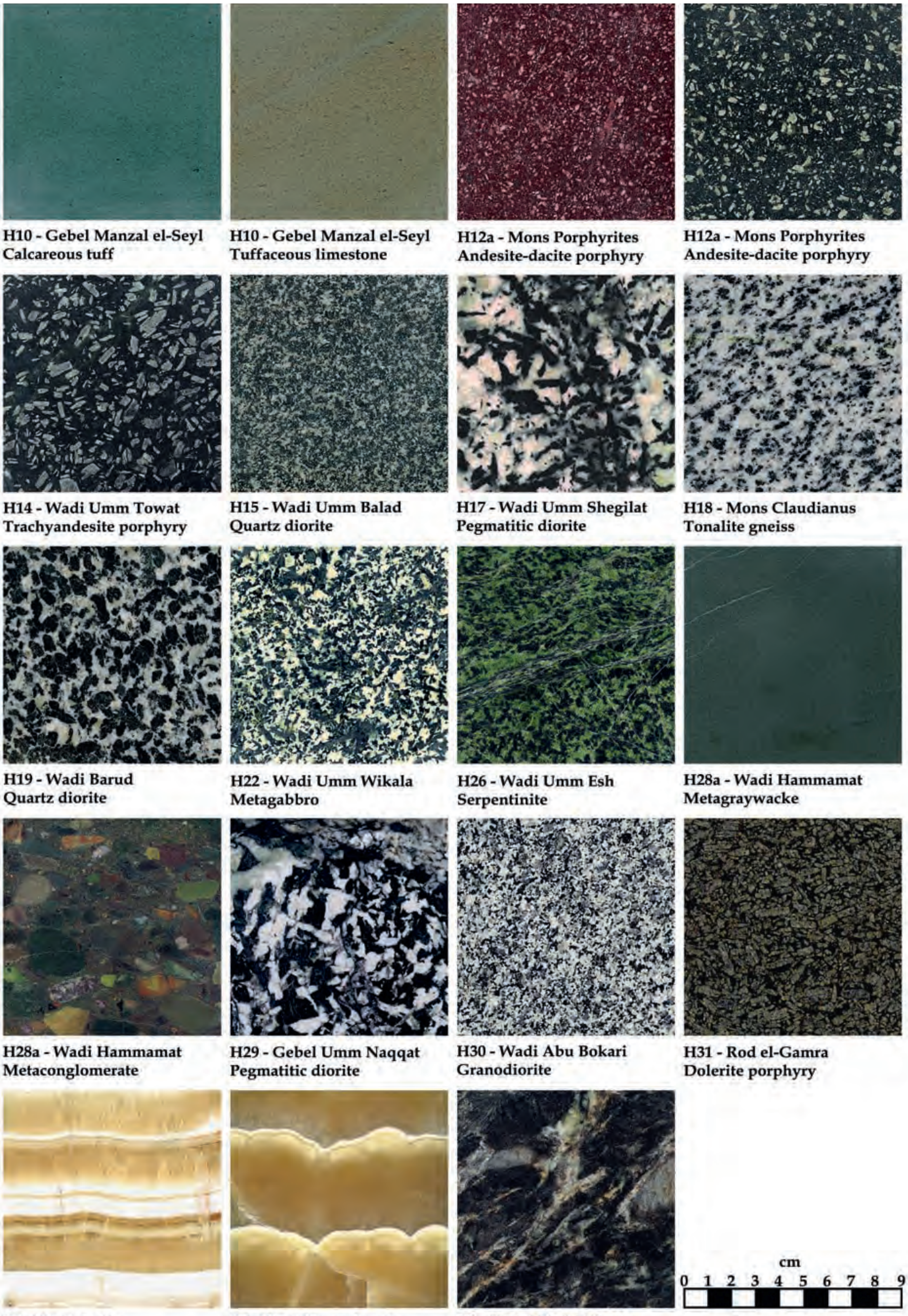

Figure 11. Selected stones from ancient quarries in the Eastern Desert. For further explanation see caption to Figure 10. Photos by James Harrell.

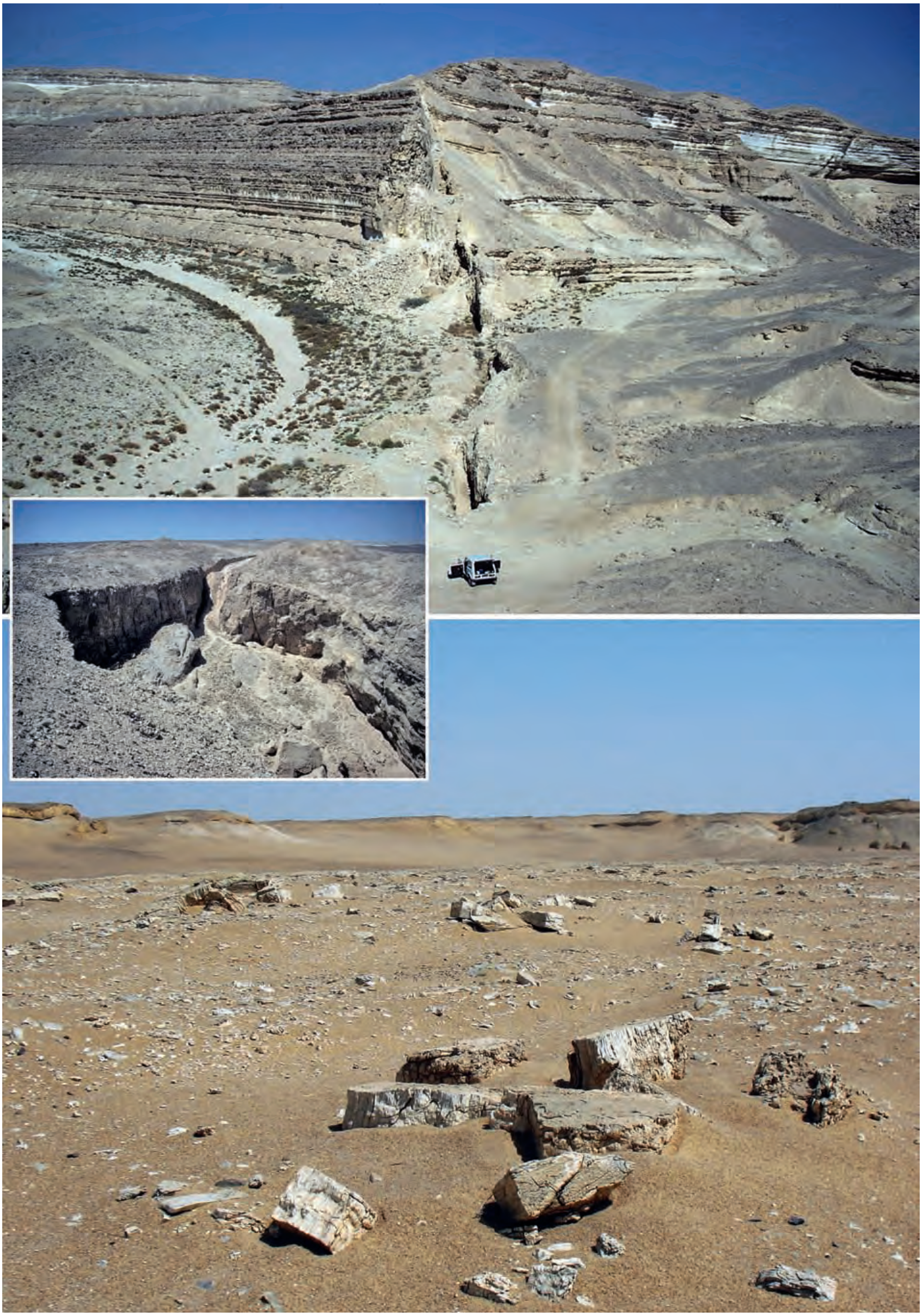

Figure 12. Travertine and gypsum quarries. Top: open-cut workings following a travertine vein in Wadi el-Garawi (T1, Old Kingdom) near Helwan. Bottom: open-cut workings in gypsum at Umm el-Sawan (O1, Early Dynastic to Old Kingdom) in northern Faiyum. Insert: originally underground and later open-cut workings in a travertine cave deposit at Hatnub (T8, 4th–6th Dynasty–Old Kingdom, 12th Dynasty–Middle Kingdom, 18th Dynasty–New Kingdom, and Roman) near El-Amarna. Photos by James Harrell except the bottom one, which is by Per Storemyr.

Figure 13. Hardstone quarries in the Eastern Desert: Top: dolerite porphyry quarry in Rod el-Gamra (H31, 30th Dynasty–Late Period) with roughed-out shrines or naoi at the entrance to the quarry cut. Middle right: tuff and tuffaceous limestone quarry on Gebel Manzal el-Seyl (H10, Early Dynastic). Middle left: pegmatitic diorite quarry in Wadi Umm Shegilat (H17, Late Predynastic to Early Dynastic, and Roman). Bottom: metagraywacke quarry in Wadi Hammamat (H28a, Late Predynastic to Roman). Photos by Per Storemyr except the middle left and bottom ones, which are by James Harrell.

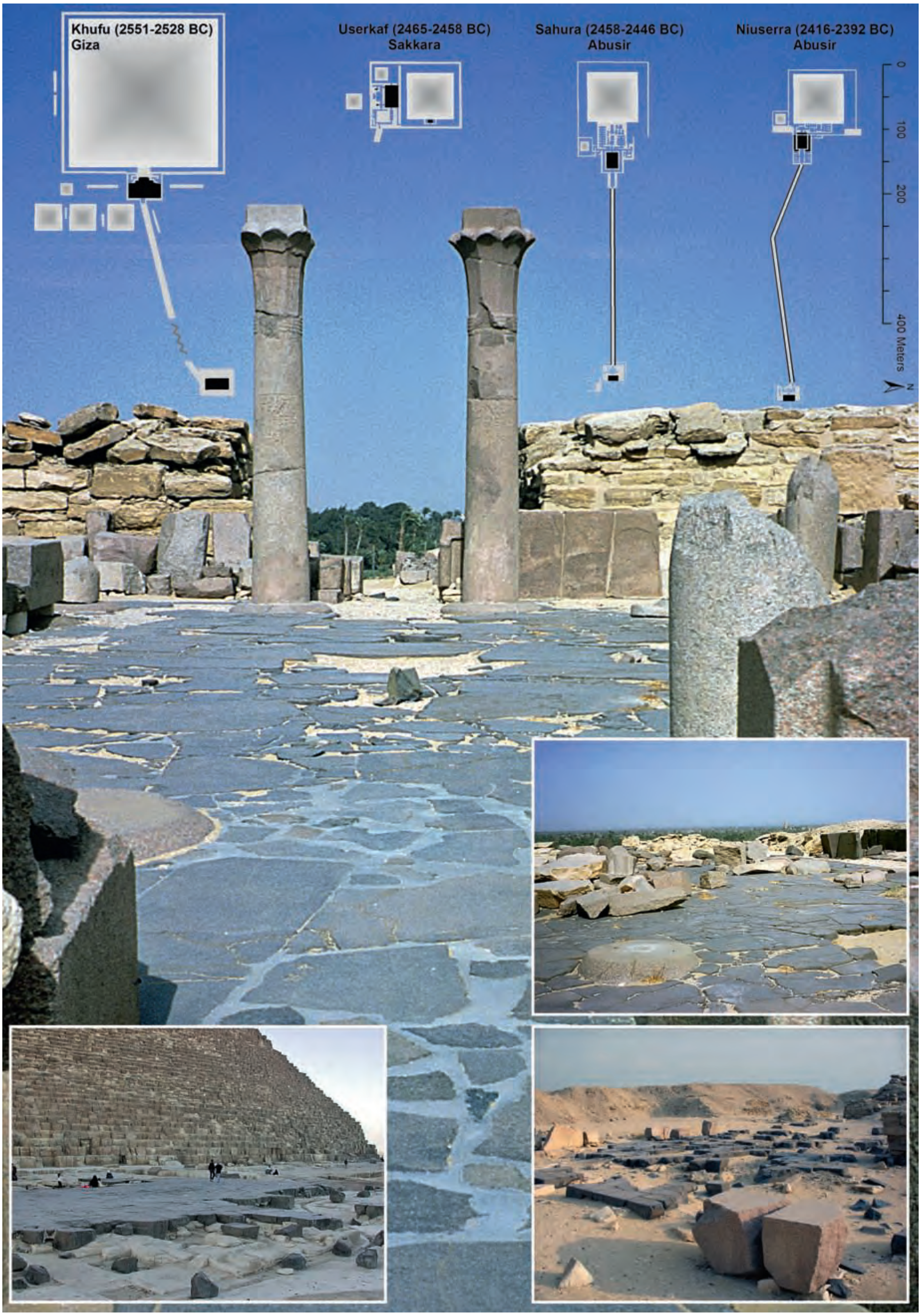

Figure 14. Basalt in Old Kingdom temple pavements used to symbolize kmt (the 'black land'), Egypt's ancient name and a reference to the dark organic-rich, life-giving soil of the Nile floodplain. Top: pyramid temple of king Sahura at Abu Sir (5th Dynasty). Lower left insert: pyramid temple of king Khufu (or Cheops) at Giza (4th Dynasty). Lower right insert, top: pyramid temple of king Niuserra at Abu Sir (5th Dynasty). Lower right insert, bottom: pyramid temple of king Userkaf at Saqqara (5th Dynasty). The basalt for these pavements came from the Widan el-Faras quarry in the northern Faiyum (H2, see also Figures 21–23). The pyramid temples and associated monuments are excellent places to study the Old Kingdom use of stone for ornamental and architectural purposes. In addition to basalt, there is granite and granodiorite, silicified sandstone, travertine and fine limestone with splendid reliefs. Photos by Per Storemyr with plans of pyramid complexes after Lehner (1997).

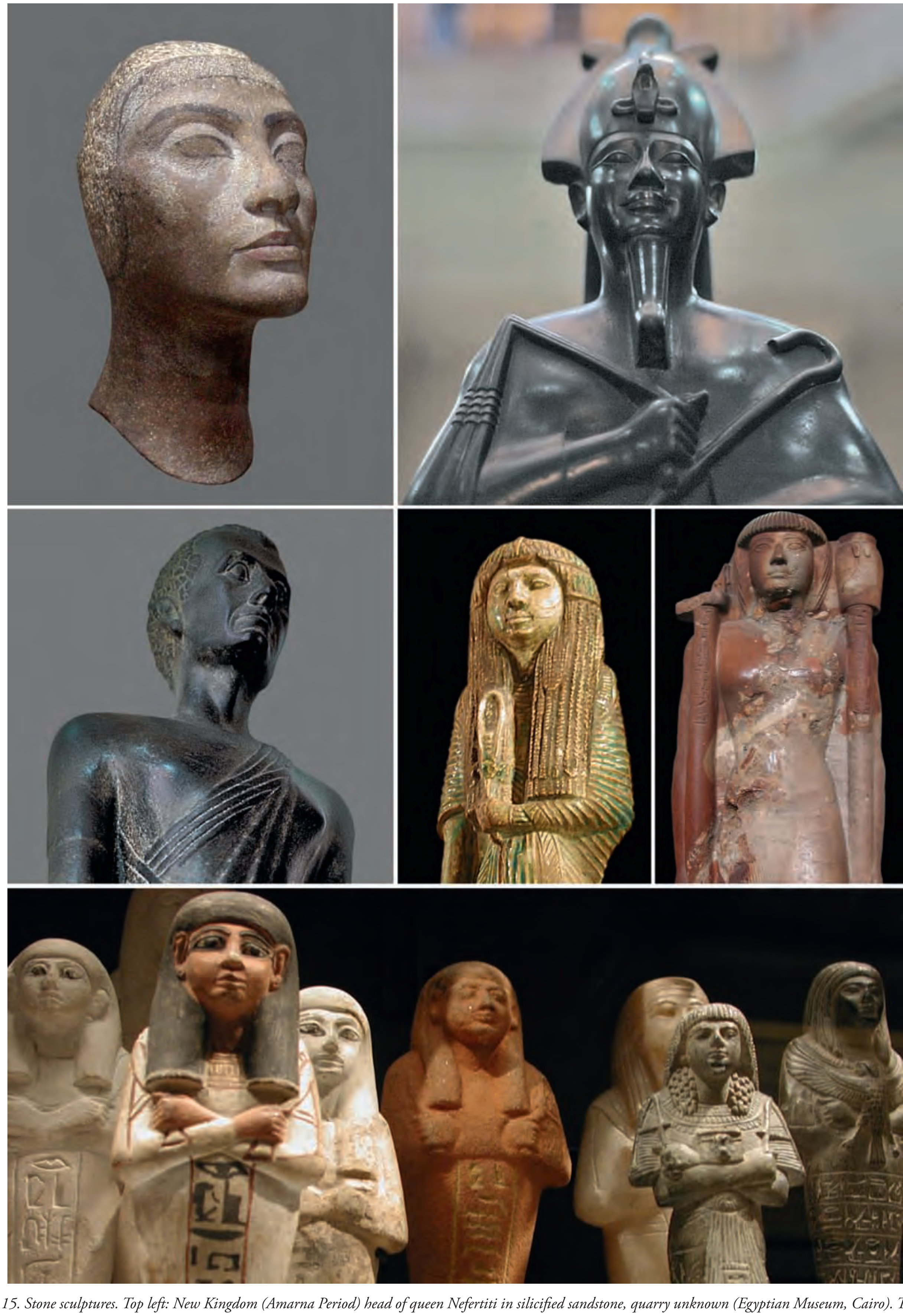

Figure 15. Stone sculptures. Top left: New Kingdom (Amarna Period) head of queen Nefertiti in silicified sandstone, quarry unknown (Egyptian Museum, Cairo). Top right: Late Period statue of Osiris in metagraywacke from Wadi Hammamat (Egyptian Museum, Cairo). Middle left: Ptolemaic statue of a priest in basalt, probably from Widan el-Faras (Egyptian Museum, Cairo). Middle center: New Kingdom statuette in glazed soapstone (steatite), quarry unknown (Louvre, Paris). Middle right: New Kingdom statue of Khaemwese, son of king Ramesses II, in silicified conglomeritic sandstone, perhaps from Gebel Ahmar (British Museum, London). Bottom: a collection of Dynastic funerary figurines or shabtis, carved, from left to right, in limestone or travertine (3), silicified sandstone, travertine, and metagraywacke (2) (Louvre, Paris). Photos by Per Storemyr.

Figure 16. New Kingdom hardstone quarrying technology at Aswan. Top and upper insert: trenches cut in granite for a colossal statue in the Unfinished Obelisk Quarry at Aswan (part of H6) using dolerite pounders like those shown at bottom right. Bottom left: cracked quarry face produced by fire setting in the silicified sandstone quarry on Gebel Gulab (H5) near Aswan. Geologist Tom Heldal pictured. Photos by Per Storemyr except the bottom right one, which is by James Harrell.

Figure 17. Roman hardstone quarrying technology. Top: abandoned column in tonalite gneiss in the Mons Claudianus quarry (H18) still attached to the bedrock with traces of wedge holes and a chiseled groove along the bottom edge. Middle right: block of metagraywacke in the Wadi Hammamat quarry (H28a) with both wedge holes and pointillé pits. Bottom: dressed (chiseled) quarry face in andesite–dacite porphyry in the Mons Porphyrites quarry (H12a) where multiple courses of blocks were extracted. Photos by Per Storemyr.

Figure 18. Slipway roads. Top: 18 m-wide slipway (quarry road) in the silicified sandstone quarry on Gebel Gulab (H5, New Kingdom) with another slipway from elsewhere in the same quarry (insert). Bottom: slipway descending 500 m from the Lykabettus workings in the andesite–dacite porphyry quarry at Mons Porphyrites (H12a, Roman). Photos by Per Storemyr except the bottom one, which is by James Harrell.

and metamorphic rocks plus silicified sandstone and chert) and the 'softstones' (limestone, sandstone, travertine, anhydrite, gypsum, and soapstone). The extraction technologies are very different for each group.

Hardstone quarrying

From Late Predynastic times through most of the Late Period, quarrying of hardstone was done with stone tools (Figure 16). These tools, which are known as pounders or mauls, were hand-held, purpose-shaped pieces of exceptionally hard and tough rock. The most popular material was dolerite, but fine-grained granite, silicified sandstone, and anorthosite gneiss were also utilized. Large, two-handed pounders were employed to either knock off the corners and edges of bedrock outcrops if only relatively small pieces were required, or hack out trenches and undercuts to isolate large blocks from the bedrock. The same tools were also used to reduce and reshape loose boulders resting on the bedrock. The extracted blocks were dressed (trimmed) with smaller stone tools, sometimes mounted on wood handles. Fire setting was employed during the Dynastic Period to weaken hardstone surfaces prior to pounding with a stone tool (Figure 16). Where the ancient quarrymen could exploit natural fractures in the bedrock, copper or bronze gads were hammered into the fractures to widen them. Natural, wedge-shaped splinters of rocks may also have been used in the same way. Wood levers (stout poles or beams) were used to help detach blocks along fractures or cut trenches.

By the 30th Dynasty of the Late Period, and possibly as early as the 26th Dynasty, 'iron' (low-grade steel) tools were first used by the Egyptians for quarrying, and included sledge hammers, picks, chisels, and wedges. In extracting blocks from the bedrock or boulders, a line of wedge-shaped holes was first chiseled into the surface (Figures 17 and 27). Iron wedges were then inserted into the holes and these were hammered until the rock split along the line of holes. Thin pieces of iron called 'feathers' may have been placed on each side of the wedges to increase the lateral, expansive force of the hammered wedges. The iron-wedge technology improved through the Ptolemaic Period and reached its zenith in Roman times, with little change between then and the present day. A fiction often repeated in the popular archeological literature is that the wedge holes were cut for wooden wedges which, when wetted, would expand and so split the rock. In reality, this cannot work for the sizes, shapes, spacings, and often inclined orientations of wedge holes found in ancient hardstone quarries. Wooden wedges have been successfully employed in some modern hardstone quarries, but these require different kinds of wedge holes. Another quarrying innovation that first appeared in Egypt during the Ptolemaic Period is the so-called 'pointillé' technique, which is still in use today (Figure 17). Whereas wedging is useful for rough splitting, lines of pointillé pits are employed for more precise, controlled separation. In this method, a straight line of small, shallow pits is chiseled across a rock surface. The quarryman then hammers a chisel back and forth along the line of pits until the rock splits. Fire setting and levers continued to be used, but the levers were probably of iron as well as wood.

Softstone quarrying

Throughout the Dynastic Period until near the end of the Late Period, when iron tools were adopted, the softstones were quarried with copper (and later bronze) chisels and picks. It is likely that chert pick heads were also commonly employed. Although copper and the harder bronze were tough enough to work the softer stones, these tools were quickly blunted and abraded. They were entirely unsuited for quarrying the hardstones, for which the stone tools were much superior. The picks were used to cut vertical trenches on three sides of an intended block which, on its open quarry-face side, was then undercut and detached by a chisel hammered with a wood mallet (Figure 6). These same tools were then employed to dress the extracted blocks. This basic approach to softstone quarrying remained unchanged during the Ptolemaic and Roman Periods, but the picks and chisels were of iron. On occasion, hammered iron wedges were also used to split limestone and sandstone. See Arnold (1991) for additional information on the tools used for quarrying and dressing stone.

Quarry excavations and transport

Quarrying in ancient Egypt was usually done in open pits and trenches. In addition to such 'open-cut' workings, in some quarries the workers followed desirable rock layers underground and in the process created cave-like 'gallery' quarries (Figures 2–3 and 9 for building stones). Unquarried rock pillars were left to support the roofs in the larger galleries but, apart from these, no other precautions were taken to prevent cave-ins. Gallery quarries are relatively common for limestone and travertine, and such excavations locally penetrate over 100 m into hillsides. Many of the limestone galleries later became the sites of Coptic Christian hermitages and monasteries, with some of the latter still active today. With the exception of the Gebel el-Silsila quarry (Figure 9), galleries were never cut into sandstone or any of the hardstone rock varieties. There are, however, underground workings, as well as open-cuts, in all the emerald quarries (Figure 30) and one of those for chert (Wadi el-Sheikh), but these involve narrow shafts and tunnels more like those found in the ancient Egyptian gold mines.

The choice of quarry location would have been based on several factors, including the quality of the stone (appearance, soundness, and available block sizes), proximity to the building site or workshop for which the stone was destined, and proximity to the Nile River if water transport was needed. In the case of limestone and sandstone, the locations of quarries on the sides of the Nile Valley were dictated more by the character of the rock than ease of accessibility, as evidenced by the many workings high above the more easily reached outcrops at lower elevations. For these building stones, the quarries were normally restricted to rock layers with uniform coloration and texture, at least moderate hardness, and thicknesses and vertical fracture spacings suitable for the sizes of blocks required.

For the ornamental stones coming from remote parts of the desert, the extra effort required to obtain them was justified by either their exceptional beauty (e.g., travertine with its translucency, and anorthosite–gabbro gneiss with its blue glow in bright sunlight) or their symbolic significance (e.g., metagraywacke with its green color, like new vegetation, signifying good health and regeneration, and the many igneous and metamorphic rocks quarried in the Eastern Desert representing the might and wealth of the Roman Empire). Gemstones were always in demand for jewelry and other decorative arts, and the long and arduous passages to their desert sources were not sufficient to discourage the ancient Egyptians from quarrying them.

During the Dynastic Period, quarried pieces of stone too large to be carried on the backs of men or animals (mainly donkeys but also camels from perhaps the Late Period onward), would have been placed on wooden sledges, which were then pulled by teams of either draft animals or, probably more commonly, men. In order to reduce ground friction, the sledges may have been pulled over either wetted ground or wooden beams ('sleepers') laid crosswise along the sledge's path. The sleepers would have traveled with the sledge, with those left behind picked up and laid down in front of the advancing sledge. It has been suggested that the sledges were also sometimes pulled over wood 'rollers', but this is unlikely as rollers would only be effective on ground that was hard, smooth, and relatively flat. Such ground conditions may have existed within some quarries, but in most cases the sledges were pulled across rocky or sandy ground or, at best, roughly made tracks where the rollers would have been ineffective. Specially built quarry tracks or roads were not uncommon during the Dynastic Period. Some were paved with a single course of dry-laid, unshaped, and loosely fitted pieces of the locally available rocks. The most notable of these is the 12 km-long road leading from the Old Kingdom basalt quarry at Widan el-Faras in the Faiyum (Figures 21–23). This is the world's oldest paved road and was constructed from irregular pieces of basalt and silicified wood, and slabs of limestone and sandstone. A complex, 20 km-long network of paved and partially cleared roads of New Kingdom date are found in the silicified sandstone quarries near Aswan at Gebels Gulab/Tingar and, across the Nile, in Wadi Abu Aggag (Figures 7 and

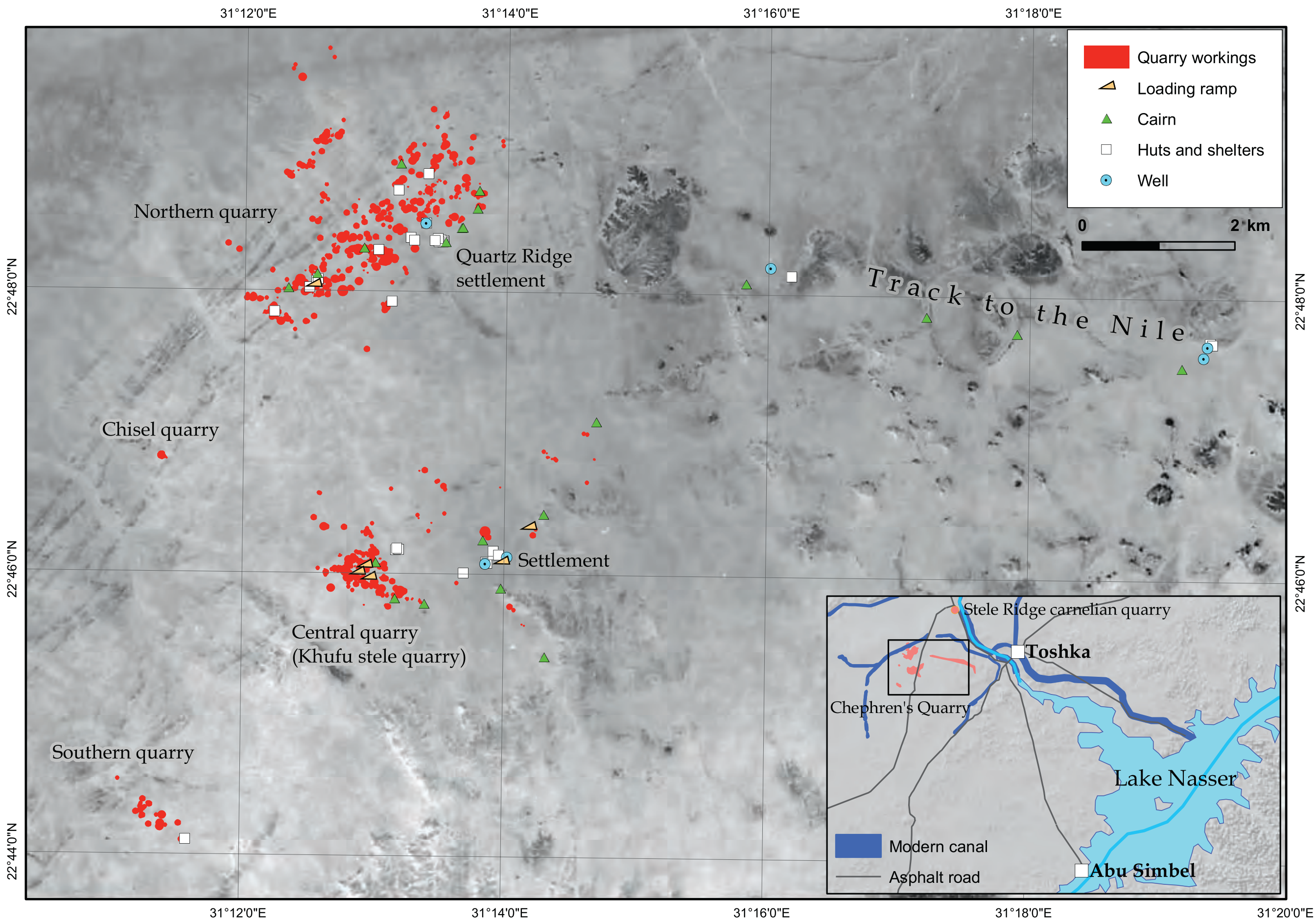

Figure 19. Map of Chephren's Quarry for anorthosite–gabbro gneiss (H7, Old and Middle Kingdoms) showing nearly 700 workings and associated infrastructure. Insert depicts how the quarry is currently being engulfed by roads and canals of the giant Toshka land reclamation project. Map by Per Storemyr based on a survey by the British–Norwegian mission to Chephren's Quarry and the QuarryScapes project with a US declassified Corona satellite image (ca. 1965) used as background.

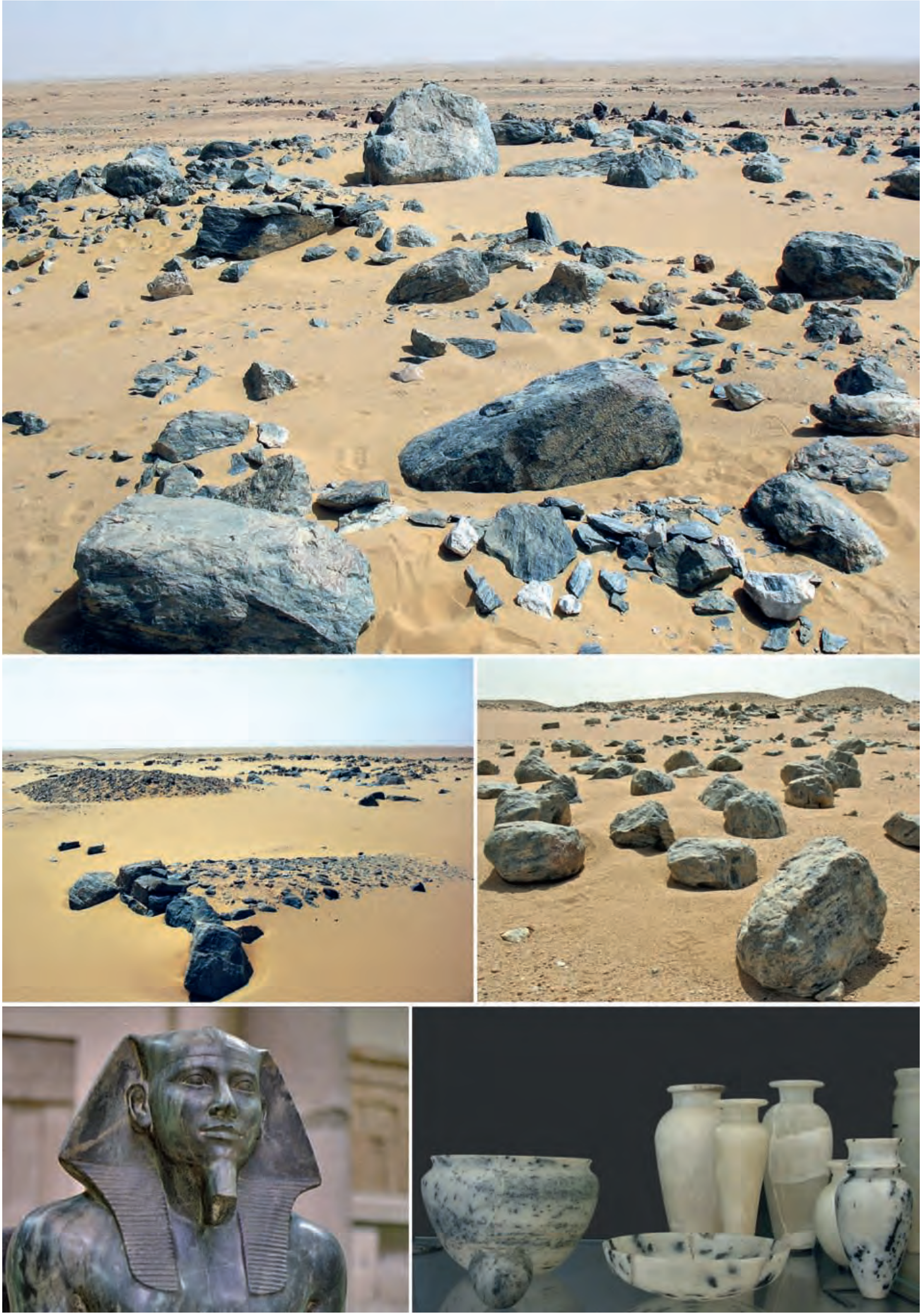

Figure 20. Chephren's Quarry for anorthosite–gabbro gneiss (H7, Old and Middle Kingdoms). Top: quarry working with roughed-out statue blocks produced from boulders. Middle left: ramp where larger blocks were loaded onto some kind of sledge. Middle right: smaller blocks destined for vessels grouped in an ancient collection area. Bottom left: statue of king Khafre (Chephren) carved from gabbro gneiss (Egyptian Museum, Cairo). Bottom right: three vessels (in the front) carved from anorthosite gneiss with the other vessels in the back carved from travertine (Louvre, Paris). Photos by Per Storemyr except the bottom left one, which is from Jon Bodsworth (www.egyptarchive.co.uk).

18). These were altered and reused in the Roman Period. Most of the Dynastic quarry roads were unpaved, and consisted only of cleared tracks, where the coarser surface gravel was swept to the sides. Where these roads crossed steep declines or surface dips, their bases were built up (and often supported by stone revetments) to reduce and even out the gradients. The outstanding example of this kind of road leads from the Dynastic travertine quarry at Hatnub to the Nile River near the modern village of El-Amarna.

Even though the Egyptians knew about the wheel from earliest Dynastic times, they had no wheeled wagons until the early New Kingdom. It is not known if these were ever used to transport quarry stone, but it is unlikely because without relatively broad roadways with firm, flat surfaces, the heavily laden wagons would either get stuck in the sand or break their wheels on the rocks. In the Roman Period, however, and possibly as early as the Ptolemaic Period, wagons pulled by draft animals were the primary means of land transport for quarried stone and this method was made practical by an extensive, well-built network of roads (cleared, unpaved tracks) linking the desert quarries with the Nile Valley (attached map and Figures 26 and 28). In all periods and for all stones, the quarry products were at least roughed out on site, and occasionally were carved to a nearly finished state. This not only reduced the weight of stone requiring transport, but also had the benefit of revealing any unacceptable flaws in the stone prior to its removal from the quarry (Figures 13, 20, 25, 27 and 31).

Archeology of quarry sites

Quarries are not simply sources of stone, but are also important archeological remains that provide a different perspective on life in ancient Egypt than the sites more commonly studied by archaeologists, such as pyramids, temples, settlements, and cemeteries. In any consideration of the archaeology of quarry sites, it is useful to distinguish between those located in or very close to the Nile Valley, and those in the remote desert. The following summary mainly draws from recent archeological research in the Eastern Desert, in the northern Faiyum, at Hatnub, in the Aswan region, and at Chephren's Quarry near Abu Simbel/Toshka, as well as more general observations. It is important to recognize that Egypt's desert climate, although already very dry, was slightly more hospitable in ancient times than it is now.

Remote desert quarries

With some notable exceptions, the remote desert quarries usually feature the following groups of archeological remains (Figures 13, 16–29, and 32–35): (1) Places of 'primary' stone extraction (e.g., bedrock outcrops and boulders) with tool marks and typically large waste dumps. There may also be 'secondary' extraction areas for stone tools and, in the Ptolemaic–Roman Period, nearby smithies for the repair of iron tools. (2) Work areas for dressing the extracted blocks, and then carving them into rough-outs or nearly finished products (many of which remain at the sites). These are sometimes associated with storage areas for such products. (3) Slipways, loading ramps, roads, or other marked routes for transportation of stone within the quarry and away to the Nile Valley. (4) Stone huts with, at times, more elaborate stone structures (such as fortified buildings) forming small to large temporary or permanent settlements used by the quarry workers. (5) Cemeteries for the larger, more permanent settlements. (6) Crude stone shelters within the primary stone-extraction areas, used by the workers as temporary resting places. (7) Wells and cisterns, without which work in the desert would be impossible. (8) Religious or other structures of worship and ritual, from simple stone enclosures and standing stones to shrines and elaborate temples. (9) Cairns and standing stones for marking transport routes and quarry locations. (10) Inscriptions, graffiti and rock art related to the quarrying activities, and sometimes also texts in the form of ostraca. (11) Pottery, generally fragmentary, which usually constitutes the most important dating tool for a site.

In addition to the above remains, at the larger Roman quarries in the Eastern Desert there are the so-called 'animal lines', a series of cubicles separated by low stone walls where draft animals were watered and fed. The Romans also built stone huts on hilltops with commanding views of the surrounding area, and these served as lookouts and signaling stations. The source of the vast quantities of food consumed by the quarry workers and their animals is somewhat problematical. It was probably largely brought in from the Nile Valley, but some of the more perishable foods may have been grown in small gardens near the quarry settlements. Although no such gardens have yet been identified, it is unlikely that they would be preserved in an easily recognizable form.

The amount, distribution and kinds of archeological remains at a given quarry is dependent upon the period in which the site was in use, its size, and the longevity and pattern of stone extraction (e.g., periodic campaigns vs. continuous exploitation). Other important factors are the local geography (e.g., exposure to flash floods and wind-blown sand) and the relative importance of the site in terms of the value of its product.

Quarries in the Nile Valley

The Nile Valley quarries supplied nearly all the building stones (limestone and sandstone) as well as the most important ornamental stones (granite and granodiorite), and so in terms of volumes of material extracted, they are usually much larger than the remote desert quarries. Another characteristic of the Nile Valley quarries is a general absence of settlements, wells, and cemeteries because the work force would have resided mainly in the nearby villages on or just beyond the Nile floodplain. These quarries, however, do typically contain many primitive shelters, some roofed over with stone slabs and others mere windbreaks, that were large enough to accommodate one or two men during day-time rest

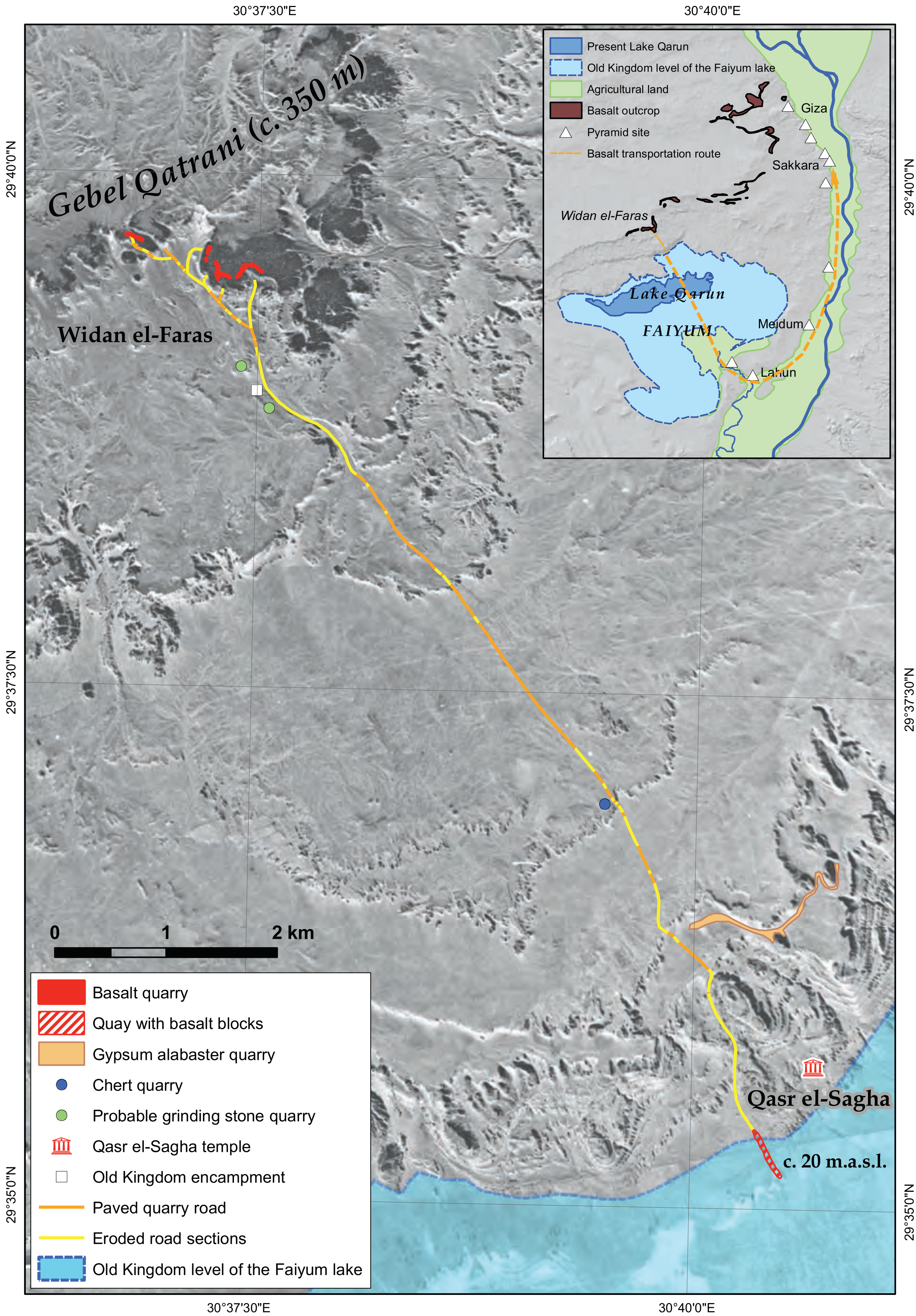

Figure 21. Map of the Widan el-Faras basalt quarry (H2, Old Kingdom) in the northern Faiyum showing the quarry workings and the 12 km-long paved road leading from the quarry to the quay near Qasr el-Sagha and formerly on the shore of a much higher Faiyum lake. Other quarries and the Middle Kingdom temple at Qasr el-Sagha are also indicated on the map. Map by Per Storemyr based on a survey by the QuarryScapes project with a US declassified Corona satellite image (ca. 1965) used as background.

periods. Those quarries located up to a few kilometers from the Nile may have a larger number of temporary shelters or even stone huts, but still lack settlements. Instead of long-distance roads, there are short slipways leading to nearby construction sites or the river. A canal for water transportation has been recently discovered leading to the Unfinished Obelisk in the Aswan granite quarry, but such constructions are very exceptional. Cairns and standing stones exist, but they are fewer and less obvious than in the desert. Religious or ritual structures, such as small rock-cut shrines and stelae, are commonly present within these quarries, but there are no elaborate temples. Some quarries, however, are located within or very near the precincts of temples and necropoleis with pyramids and mastabas. In general, it is expected that quarries will be located in the immediate vicinity of construction sites, assuming that stone of suitable quality is available. The conspicuous limestone quarry beside Khafre's pyramid at Giza is a good example of this (Figure 6). Many such quarries, however, have gone unrecognized because they are buried under ancient construction or modern excavation debris, or river- or wind-deposited sediments. Others have been destroyed by later building activities.

Skilled practice and local traditions

Taking a broad view of the extremely long time period covered in this paper, the archaeology of quarry sites suggests that, contrary to the boasts in ancient quarrying inscriptions, relatively small numbers of highly skilled, free craftsmen constituted the primary workforce. Criminals and enslaved war captives comprised only a minor component. The numbers of such personnel were rarely in the hundreds and never in the thousands. However, an often sizeable number of auxiliary personnel were present, and these were responsible for the supply and transport logistics, and guard duties. Life must have been hard, especially at remote desert quarries, but there were exceptions such as at the far-away Roman site of Mons Claudianus in the Eastern Desert. This had as many as 900 workers in its most active period, and boasted a bathhouse and wines imported from other parts of the Roman Empire. Although the quarries were of prime importance for the state and its elites, whether in Dynastic or Ptolemaic Egypt or in distant Rome, in recent years there has been a trend among researchers to downplay the role of central state control in favor of local, family- or clan-based entrepreneurship. Research on such issues

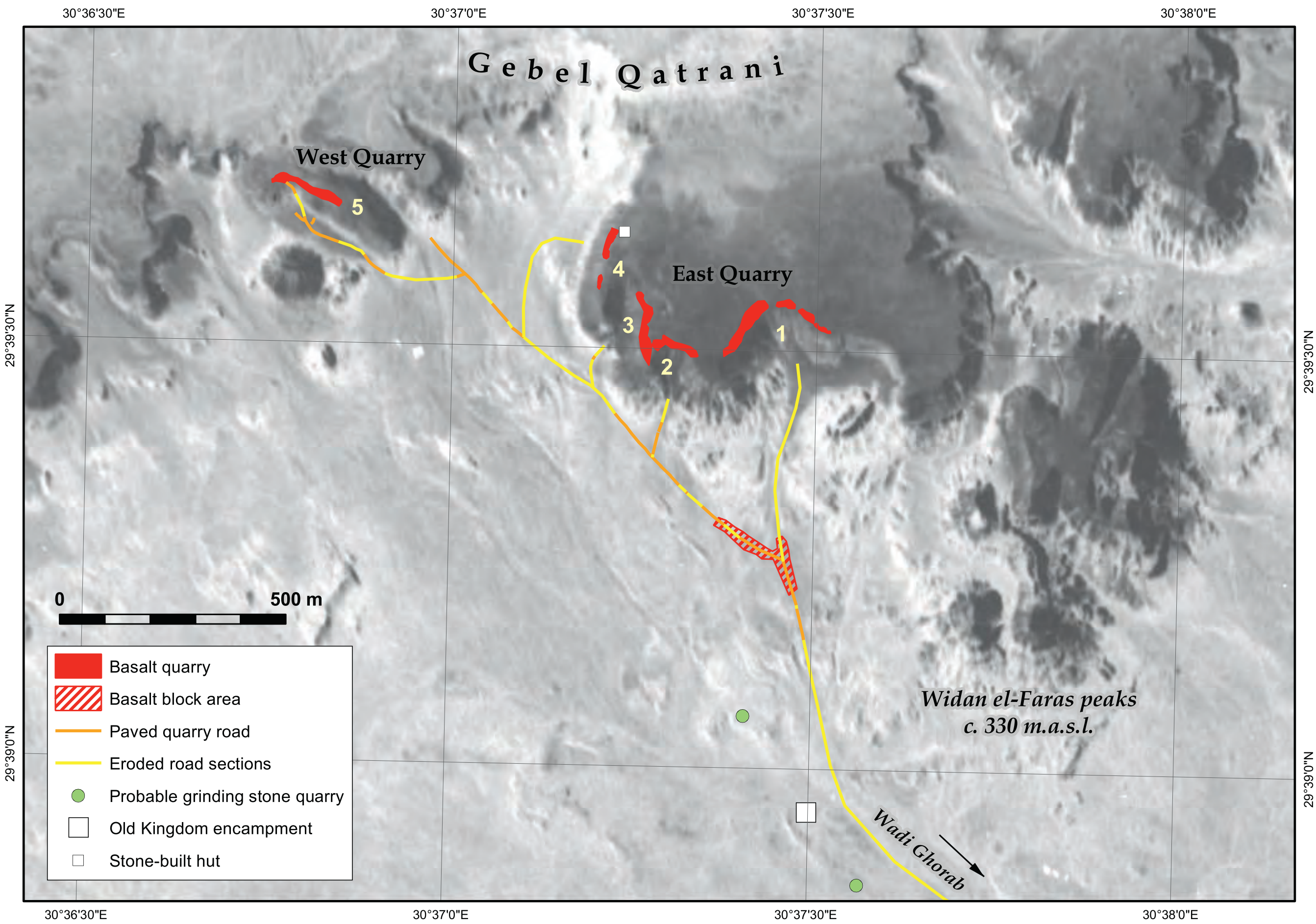

Figure 22. Detailed map of the Widan el-Faras basalt quarry (H2, Old Kingdom) showing the five areas with workings, the network of branching, mostly paved quarry roads, and other associated infrastructure. Map by Per Storemyr based on a survey by the QuarryScapes project with a US declassified Corona satellite image (ca. 1965) used as background.

Figure 23. Widan el-Faras basalt quarry (H2, Old Kingdom). Top: view from the quarry looking south past the peaks of Widan el-Faras toward Lake Quran just visible on the horizon. Middle left: circular waste piles below the quarry produced by the dressing of basalt blocks. Middle right: part of the paved road leading from the quarry (on the escarpment in the distance) to a quay. This segment of the road is made with pieces of silicified (petrified) wood. Bottom: 300 m-long quay near Qasr el-Sagha with abandoned basalt blocks littering its surface. Photos by Per Storemyr.

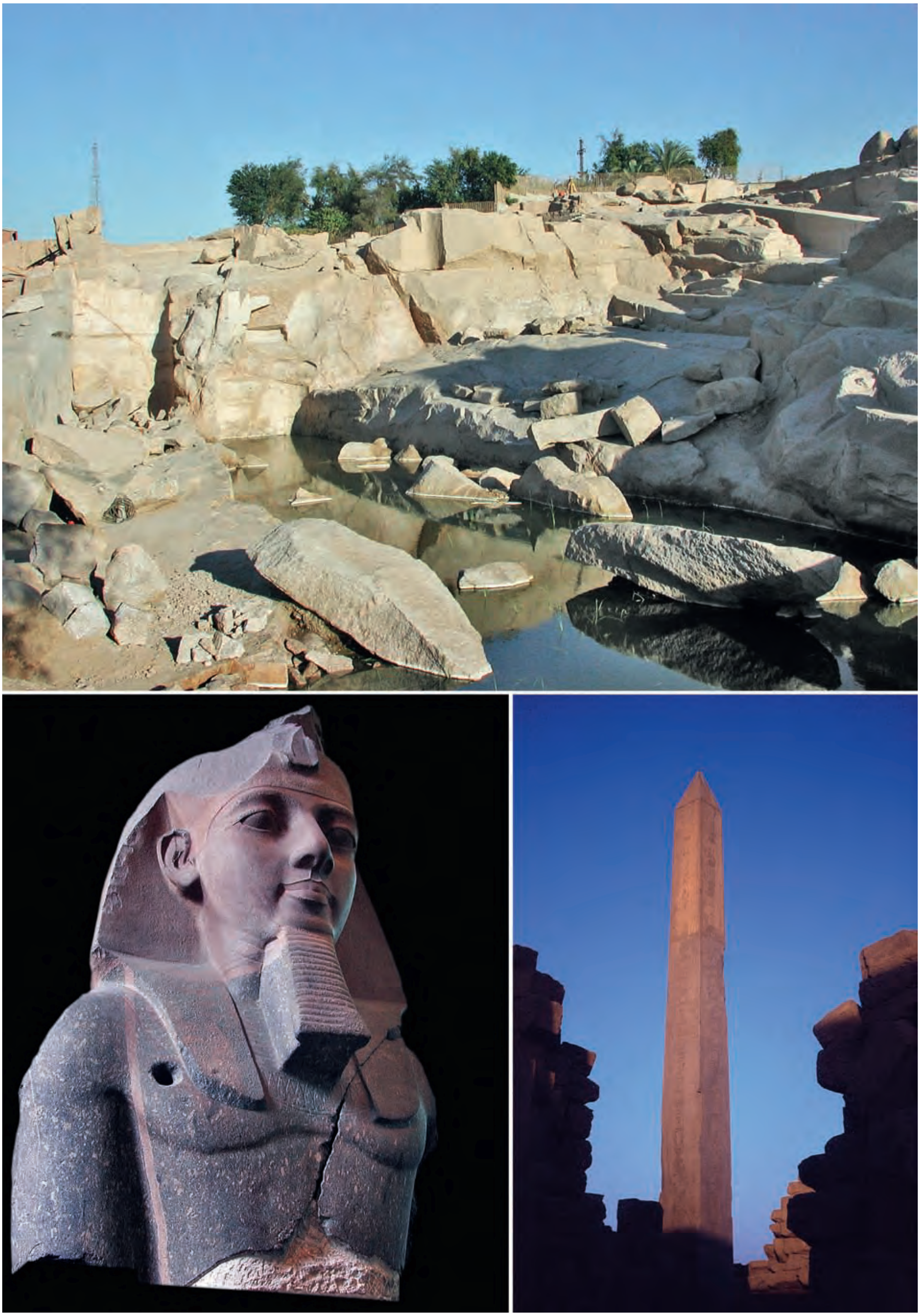

Figure 24. Aswan granite/granodiorite quarry (H6, Early Dynastic to Roman) and its products. Top: part of Aswan's Unfinished Obelisk Quarry in granite (as seen under archeological excavation in 2003). Bottom right: obelisk of pink, coarse Aswan granite erected for queen Hatshepsut in Karnak temple, Luxor. Bottom left: torso of a colossal statue of king Ramesses II carved from dark granodiorite with veins and patches of pink, fine granite from Aswan (originally from the Ramesseum in western Thebes and now in British Museum, London). Photos by Per Storemyr.

Figure 25. Gebels Gulab and Tingar silicified sandstone quarry (H5, New Kingdom and Roman). Top: working in the so-called Khnum's Quarry with the abandoned base for an obelisk (at center) and the city of Aswan in the background. Bottom: working on Gebel Sidi Osman with an abandoned statue blank (foreground) and the ruins of the medieval St. Simeon's Coptic monastery in the background. Right insert: quarry workings on Gebel Gulab, where large boulders were reduced to circular waste piles. Photos by Per Storemyr.

has only just begun, but it is an example of the significant role that the archeology of quarry sites can play in understanding life in ancient Egypt.

Ancient quarry landscapes

A glance at the maps in this paper (attached map and Figures 7, 8, 19, 21, 22, 26, 28, and 32) reveals that quarry sites may be large, locally more than several tens of square kilometers, and very often form clusters that are intricately linked with each other in terms of logistics and other features. In addition, they have frequently altered the natural landscape to such an extent that we, from a physical perspective, may speak of an 'ancient quarry landscape'. The tremendous lateral extent of some quarries as well as the great number of quarries overall are two of the greatest challenges in present conservation efforts, especially since land is becoming scarce in Egypt, as shown in other papers in this volume. When smaller (or larger) pieces of a quarry landscape are destroyed, its context may be lost and perhaps rendered impossible to reconstruct when trying to interpret how it was used and perceived in antiquity. The term 'quarry landscape' may also be seen as a research perspective on the social and cultural significance such places once held: the relationships among different quarries, and their links with nearby (and more remote) villages were maintained by the people that traversed, worked and settled the physical landscape, and exchanged ideas and more tangible items, such as tools. The quarries were also strongly related to the places where the stones were put in use, again by people for whom stone was important, whether for the elites as a way of exhibiting power or wealth, or for the humble craftsman as a way of supporting his family.

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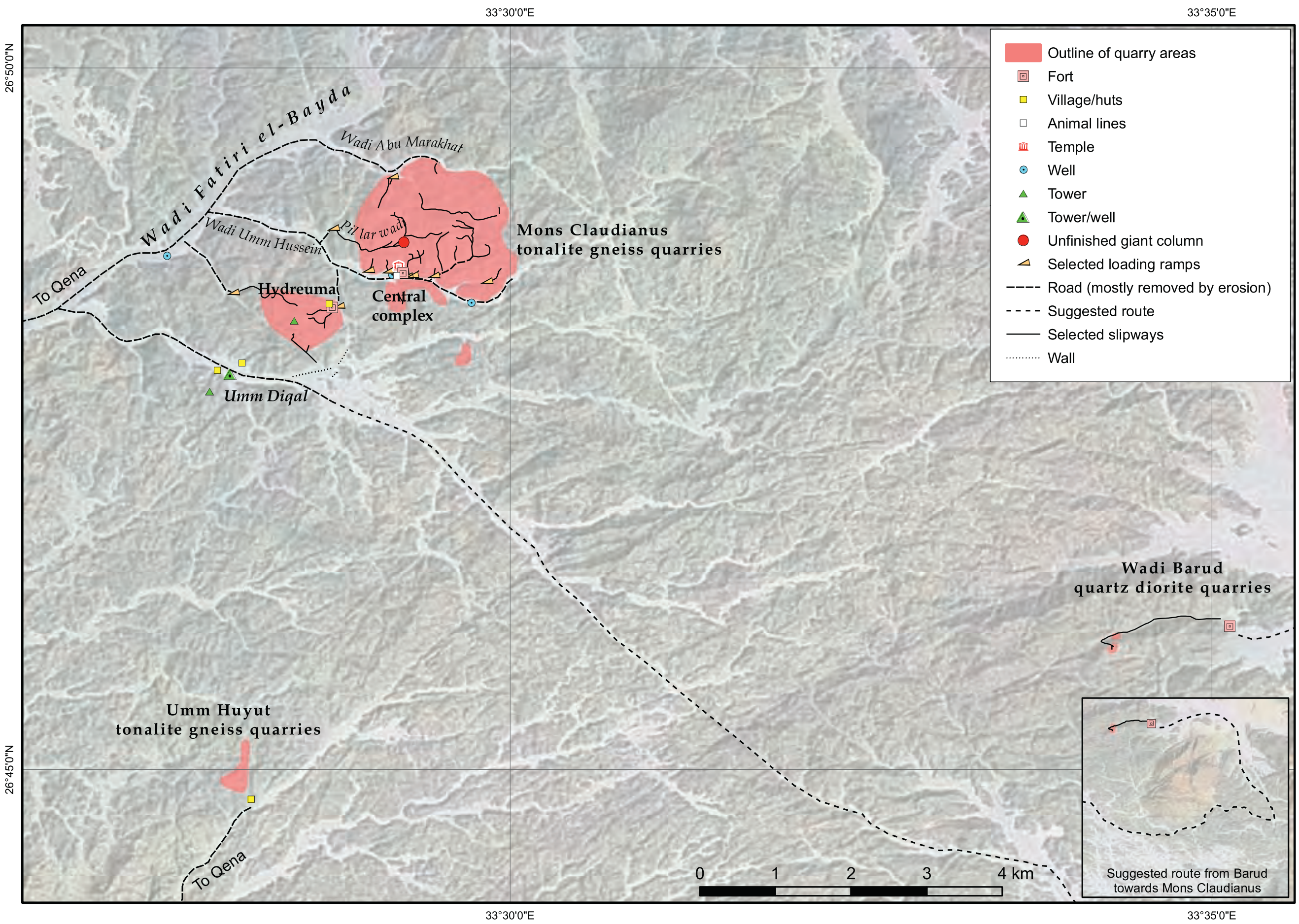

Figure 26. Map of the Mons Claudianus tonalite gneiss quarry (H18, Roman) in the central Eastern Desert showing the areas with quarry workings plus selected slipways, roads, and other infrastructure. Also indicated are the contemporary Roman quarries in Wadi Barud for quartz diorite (H19) and Wadi Umm Huyut for tonalite gneiss (H20). Map by Per Storemyr and James Harrell based on Peacock and Maxfield (1997) as well as their own observations with a Landsat satellite image (ca. 2000) used as background.

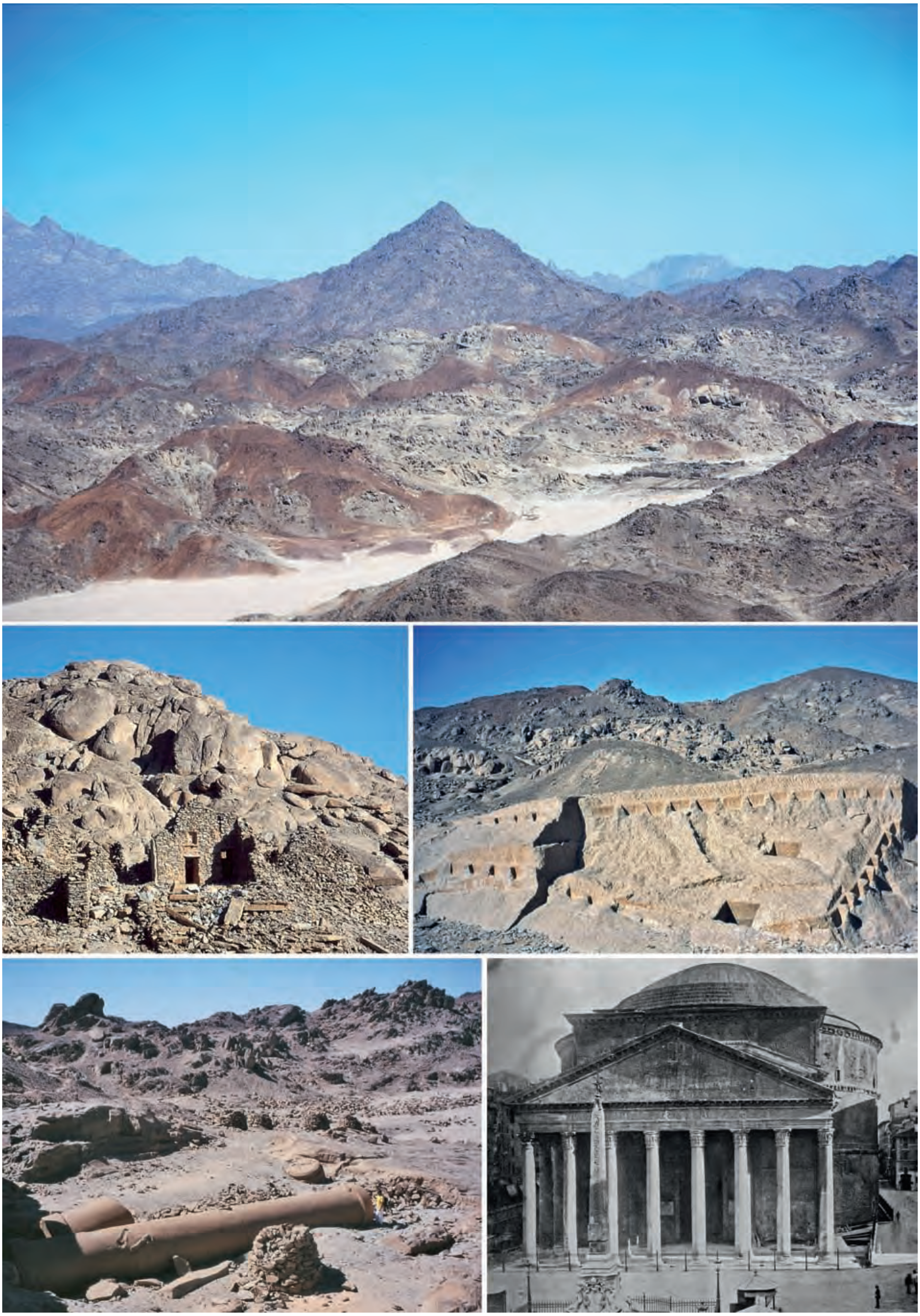

Figure 27. Mons Claudianus tonalite gneiss quarry (H18, Roman) and its products. Top: view across a portion of the quarry showing numerous workings and the central complex with a large fortified settlement. Middle left: temple in the quarry settlement. Middle right: working with traces of wedge holes. Bottom left: abandoned column, 18 m long with a diameter of 2.3 m. Bottom right: Pantheon in Rome with seven columns from Mons Claudianus (and one of Aswan granite). Photos by Per Storemyr except the bottom right one, which is from the Bain Collection (ca. 1910–1915, PPOC, digital ID: http://hdl.loc.gov/loc.pnp/ggbain.10183).

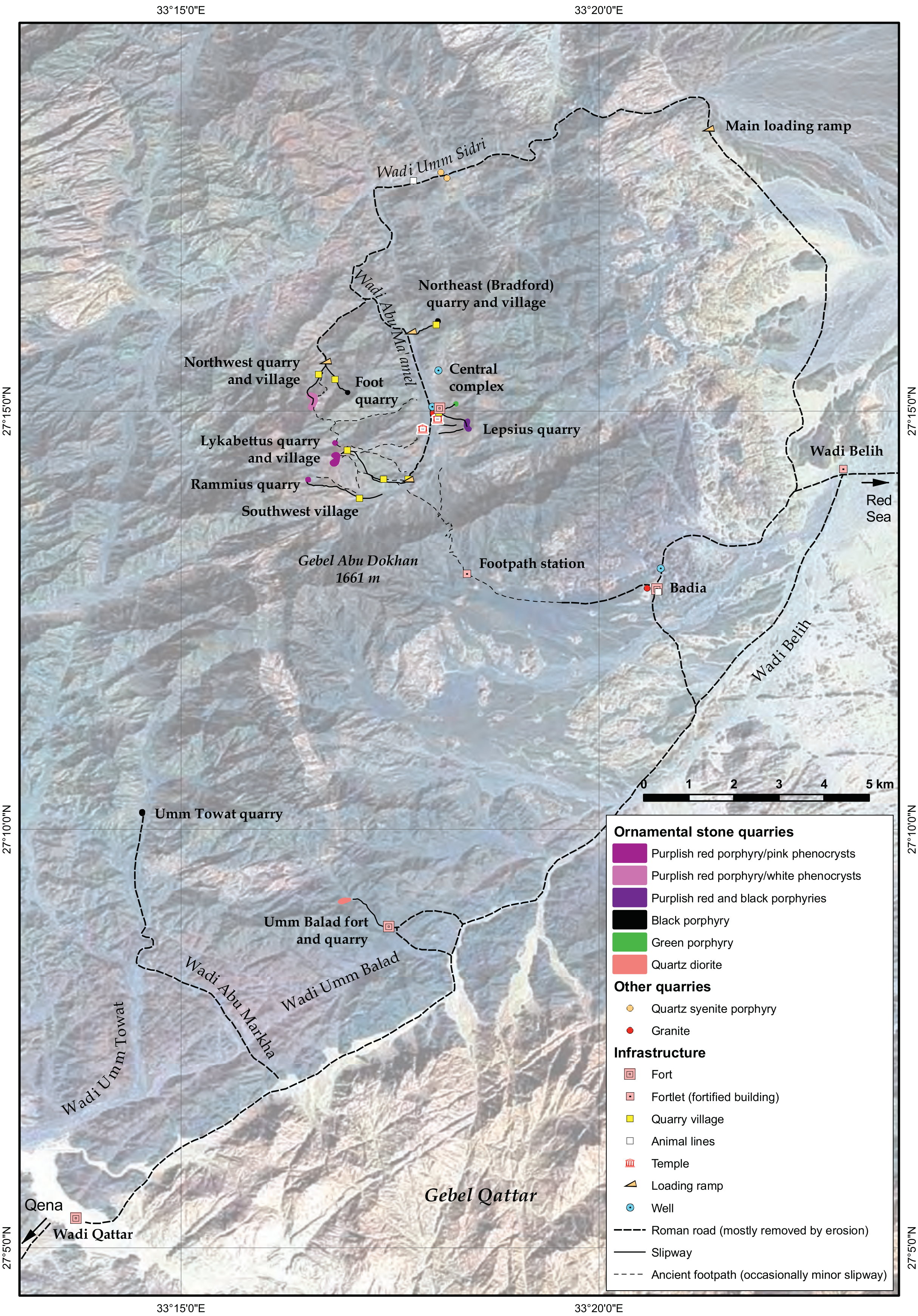

Figure 28. Map of the Mons Porphyrites andesite–dacite porphyry quarry (H12a, Roman) in the north-central Eastern Desert, showing the areas with quarry workings plus selected slipways, roads, and other infrastructure. Also indicated are the contemporary Roman quarries in Wadi Umm Sidri for syenite porphyry (H11), Wadi Abu Ma'amel for granite (H12b), Badia for granite (H13), Wadi Umm Towat for trachyandesite porphyry (H14), and Wadi Umm Balad for quartz diorite (H15). Map by Per Storemyr and James Harrell based on Maxfield and Peacock (2001) and their own observations with a Landsat satellite image (ca. 2000) used as background.

Figure 29. Mons Porphyrites andesite–dacite porphyry quarry (H12a, Roman) and its products. Top: the so-called Lykabettus quarry or workings with its workers' village and the upper part of the slipway seen in Figure 18. Middle left: abandoned roughed-out basin in one of the quarry workings. Middle right: loading ramp northeast of the quarry on the track leading to the Nile Valley. Bottom left: drawing of the facade of medieval St. Mark's Basilica in Venice showing, at its right edge, a portion of the carving of the Four Tetrarchs (a reused, late Roman sculpture) made from the red andesite–dacite porphyry (or Imperial Porphyry) of Mons Porphyrites (this carving is seen again in the bottom right photograph). Photos by Per Storemyr except the bottom left one from the Detroit Publishing Co. (1890–1900, PPOC, digital ID: http://hdl.loc.gov/loc.pnp/ppmsc.06661), and the bottom right one from Nino Barbieri (Wikimedia Commons, http://commons.wikimedia.org/wiki/File:Venice_%E2%80%93_The_Tetrarchs_03.jpg).

Figure 30. Gemstone quarries. Top: workings for carnelian (shown in upper insert) and other colored varieties of chalcedony at Stela Ridge (G13, Middle Kingdom) west of Abu Simbel in the Western Desert. Bottom: workings for emerald (or green beryl, shown in lower insert) in Wadi Sikait (G6, late Ptolemaic to Roman) in the southern Eastern Desert. Photos by Per Storemyr.

Figure 31. Utilitarian stone quarries. Top and upper insert: silicified sandstone quarry for grinding stones at Gebel Qubbet el-Hawa (part of H5, Dynastic–period unknown) near Aswan. Bottom: chert quarry for blades in Wadi el-Sheikh (H33, Old Kingdom and later Dynastic?). Lower insert: chert borer for hollowing out gypsum vessels found in the northern Faiyum near Qasr el-Sagha. Photos by Per Storemyr except the bottom one, which is by James Harrell.

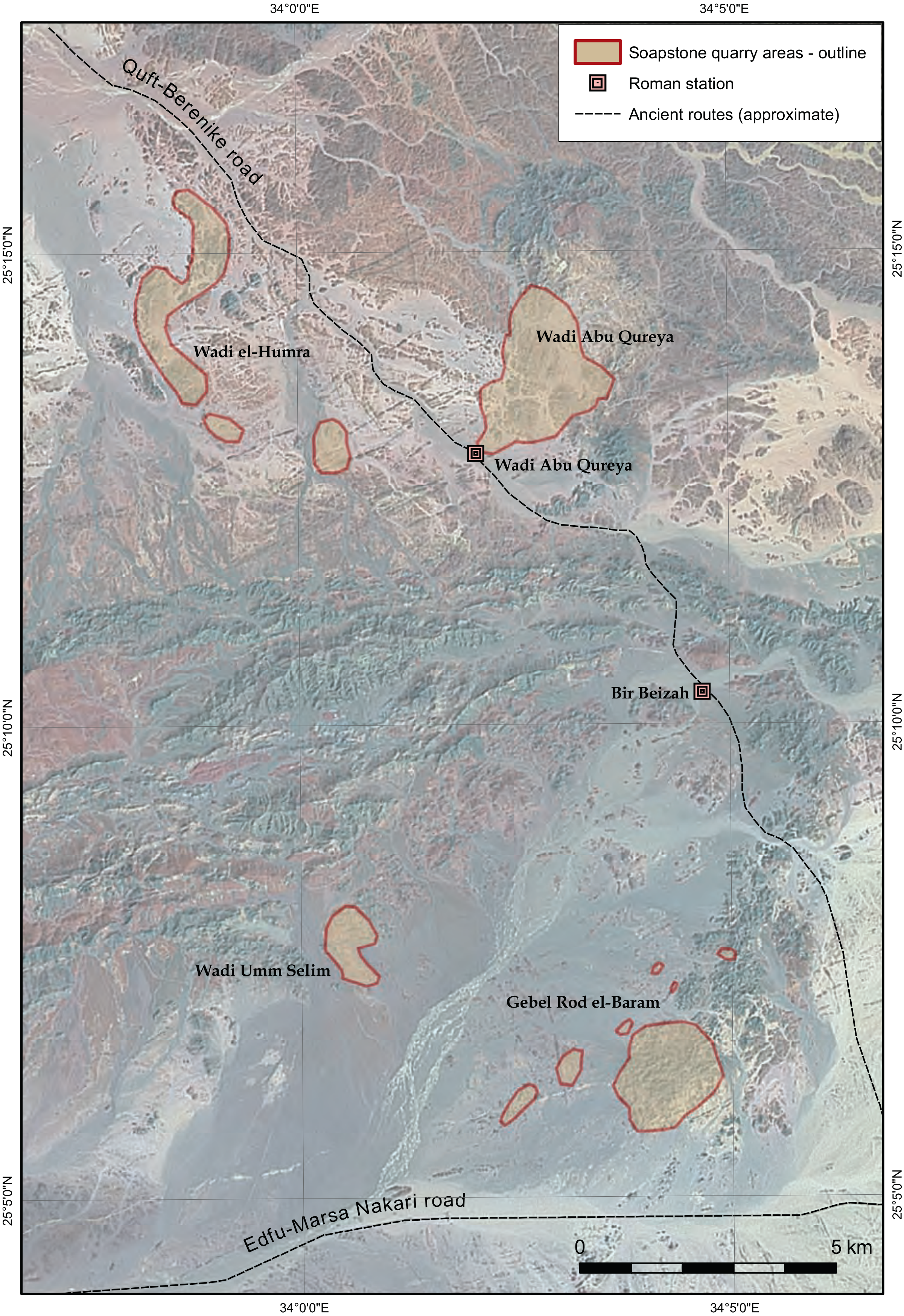

Figure 32. Map of the principal medieval to modern Islamic soapstone (steatite) quarries in the southern Eastern Desert, including Wadi Abu Qureya (O5, also late Roman?), Wadi el-Humra (O6), Wadi Umm Selim (07), and Gebel Rod el-Baram (O8, also late Roman). Map by Per Storemyr based on based on fieldwork by James Harrell (see Harrell and Brown 2008) with a Landsat satellite image (ca. 2000) used as background.

Figure 33. Soapstone (steatite) quarry workings. Top and bottom right: work place and abandoned roughed-out soapstone cooking vessels (Arabic 'barams') in the Wadi Abu Qureya quarries. Bottom left: some of the hundreds of small workings in the Gebel Rod el-Barram quarry (O8, late Roman and Islamic). Photos by Per Storemyr.

Figure 34. Quarry settlements and huts. Top: ephemeral Old Kingdom encampment in the Widan el-Faras basalt quarry (H2). Middle left: well-constructed Roman settlement in the Mons Claudianus tonalite gneiss quarry (H18). Bottom right: cistern at the Roman fort guarding the Wadi Umm Balad quartz diorite quarry (H15). Bottom left: either New Kingdom or Roman stone shelter in the silicified sandstone quarry on Gebel Sidi Osman by Gebel Tingar (H5). Photos by Per Storemyr.

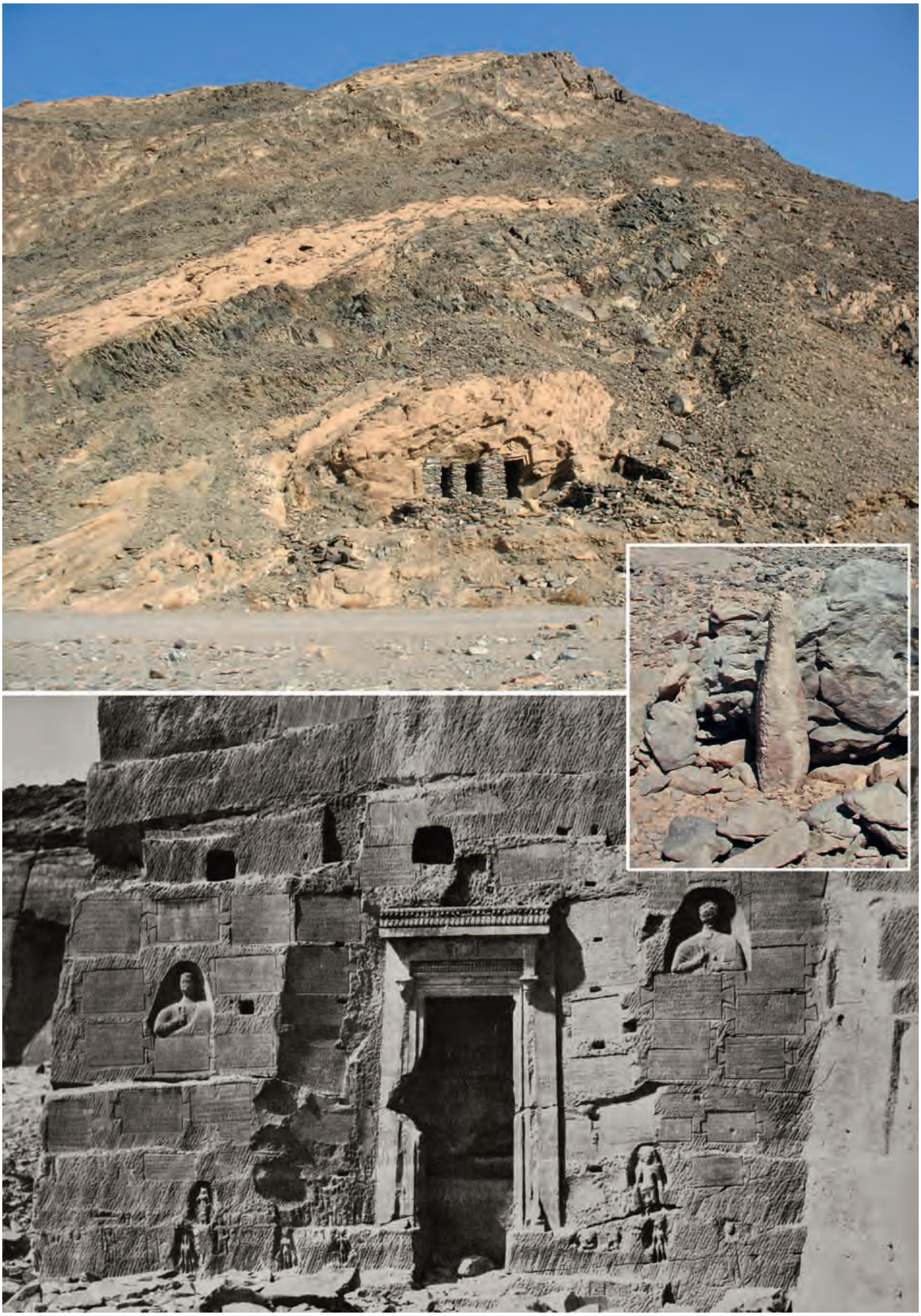

Figure 35. Quarry temples and shrines. Top: temple in the Wadi Sikait emerald quarry (G6, late Ptolemaic to Roman) cut into soapstone (talc schist). Bottom: Roman shrine in the Qertassi sandstone quarry (S20, Ptolemaic to Roman) now under Lake Nasser. Middle right insert: an upright stone that may have had a ritual function in the silicified sandstone quarry on Gebel Gulab (H5). Photos by Per Storemyr except the bottom one, which is from Félix Teynard (1850–1860, PPOC, digital ID: http://hdl.loc.gov/loc.pnp/cph.3c27965).

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Gypsum quarries in the northern Faiyum quarry landscape, Egypt: a geo-archaeological case study

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An ancient gypsum quarry is situated at Umm el-Sawan in the northern Faiyum desert, approximately 40 km southwest of the Giza Plateau. The gypsum was used largely in the Early Dynastic Period/ Old Kingdom for ornamental purposes such as small vessels, as well as for utilitarian purposes such as wall plaster. Geologically, the gypsum occurs within the upper part of the Eocene Qasr el-Sagha Formation, in which deposits and smaller extraction sites are found also elsewhere in the northern Faiyum area. Blocks of gypsum were moved from the quarry to a number of workshops where the shaping of the vessels took place. Within the quarry and in nearby areas the ground is scattered with several types of stone tools. These have a bipartite provenance, originating partly from a local to semilocal source in other parts of the Tertiary rock successions, and partly from Upper Egypt. In the latter case, the presence of such exotic rocks links the vessel production at Umm el-Sawan with similar production elsewhere from the same period (3rd–4th Dynasties). The previous interpretation of a 'hut-circle' area for the workmen was proven to represent a group of grinding stone quarries, bearing implications for the interpretation of the social organisation of the gypsum quarrying. The remains from gypsum quarrying and working, extraction of secondary stone resources for tools, and quarries targeting domestic utensils, collectively illustrate the interaction between man and the geological resources throughout the landscape, and illuminate the problem of delineating a small part of this landscape for preservation.

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Introduction

In ancient Egypt, gypsum was used for several purposes (Aston 1994, Aston et al. 2000). Alabaster (massive, finely crystalline gypsum) vessels of various shapes and sizes were produced from the Predynastic Period (prior to 3100 BC) to at least the 4th Dynasty (2613–2494 BC). In the New Kingdom, it was used for kohl jars, and in the Late Period for alabastra. Selenite (coarsely crystalline gypsum) was applied for making gypsum plaster from the Predynastic onwards.

The only known Dynastic gypsum quarries in Egypt are found in the northern Faiyum (Aston 1994, Aston et al. 2000) (Figures 1 and 2), with the Umm el-Sawan quarry as the most heavily exploited (Figure 3). They are situated approximately 20 km northeast of Lake Qarun and 40 km southwest of the Giza Plateau. The quarry was found and investigated in detail by Caton-Thompson and Gardner (1934). They identified quarry areas, workshops for making alabaster vessels, and settlements for the workers. Numerous rough-outs of vessels as well as chert tools for making them were documented, but unfortunately were removed from the site.

The present paper builds on a QuarryScapes survey carried out in March 2006, the objectives of which were to put the archaeological infrastructure on the map, make fresh observations and interpretations, and provide the geological background to the gypsum quarrying. The mapping was carried out using a Quickbird satellite image combined with GPS.

Geology

The geology of the northern Faiyum desert comprises a series of Eocene to Oligocene sedimentary rocks overlain by Oligocene basalt (Widan el-Faras basalt) and Miocene sediments (Figure 2, Table 1). The gypsum deposits described below are situated in the upper part of

Figure 1. Location of the northern Faiyum area in Egypt (extent of Figure 2 indicated by red rectangle).

the Late Eocene Qasr el-Sagha Formation (Figure 4). This formation, and the overlying Early Oligocene Gebel Qatrani Formation, has been studied in detail by many authors (see Bown and Kraus 1988 and references therein). The Qasr el-Sagha Formation comprises a series of essentially nearshore marine and fluvial deposits. According to Bown and Kraus (1988) the upper part of the formation, the Deir Abu Lifa Member, consists of "*77 meters of nearshore marine sandstones*

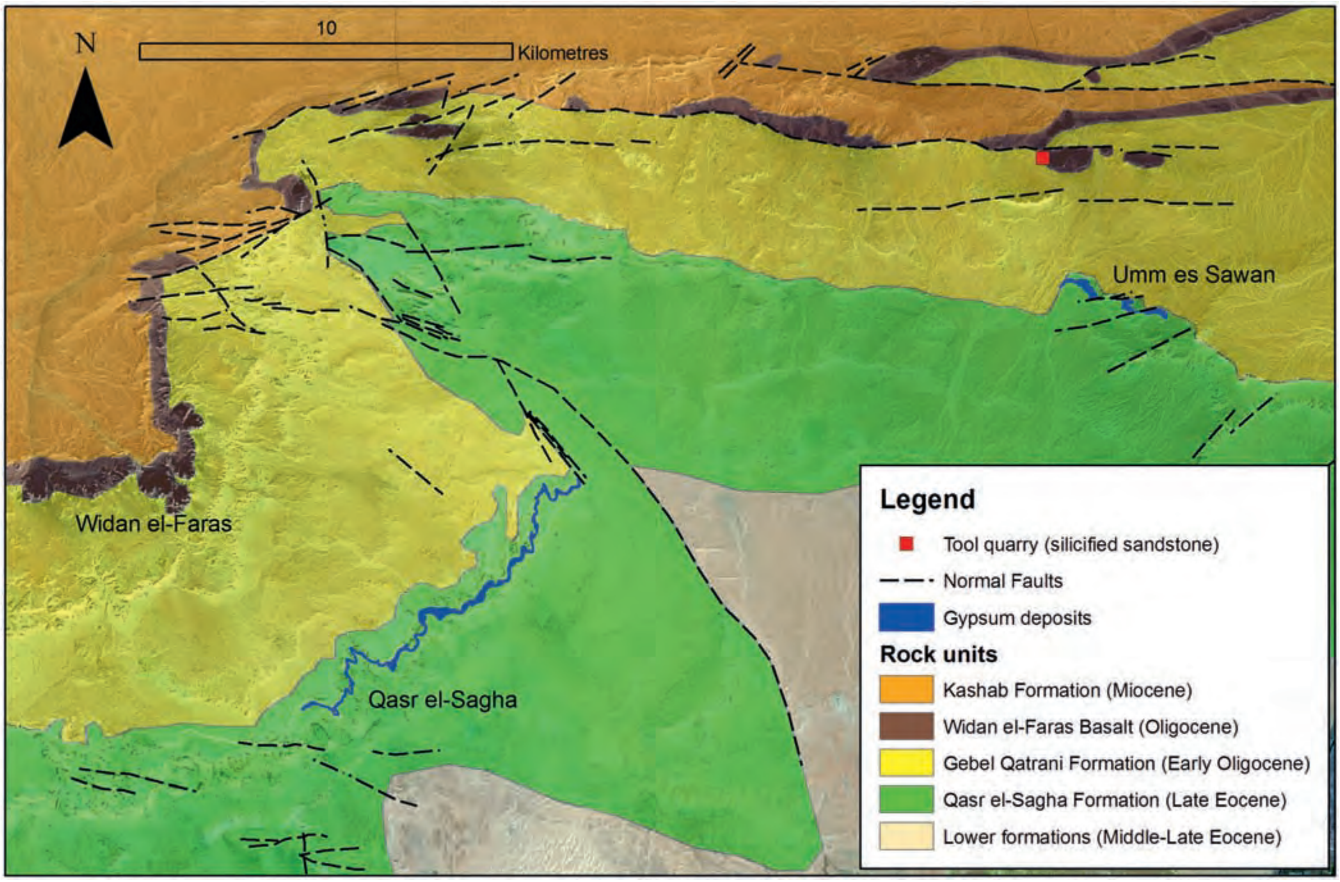

Figure 2. Geology of the northern Faiyum area. Background based on Landsat satellite imagery.

Table 1. Tertiary stratigraphic sequence in the Fayum area.

MIOCENE		Kashab Formation	>100 m
OLIGOCENE	Late	Widan el-Faras basalt (24–27 Ma)	0–10 m
	Early	Widan el-Faras basalt (31 Ma)	0–15 m
		Gebel Qatrani Formation	340 m
EOCENE	Late	Qasr el-Sagha Formation (Deir Abu Lifa Member)	77 m
		Qasr el-Sagha Formation (Temple Member)	123 m
		Birket Qarun Formation	50 m
	Middle	Gehannam Formation	70 m
		Wadi Rayan Formation	130 m

From Bown and Kraus (1988), based on the work of Beadnell (1905), Said (1962), Vondra (1974), Bowen and Vondra (1974) and Bown (1982).

and alluvial lateral accretion channel deposits that record sporadic but gradual Late Eocene regression of the Tethys Sea". Sandstone with gypsum is found in the upper part of the member. On top of the Qasr el-Sagha Formation follows the dominantly fluvial Gebel Qatrani Formation. The boundary between the two is described by Bown and Kraus (1988) as a "*conformable to minor erosional unconformity*". The Gebel Qatrani Formation contains several levels with petrified forests, and clusters of logs of fossil wood can be viewed at several localities.

Although there are some geological differences between the western (i.e., Qasr el-Sagha) and the eastern (Umm el-Sawan) parts of the area, the rock strata can be correlated. However, the characteristic upper part of the Deir Abu Lifa Member (the 'bare limestone' of Beadnell 1905 and the 'upper cross-bedded sandstone and mudstone' of Bown and Kraus 1988), as defined near Qasr el-Sagha, seems to be lacking at Umm el-Sawan. Furthermore, the upper boundary of the Gebel Qatrani Formation at Umm el-Sawan is clearly an erosional unconformity, displaying palaeosol development (Figure 5) and strong palaeotopography. Logs of petrified wood (Figures 6 and 7) and fluvial channels with silicified conglomerate are found on top of the un-

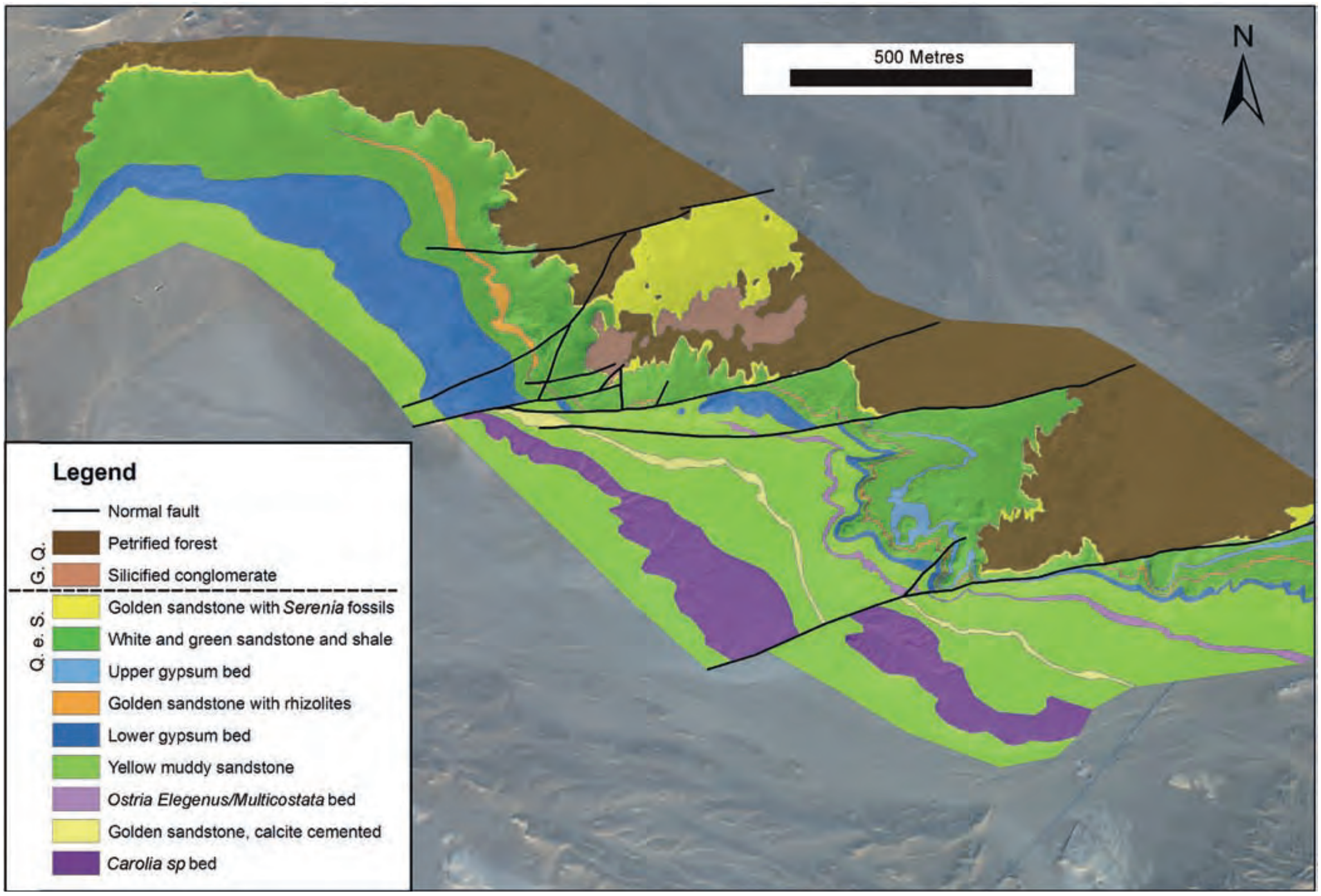

Figure 3. Geological map of the Umm el-Sawan area. Q. e. S.=Qasr el-Sagha Formation, G. Q. = Gebel Qatrani Formation. Background based on Quickbird satellite imagery.

conformity surface. In the Qasr el-Sagha area, such features are found higher up in the formation (Bown and Kraus 1988).

The Qasr el-Sagha Formation is mapped in detail at Umm el-Sawan (Figures 3 and 4). The lower part of the strata in the outcrop area is composed of yellowish muddy sandstone with two distinct fossiliferous beds, one with *Carolia sp.* (Figure 8) and the other with *Ostria Elegenus-Multicostata*, and a distinctive, calcite-cemented golden sandstone. In the middle part of the succession, two gypsum beds (in the following referred to as the upper and lower, respectively) occur and these are separated by greenish and golden rhizolitic sandstones (Figure 9). Above the upper gypsum bed is a white to greenish sandstone, partially displaying tabular cross stratification with thin ferruginous layers (Figure 10). The uppermost part of the formation is defined by a distinct bed of gypsiferous golden sandstone containing *Serenia* (manatee) bones. Because the lower boundary of this sandstone bed defines an angular unconformity with the substrata (Figure 11), it should be recognised as a separate member.

The Qasr el-Sagha Formation thins towards the northwest, against the unconformity developed on the base of the Gebel Qatrani Formation. On the irregular surface of the unconformity, calcrete (Figure 5), channels of silicified conglomerates, and logs of fossil wood are found. It seems likely that the disappearance of the upper part of the Qasr el-Sagha Formation (including the gypsum layers) between Umm el-Sawan and the Qasr el-Sagha areas (see Figure 2) is caused by erosion prior to deposition of the Gebel Qatrani Formation. Thus, there seems to be a pattern of uplift and erosion characterising the upper part of the Qasr el-Sagha Formation. There are numerous normal faults in the area (Figures 2–3, 12) (predominantly related to Oligocene faulting, Bown and Kraus 1988), disrupting the continuity of the layers, and causing local rotation of the beds.

The lower gypsum bed is by far the richest and thus most heavily exploited both at Umm el-Sawan and near Qasr el-Sagha (Figure 13). The upper bed is thin or completely absent and only minor extractions are seen. Within the gypsum beds there are two types (or generations) of gypsum: veins of impure gypsum (alabaster with minor calcite and barite) cutting across the strata, and sheets of coarsely crystalline gypsum (selenite) parallel to the strata (Figure 13a). The alabaster gypsum veins are generally steeply inclined and measure up to 50 cm in thickness, and from above their distribution resembles a honeycomb pattern (Figure 6). The veins seem to have been the most important target for the production of vessels. The selenite gypsum can only be collected in thin flakes that are too small for vessels; however, piles of such gypsum suggest that it was collected for use, possibly for gypsum mortar.

Gypsum quarries and workshops

The gypsum workings are predominantly shallow, and in several places it is difficult to separate them from natural depressions in the desert surface (Figure 13b, see also map in Figure 14). Because the quarrying targeted mainly the randomly distributed veins, there are no clear quarry walls but instead irregular pits and trenches (Figure 13c) of varying size scattered across the outcrops of the main gypsum deposits. Hence, despite the workings giving the impression of a haphazard distribution, it seems clear that all the gypsum deposits in the area were subjected to systematic prospecting and trial quarrying in order to locate the best quality rock. In fact, traces of small-scale quarrying and/or trial quarrying are seen in most places where there are outcrops of gypsum, including the Qasr el-Sagha area (Figure 13d).

Within the quarry, as well as in nearby areas, the ground is scattered with several types of stone tools (Figure 15), including stone hammers (pounders) of different sizes and types. Most frequently observed are rounded cobbles of chert. These are not found in natural occurrences in the quarry area, and are assumed to have been brought to the place either from bedrock deposits in more distant parts of the Gebel Qatrani Formation or (more likely) from concentrated alluvial deposits of chert cobbles that exist in the eastern part of Fayium (the Faiyum–Nile divide, Sandford and Arkell 1929).

Other stone hammers from local and semilocal sources include the silicified conglomerate described above, basalt (nearest source is approximately 4 km to the north), and a characteristic silicified sandstone believed to come from a small quarry discovered during the survey 3.5 km to the northwest (see below). Rod-shaped pieces of silicified wood are abundant in the gypsum quarries, and collection places as well as small quarries of silicified wood are found in the vicinity (Figure 16). Thus, silicified wood seems to have been used in the quarrying, probably as chisels and wedges.

Blocks of gypsum were moved from the quarry to a number of workshops (Figure 17), where the shaping of the vessels took place. These comprise three mounds designated A, B and C (see Figure 14) by Caton-Thompson and Gardner (1934), who excavated them in the mid

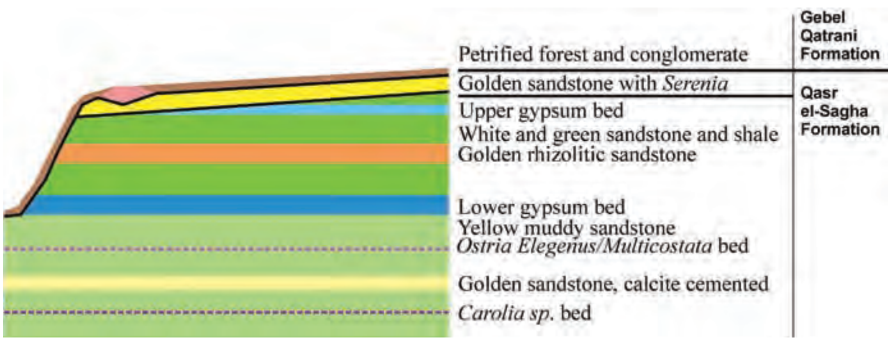

Figure 4. Stratigraphy of rock units in the Umm el-Sawan area. See legend in Figure 3 for colour coding of units.

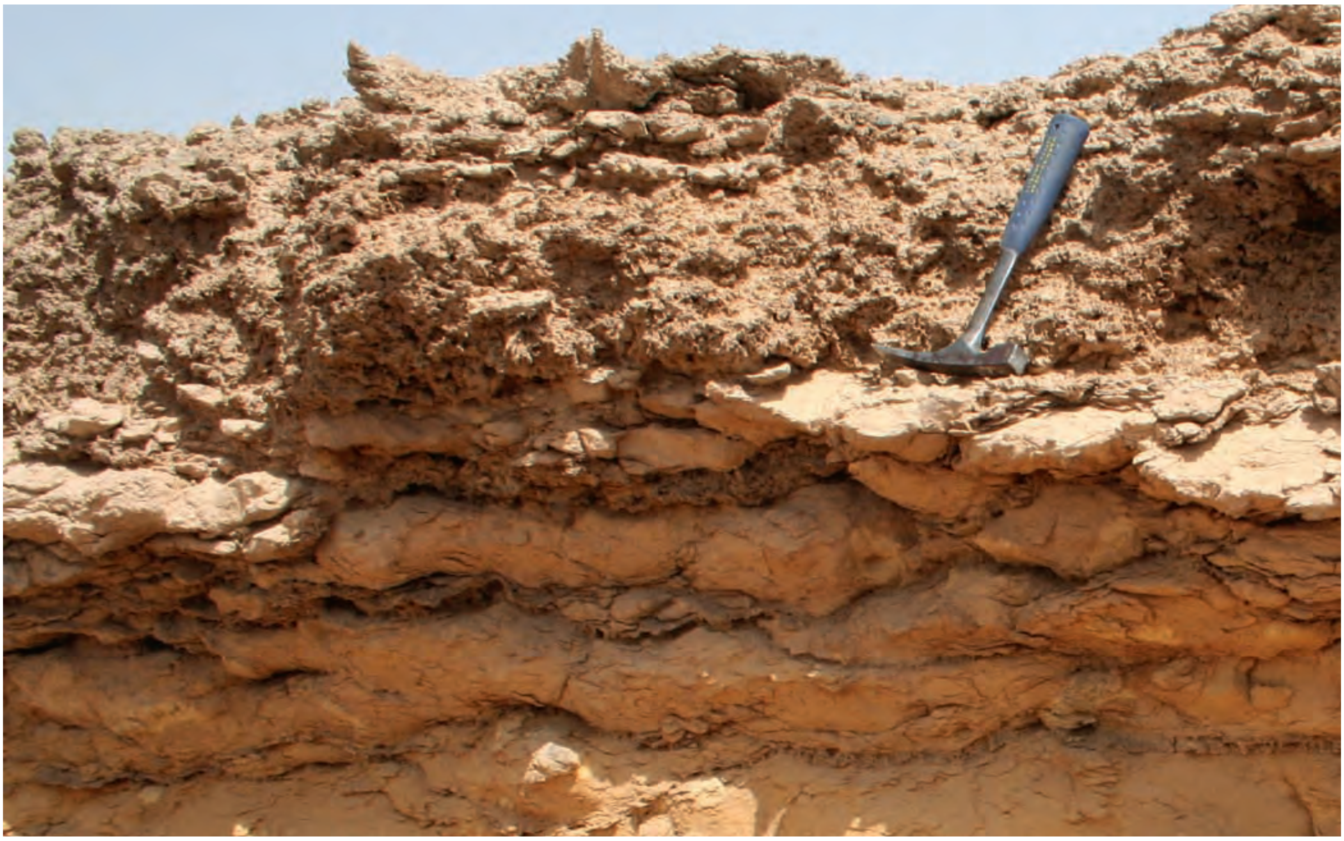

Figure 5. Palaeosol development at the base of the Gebel Qatrani Formation.

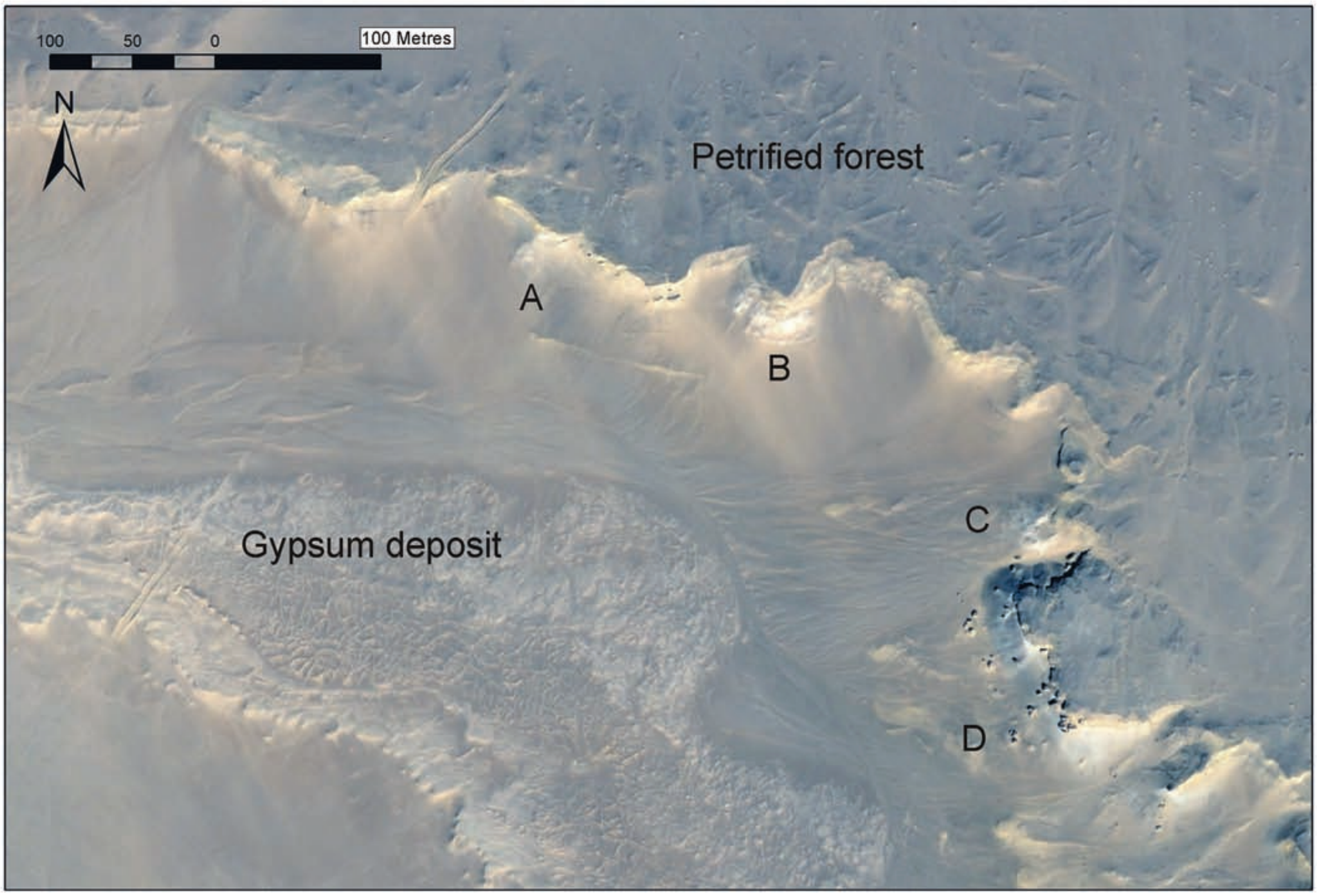

Figure 6. Gypsum deposits/quarries (lower left), petrified forest (randomly oriented logs at top right) and gypsum workshops (white areas along the escarpment, labelled A, B, C and D) as seen on Quickbird satellite image.

Figure 7. Log of petrified wood on the desert surface with smaller pieces in the inset at lower right.

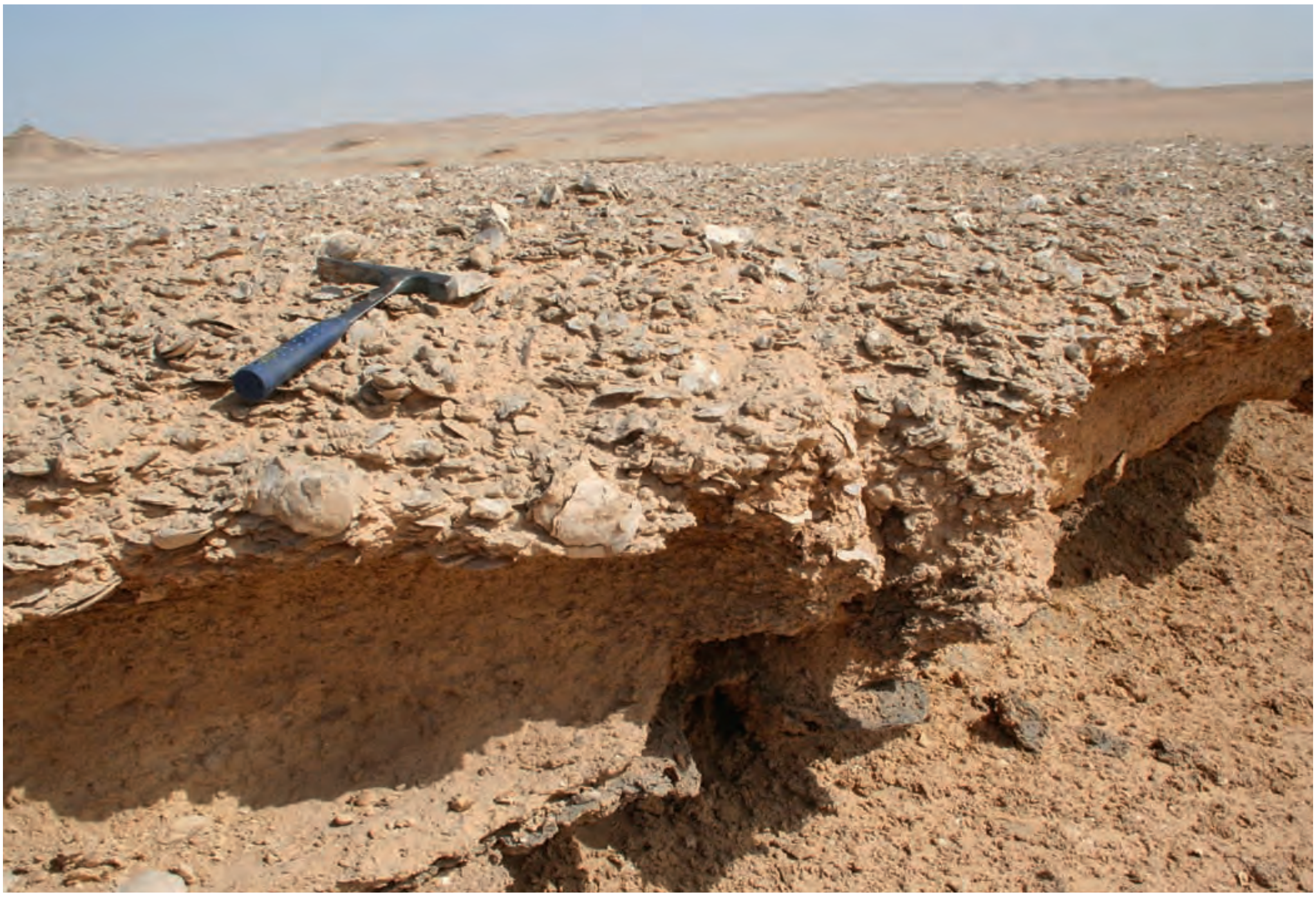

Figure 8. Carolia sp. *bed at Umm el-Sawan.*

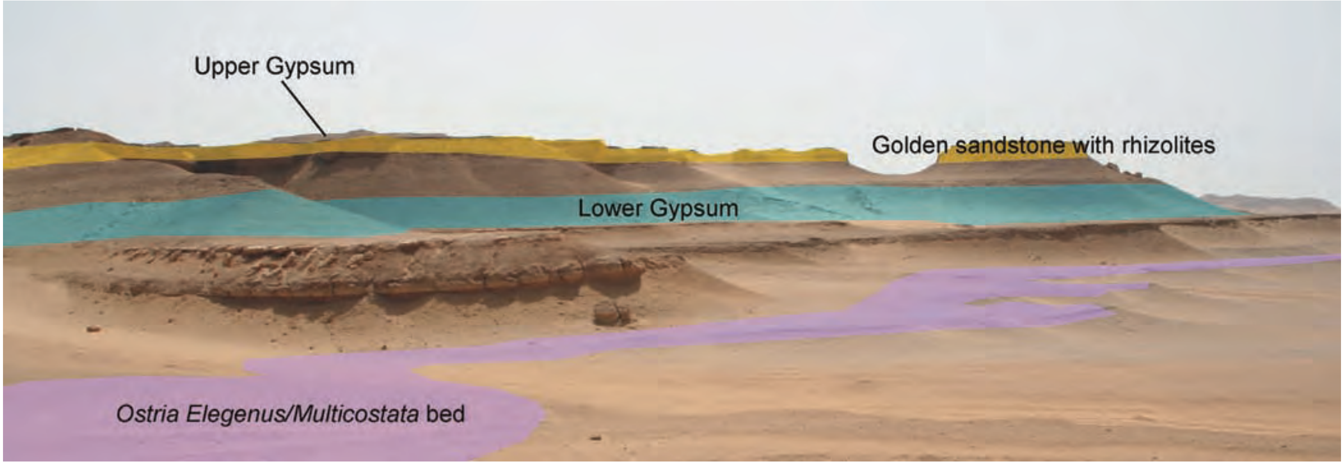

Figure 9. The middle part of the succession at Umm el-Sawan. Drawing on field photo.

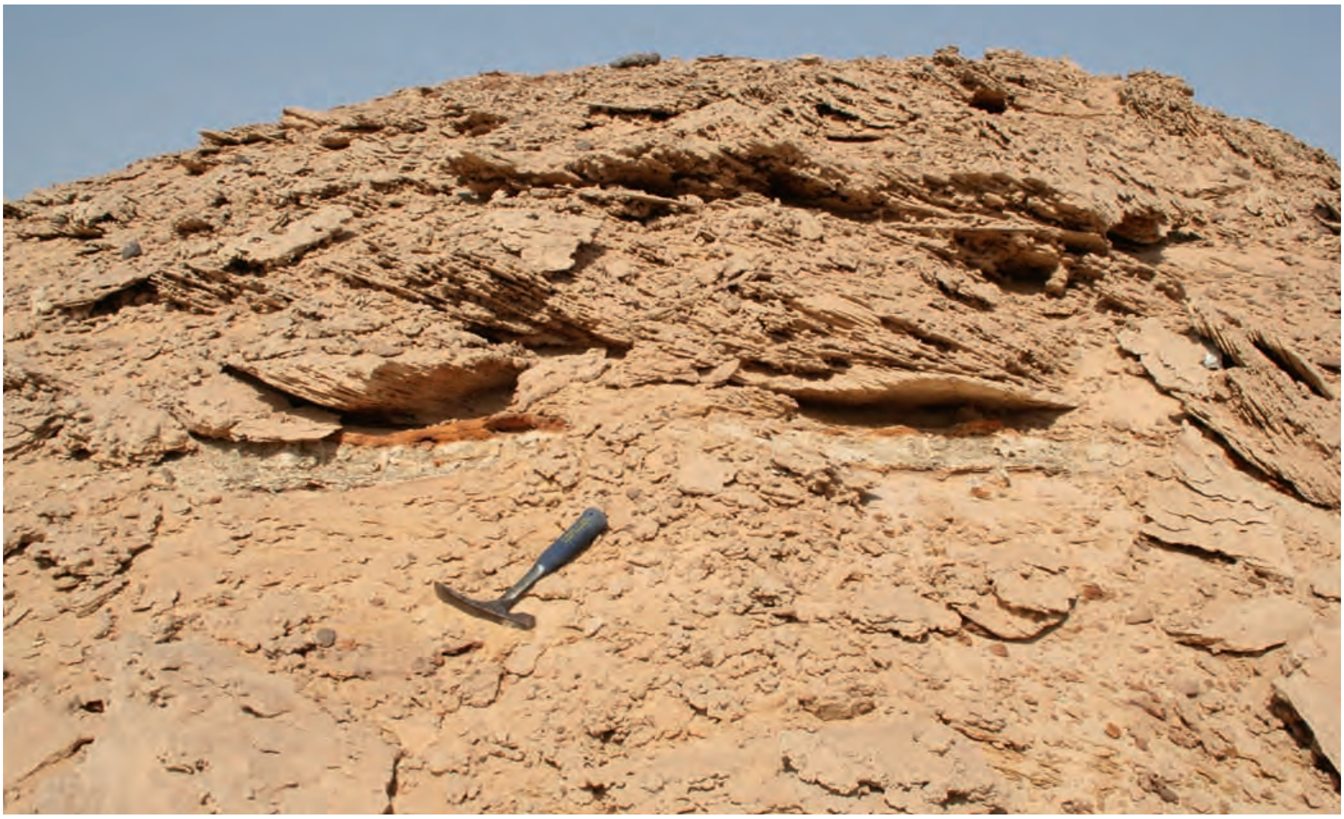

Figure 10. Cross-stratified sandstone and shale layers in the upper part of the Qasr el-Sagha Formation.

Figure 11. Unconformity between the golden sandstone with Serenia *(above dotted line) and the underlying strata.*

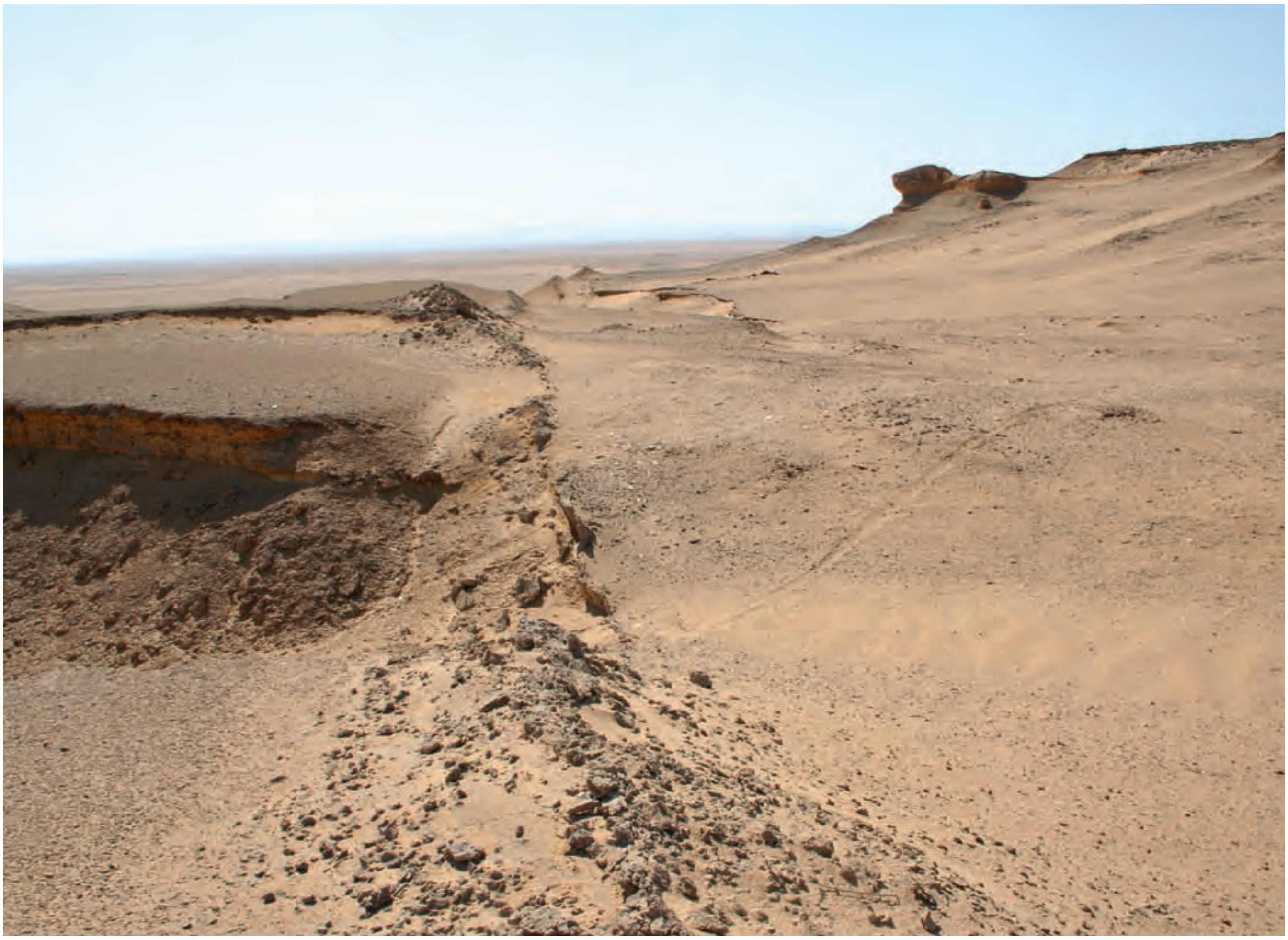

Figure 12. Normal fault showing down-throw towards north (right-hand side of the photo).

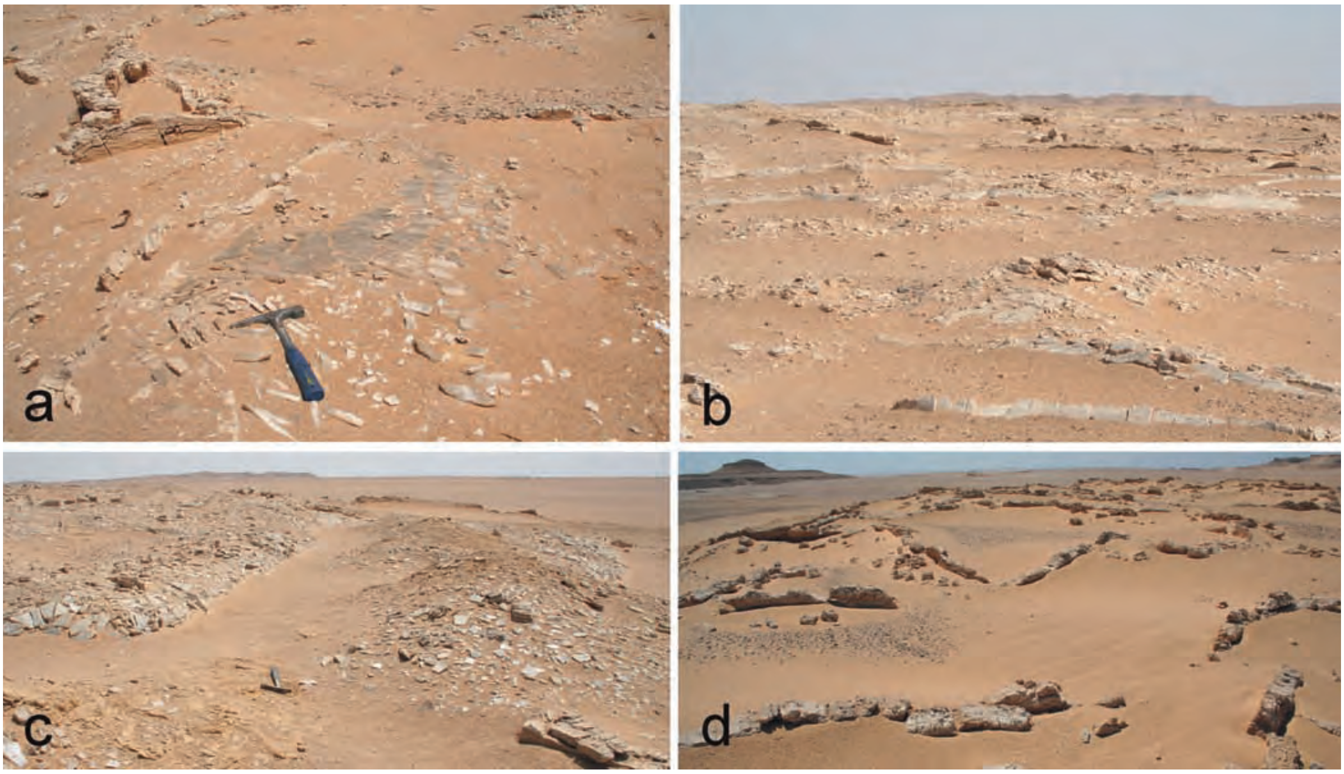

Figure 13. (a) Gypsum outcrop displaying selenite layers (greyish, just behind the hammer) and thick veins of milky-white alabaster. (b) Shallow gypsum quarry with scattered small extraction pits. (c) Trench quarry in gypsum deposit with a spoil heap to the right. (d) Gypsum deposit with small extraction pits near Qasr el-Sagha.

1920s, and a smaller mound (D). The mounds consist of a matrix of gypsum debris produced by working the stone into circular, cylindrical vessel blanks. Two smaller mounds, also documented but not excavated by Caton-Thompson and Gardner, were the subject of closer examination during the March 2006 survey. These mounds generally consist of chert cobbles, some shaped into picks, gypsum debris, fragments of non-local stones, fossilised wood chips and pottery (Figure 17).

In addition to using cobbles as natural hammers, chert cobbles have also been worked into finer tools for cutting and carving gypsum, such as crescent drills (Caton-Thompson and Gardner 1934). Several such chert chipping floors (Figure 17d) are found in the area, close to some of the workshops. The occurrence of such chipping floors, together with all the chert tools scattered across the quarries and workshops, was probably the reason for the name Umm el-Sawan. 'Haggar sawan' means chert in Arabic, and so Umm el-Sawan means the 'mother of chert'.

The tools and many of the vessel blanks were removed by Caton-Thompson and Gardener when the major quarries were excavated in the mid 1920s, but similar chert tools fitting their description have been found by the present authors near Qasr el-Sagha (Figure 17e). In some of the quarries there are stockpiles of alabaster gypsum (Figure 17f), which may relate to later periods of quarrying (see below).

Workmen's camp, or not?

Near the workshops along the escarpment at Umm el-Sawan are several natural shelters, some of which were clearly used as temporary settlements for the quarrymen (Caton-Thompson and Gardner 1934) (Figure 18). Caton-Thompson and Gardner also recorded approximately 250 'hut circles' located on top of a plateau, 700 m southeast of the main gypsum quarry, which they interpreted as representing an area of settlement for the gypsum-quarry workers (Figure 19). This area of 'hut circles' was surveyed in 2006 and can be more accurately visualised as a series of shallow, sand-filled depressions surrounded by mounds of worked stone (Figure 20). The stone is a silicified conglomerate of fluvial origin that occurs at the base of the Gebel Qatrani Formation. Within the spoil mounds, it was possible to identify fragments of grinding stones and bases, diagnostically similar to those found at the Gebel Gulab silicified sandstone quarries on the West Bank at Aswan (Heldal et al. 2005). Planning and spot clearing was undertaken at one of the sand-filled depressions and this work confirmed that the area was not a hut but rather a quarry pit, mainly for the production of grinding stones. This observation clearly changes the previously held view (Caton-Thompson and Gardner 1934, p. 120) that a large labour force, as many as several hundreds, dwelt here. Caton-Thompson and Gardner (1934, v. 1, p. 121–122) also reported finding exotic pieces of 'diorite' (i.e., the Chephren gneiss) and ash/charcoal layers in the excavated 'hut circles'. This may well relate to quarrying; the 'diorite' pieces being tool fragments, and the charcoal remains

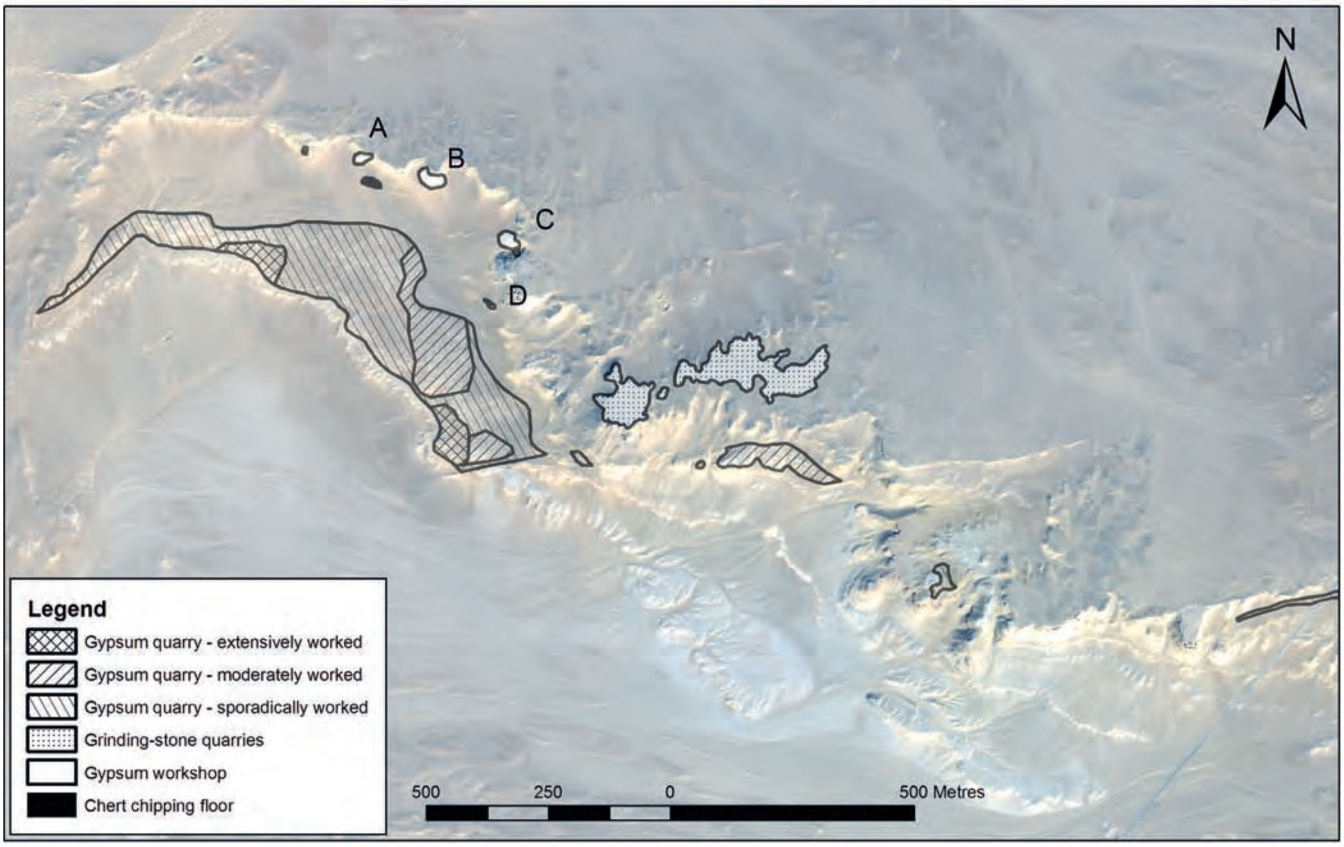

Figure 14. Archaeological features recorded at Umm el-Sawan. Background based on Quickbird satellite imagery.

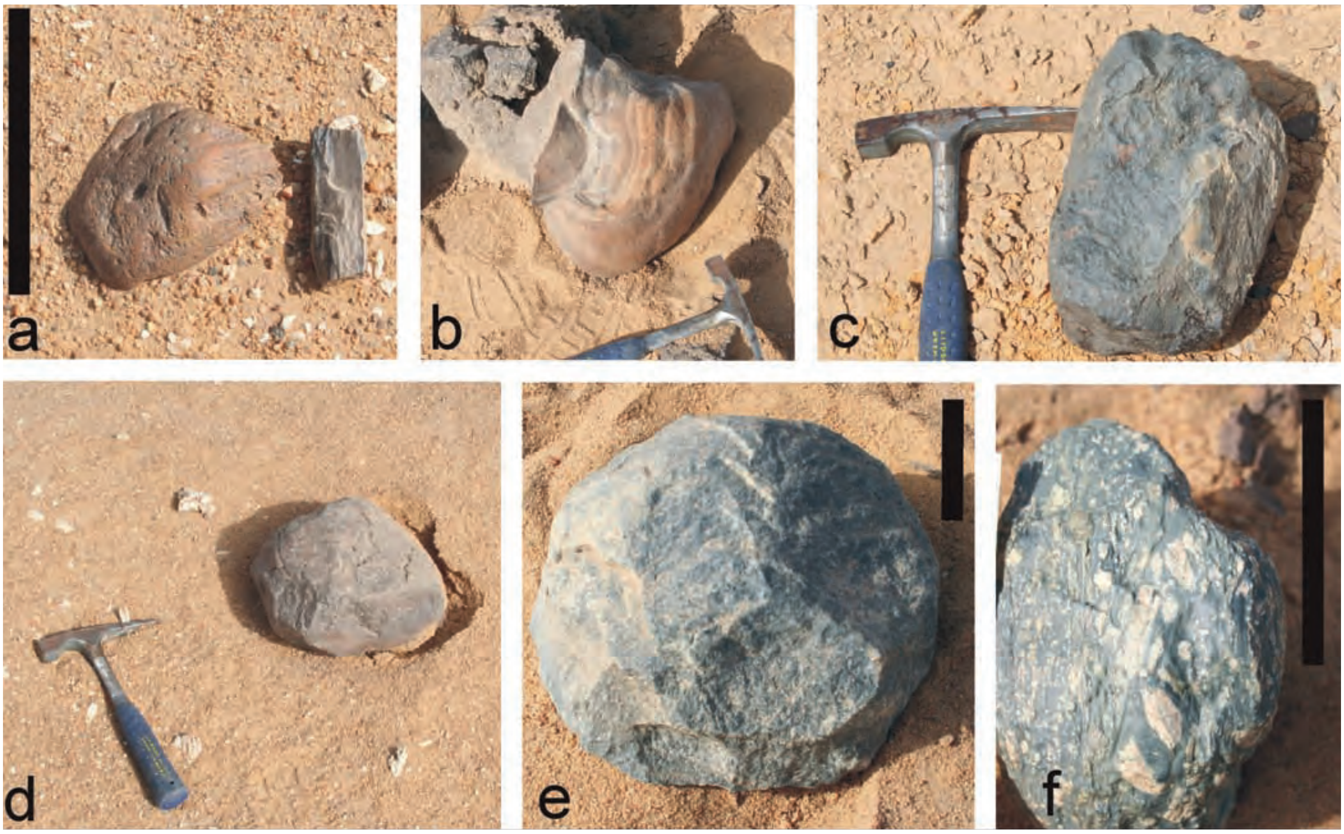

Figure 15. Variety of stone tools: (a) hammer of chert cobble and chisel of petrified wood (black line=10 cm); (b) broken pounder made from silicified sandstone (see Figure 22); (c) basalt pounder; (d) pounder of silicified conglomerate; (e) vessel blank(?) made from Chephren gneiss, brought from Lower Nubia (black line=10 cm); and (f) pounder of mylonitic granitoid, probably from the Aswan area (black line=10 cm).

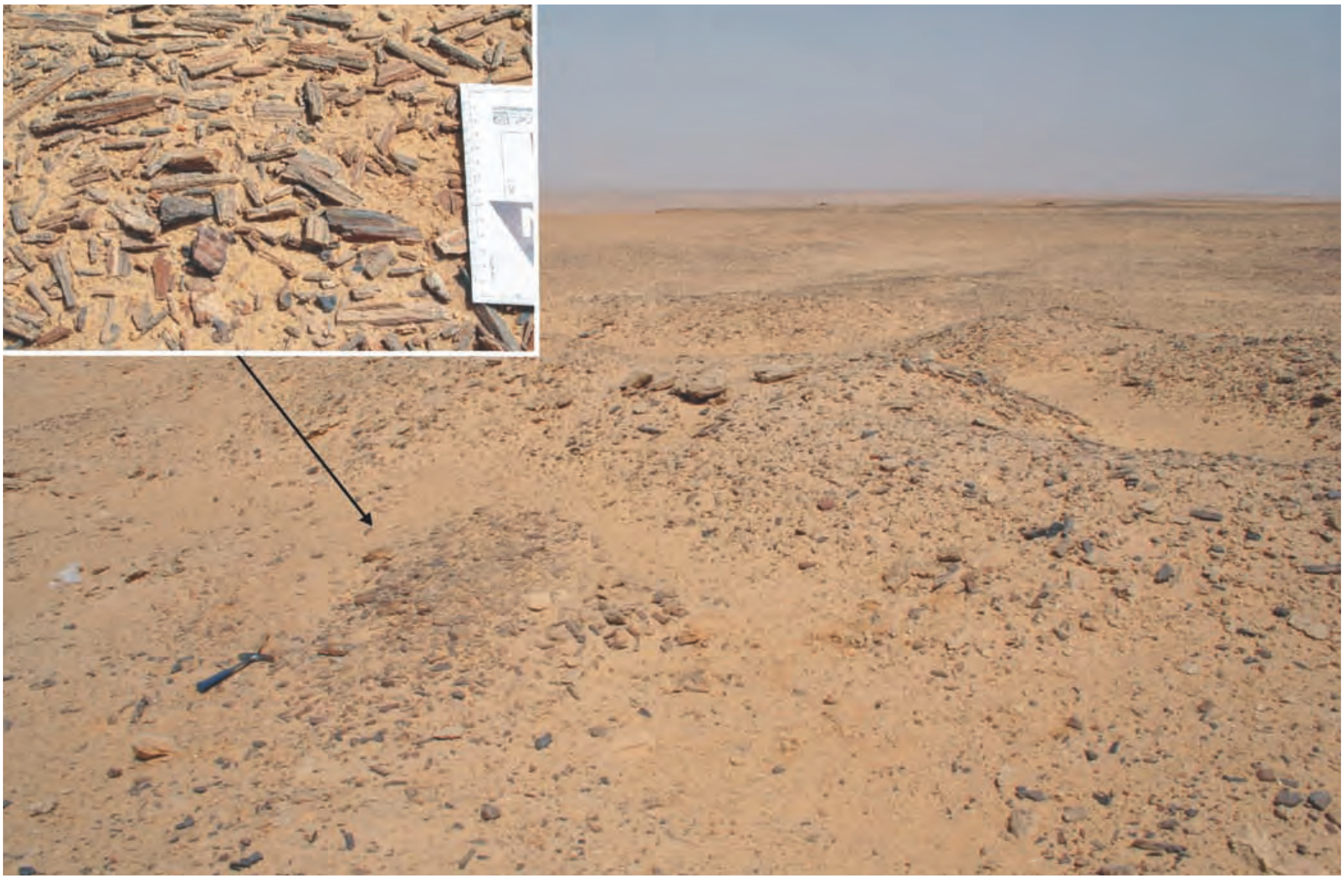

Figure 16. Small quarry for petrified wood with the small pieces shown in the inset (at upper left) probably designated for quarry tools.

Figure 17. (a) One of the main workshop mounds (workshop C), containing debris from gypsum production, tool fragments and pottery. (b) Remaining blanks from gypsum vessel production, workshop C. (c) Consolidated debris from one of the workshops (B) with gypsum fragments and chert flakes from working the gypsum. (d) Chert chipping floor. (e) Chert flakes and crescent drills found near Qasr el-Sagha in a small gypsum quarry. (f) Stockpile of alabaster blocks possibly dating to the Graeco–Roman Period.

from the use of fire during quarrying, as reported from other areas with grinding stone quarries (Heldal and Storemyr 2007, p. 93–94). Moreover, this finding adds significantly to a growing body of data from other Old Kingdom quarries, which suggests that quarry labour forces consisted of relatively small groups of specialists, probably less than one hundred (Bloxam 2003, Bloxam and Heldal 2007).

The slopes leading up to the plateau with grinding stone quarries are covered with extensive scree or waste from the working of silicified conglomerate. Some working platforms could be seen on these slopes as well as footpaths and a shallow, oval paved feature of unknown purpose. Several varieties of stone of exotic origin were found on the waste slopes, most significantly small blocks, pounders, a large vessel blank of Chephren gneiss (from Chephren's quarry near Abu Simbel), black granodiorite and mylonitic granitoid (probably from the Aswan region), and other stones that have a possible source in the Eastern Desert. Local material was also found and included fossilised wood, a few cobbles of chert/flint (source yet unknown), and another type of silicified sandstone, the source of which was found during the survey (see below). The exotic rocks in the quarry area could

Figure 18. Natural shelters that served as temporary habitation areas for the quarry work force, beneath the Golden sandstone with Serenia *fossils at the top of the Qasr el-Sagha Formation.*

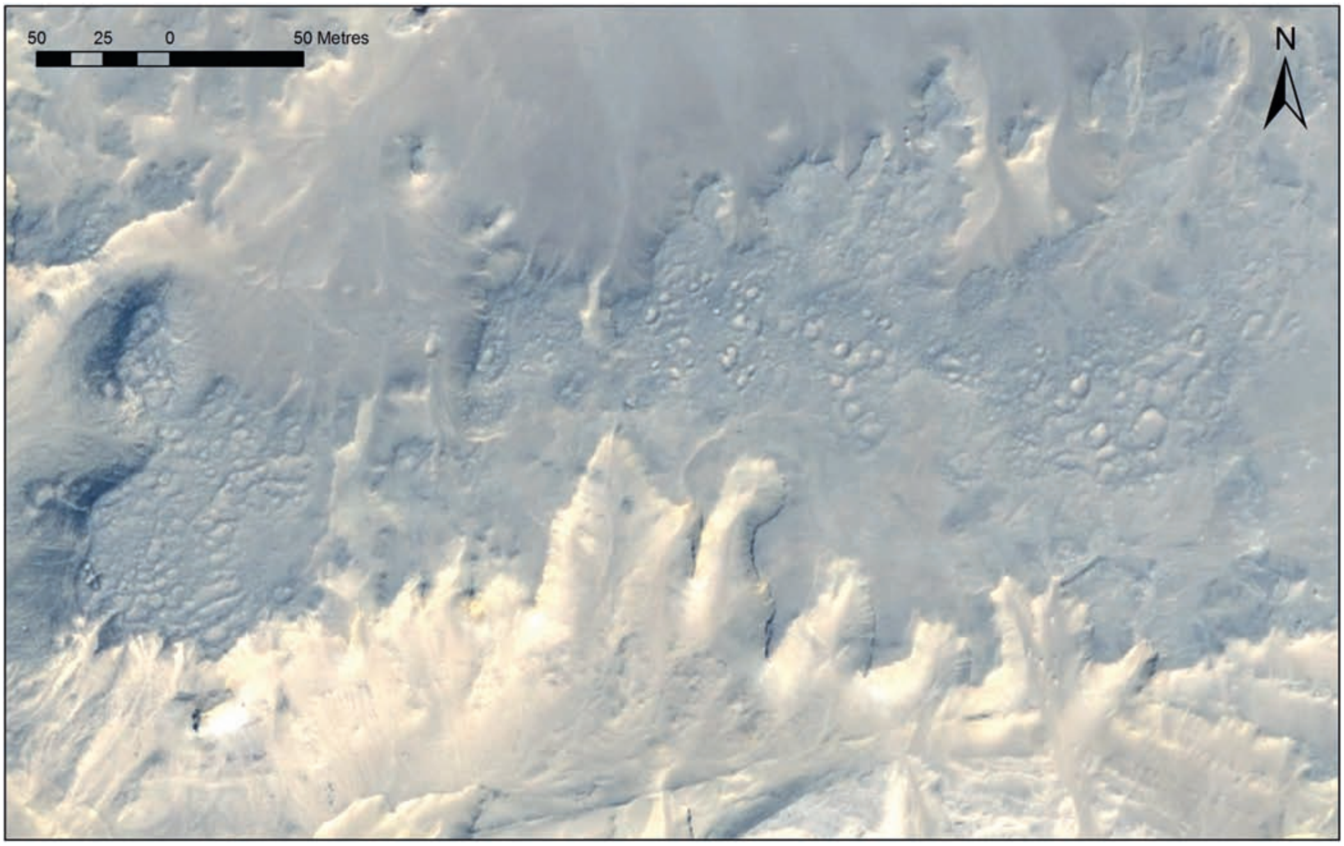

Figure 19. Caton-Thompson and Gardener's 'hut circles'. The area with 'crater-like' structures in the middle part of the photo turned out to be grinding stone quarries. Background based on Quickbird satellite imagery.

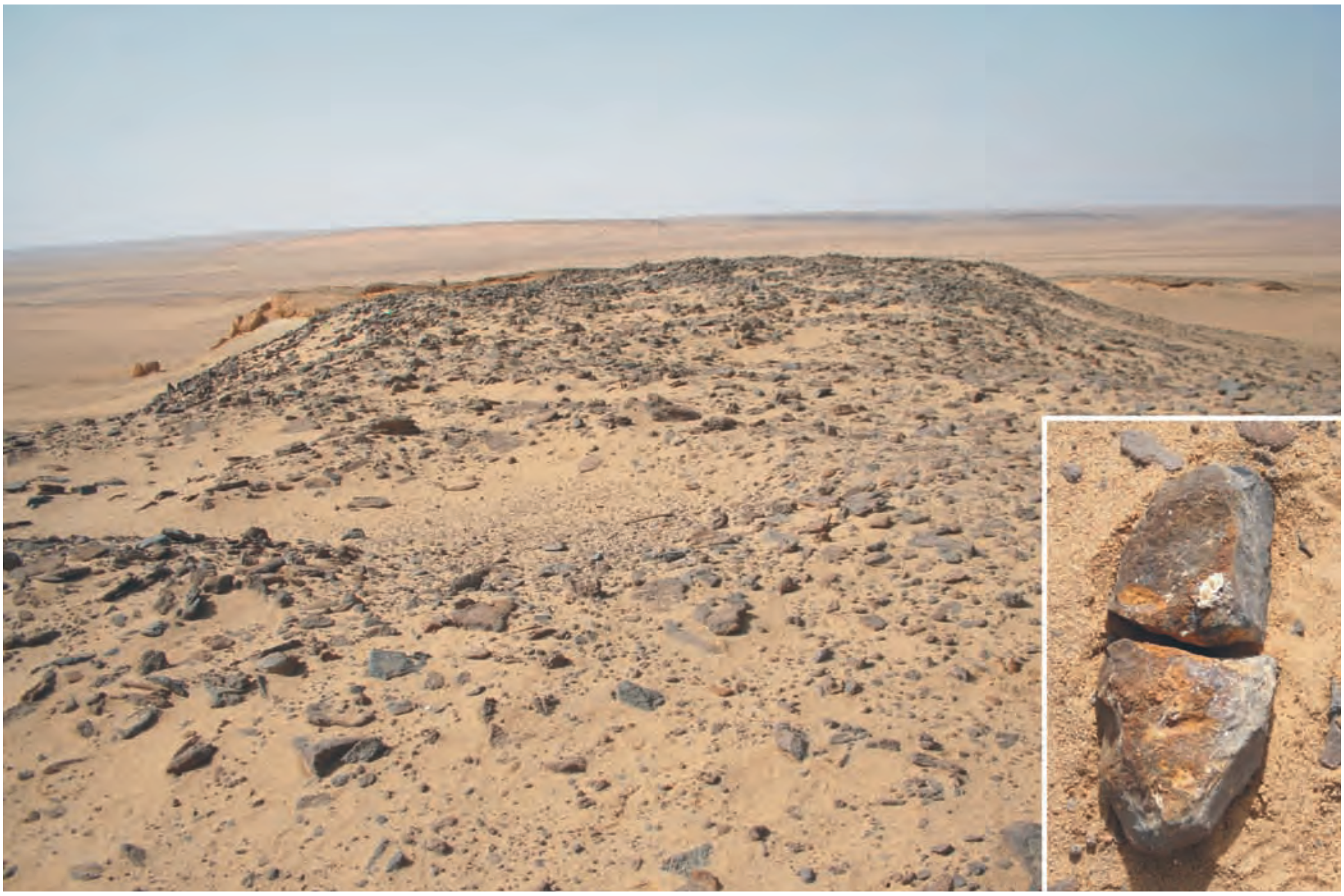

Figure 20. Shallow grinding stone quarries with a grinding stone blank shown in the inset at lower right. The quarries are pseudocircular, with a central, sand-filled extraction area surrounded by a ring of debris from the production.

either have been brought to the site as tools (as in the case of the Widan el-Faras basalt quarry, Harrell and Bown 1995, Harrell 2002) and/or as blanks of vessels or other objects. In either case, it is likely that they were connected to the gypsum quarrying and then reused for grinding-stone production. Pottery was limited to a few scattered fragments, and although the pottery report is not finalised, spot identification suggests the majority to be of Old Kingdom date and to a lesser extent from the Roman Period.

A peculiar tool quarry

Pounders of a particular variety of silicified sandstone are found in both the gypsum and the grinding stone quarries at Umm el-Sawan and in gypsum workings near Qasr el-Sagha. The sandstone pounders display a peculiar concentric pattern reminiscent of onion shells (Figure 17b). During the 2006 survey season, the source of this sandstone was located approximately 3.5 km north of Umm el-Sawan (Figure 2). The deposit consists of a 50 m-long hill composed of hard, silicified sandstone (Figure 21) displaying the same concentric pattern as the pounders (Figure 22). The pattern is most likely caused by the migration of fluids responsible for the silicification. As the sandstone hill occurs as an 'island' in the lower basalt flow, it is likely that the fluids originated beneath the hot lava and 'escaped' through the sandstone hill, creating a particularly hard rock suitable for stone tools. Collection and simple shaping of pounder-sized pieces was carried out at numerous small quarries and work areas exploiting the blocky sandstone outcrops around the hill.

Dating the gypsum quarrying

Pottery found at the site confirms the observation made by Caton-Thompson and Gardener (1934), indicating a strong presence during the Old Kingdom (especially 3rd to early 4th Dynasties) (El-Senussi 2006). This group of pottery dominates in most of the quarry area, as well as in the vessel workshops, suggesting peak vessel production occurred during the early to middle Old Kingdom (Figure 23). However, Aston (1994) argues for a 1st to 4th Dynasty date for Umm el-Sawan based on the use of the gypsum vessels. The fact that there is no 1st or 2nd Dynasty pottery does not mean there was no activity here at these times! Another group of pottery is from the Graeco–Roman Period. The latter fits observations of the stockpiles of gypsum blocks in some of the workings, which seem to have been collected for transport to places other than the nearby workshops (Figure 17f). One piece of white marble, most likely from mount Pentelikon, Greece, was found in one of the workshop mounds. As this rock was not introduced into Egypt before the Graeco–Roman Period, it also supports a later date. Small amounts of pottery associated with the grinding stone quarries,

Figure 21. Hill with silicified sandstone and small quarries along the perimeter (stone piles).

suggest the same chronology of activity; a peak in the Old Kingdom and renewed small-scale activity in the Roman Period.

Discussion

Revisiting the Umm el-Sawan gypsum quarry has added new information about the site that requires revision of Caton-Thompson and Gardner's (1934) earlier interpretations. Firstly, their so called 'hut circles' are in fact an area with numerous shallow grinding stone quarries. This has major implications for interpretations of social organisation of the quarrying, because our reinterpretation rejects Caton-Thompson and Gardner's evidence for a large labour force. The pottery evidence suggests that grinding stone quarrying was simultaneous with—and may have been related to—gypsum quarrying in the Old Kingdom Period. Furthermore, a reinterpretation of quarrying techniques highlights the likely use of stone hammers and silicified wood to extract the gypsum. Of particular interest is the presence of rocks from Upper Egypt, linking the site with Chephren's quarry, as previously suggested by Bloxam (2003) and Bloxam and Heldal (2007, p. 317). There is also a clear connection with the Widan el-Faras basalt quarries further to the west with respect to pottery (Bloxam and Storemyr 2002, El-Senussi 2006, Bloxam and Heldal 2007, p. 315–317). This link is supported by the geographical distribution of quarries, since the same gypsum beds are found close to the Qasr el-Sagha Temple and the ancient basalt quarry road, and several small gypsum workings comparable with the ones at Umm el-Sawan are found in the area. Some of the workings were described by Caton-Thompson and Gardner (1934), others were observed by us during the 2006 field season. These gypsum deposits are of poorer quality than at Umm el-Sawan, yet it is tempting to suggest that the establishment of the latter as the main production site resulted from a more or less systematic search along the whole length of the gypsum deposits in the Qasr el-Sagha Formation, from Widan el-Faras in the west to Umm el-Sawan in the east.

Thus, Umm el-Sawan clearly demonstrates a strong link between Old Kingdom production sites in different parts of Egypt. As previously hypothesised by Bloxam (2003), foreign stone tools at Umm el-Sawan might imply trading between specialists in prized stone tools, or alternatively, northern Faiyum was a centre where such people resided and from where they were deployed (Bloxam 2007). A closer examination of the data from Umm el-Sawan may add significantly in developing further hypotheses into the social context of stone quarrying during the Old Kingdom.

The survey at Umm el-Sawan and related areas has also illuminated some challenges regarding the future protection of the site. How can it be delineated? The gypsum beds stretch at least 25 km to the southeast, and there are important, related quarries (stone tools) several kilometres from the quarry site. Moreover, the spatial link between the ancient gypsum and basalt quarry sites, and the discovery of grinding stone and tool quarries, show how important it is to move out of the main sites and see the resource

Figure 22. Silicified sandstone with concentric 'shells' as occurring in the deposit.

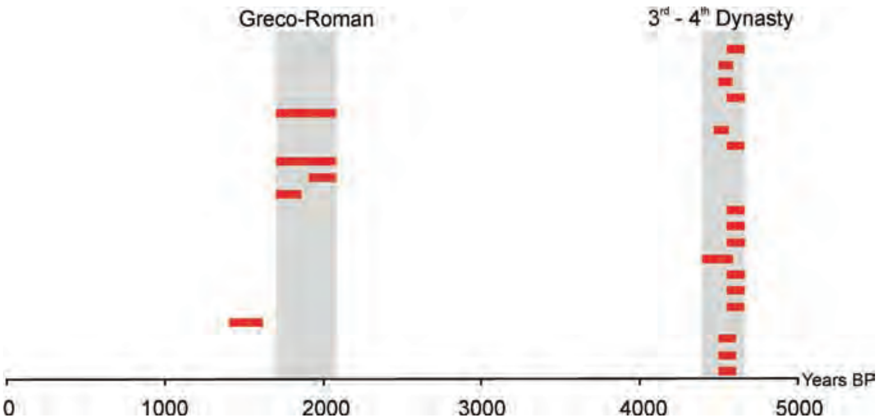

Figure 23. Pottery recorded at Umm el-Sawan during the 2006 field season (El-Senussi 2006). The red lines each represent one piece of pottery and its maximum period of use. The grey fields are the assumed maximum time span displayed by the pottery findings.

acquisition in the landscape in its totality. Such issues in relation to the northern Faiyum quarry landscape as a whole, and current attempts for its nomination as a World Heritage Site, has recently been discussed by Bloxam and Heldal (2007). Finally, it is important to focus on the remarkable interaction between geology and archaeology displayed in the northern Faiyum. The quarrying itself, as well as the exploitation of secondary resources, are spectacular illustrations of human utilisation of a wide spectrum of resources in a geological landscape.

Acknowledgements

We gratefully acknowledge the help and assistance from the SCA in providing us with the opportunity to carry out this work, as partners in the EU-funded QuarryScapes project (contract 015416). Special thanks are due to Ahmed Abdel Al (Director of SCA Faiyum) and Magdy el-Ghandour (director of foreign missions, SCA Cairo) for their assistance in all aspects of this survey. Geologist Gebely Abdul Maksoud from the Lake Qarun Protectorate Administration helped us identify the fossils. We extend much appreciation to our SCA inspector Mohamed Hamed Mohamed, who was a great companion in the field and helped enormously to make the survey a success. Thanks also to Dr. Tor Grenne and Prof. James A. Harrell who kindly reviewed the paper, and to the Sixth Framework Programme (FP6) of the European Union for giving financial support to the project.

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The quarryscapes of Gerasa (Jarash), Jordan

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The quarry landscapes of Jarash offer an important opportunity to understand ancient Gerasa in its natural environment as well as its building materials. A number of quarry sites have been documented in the Jarash area as part of the QuarryScapes project, including four major locations at Asfur, Al Shawahid, Wadi Suf and Majar. The quarries were used to extract building stone from the Upper Cretaceous Naur, Fuheis and Wadi As Sir Formations of the Ajloun Group. The limestone from the quarries is easily correlated with most building stone used for the construction of Gerasa using petrographical analysis. The quarry sites include intriguing evidence of the extraction techniques. Tool marks, evidence of chiselling, dressing and extraction planning, as well as unfinished blocks and columns, are commonly seen at the quarries. These quarry sites should be considered an integral part of Gerasa as cultural heritage sites that can give visitors a chance to better appreciate the ancient city in its natural setting, at a distance from the modern city of Jarash. Unfortunately, urban expansion poses a threat to these sites and endangers their existence and undermines their protection. The situation is exacerbated by inadequate legislation and lack of an effective conservation strategy.

Introduction

Background

The ancient Graeco–Roman city of Gerasa is a magnificent example of a large provincial capital from the period. It attracts visitors from all over the world to admire its majestic architecture. However, due to the proximity of the modern city of Jarash, and the impingement of this city on the archaeological site, it is difficult to visualise the ancient city in its true natural environment. The reason why this site was chosen for early settlement can easily be appreciated if the environment is understood (strategic location, availability of water, building materials and agricultural resources). While it is a shame that the setting is obscured by the modern city, little can be done to alter this reality.

The quarries from which stone was extracted to build the ancient city provide an excellent opportunity to allow visitors to better appreciate the hinterland of Gerasa. A number of excellent examples of Roman quarrying sites in the area

Abu-Jaber, N., al-Saad, Z. and Smadi, N. (2009) The quarryscapes of Gerasa (Jarash), Jordan. *In* Abu-Jaber, N., Bloxam, E.G., Degryse, P. and Heldal, T. (eds.) *QuarryScapes: ancient stone quarry landscapes in the Eastern Mediterranean*, Geological Survey of Norway Special Publication,**12**, pp. 67–75.

can be seen and appreciated. These sites deserve documentation and protection both for their archaeological value, as they record ancient technology adopted for stone extraction, and for their tourism attraction potential. Current legislation and land-use practices will offer no long-term protection for these sites. If this situation is to be changed, the decision makers should be convinced of the high significance and value of these sites. This can only be done through full documentation and analysis. Interpretation and presentation of these sites, as well as any attempt to convince decision makers of their value will only be convincing when all relevant information is readily available. Detailed assigning of significance, as articulated by Bloxam (2009) is beyond the scope of this paper. However, it is clear that some aspects of quarry significance can be easily identified in the Gerasa quarry landscapes (i.e., stone sources and production), while others such as logistics and social context are difficult to recognise.

Few previous studies have been made on the quarries of Gerasa (Utoum 2003). The focus of these studies was on the building materials used in terms of their nature and characteristics and not on the ancient quarrying and quarrying techniques. The various aspects of the ancient quarrying as a process have not been dealt with.

The QuarryScapes project was initiated to highlight the importance of stone sources and their extraction locales and techniques in the eastern Mediterranean. While ancient monuments are well protected and presented, the quarries from which the monuments were built often receive little recognition or protection.

As part of QuarryScapes, Yarmouk University undertook the study of the Early Bronze chert quarries of Al Jafr, the Nabatean sandstone quarries of Petra and the limestone quarries associated with the Graeco–Roman city of Gerasa. The purpose of this paper is to report and document some of the most significant examples of quarry sites related to ancient Gerasa, with respect to geology, landscape, notable features and potential threats. How the various quarries contributed different stone for different uses will also be explored based on petrographical analysis.

Location

Jarash is situated about 40 km north of Amman and about 30 km south of Irbid (Figure 1). The topographical map sheet of the region covers an area of 660 km^2, located between coordinates 35°45`–36°E and 32°15`–32°30`N. It lies within the drainage basin of Wadi Jarash, which in turn drains into the Zerqa River to the south of the city of Jarash. The upper reaches of the Wadi Jarash drainage basin are relatively steep, and are covered by a mixture of forests, planted orchards and fallow lands. This area was where most Roman quarrying activities took place. Downstream, the ancient city of Gerasa is located. Gerasa is one of the most complete examples of a provincial Roman city to be seen anywhere. The site now lies on a modern highway that links Amman with the north of the country. The topography of the area is illustrated in Figure 2.

Climate

The majority of the area is within the mountainous part of the northern highlands of Jordan. Winters are cold with a mean daily temperature of less than 10°C, and it receives a relatively high mean annual rainfall exceeding 500 mm. Summers are fairly hot and dry, with a mean monthly and yearly temperature of 20°C, and practically no precipitation.

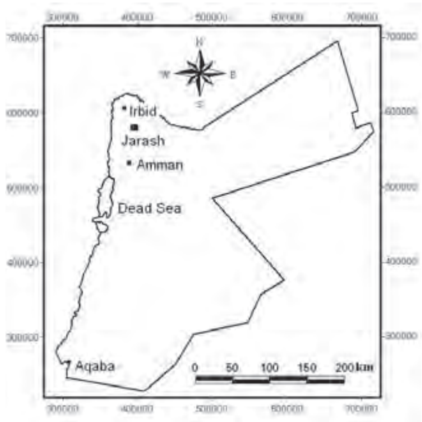

Figure 1. Location map of study area of Jarash.

The geology of Jarash

The geology of the Jarash area was described and mapped by Abdelhamid (1995). The sheet area, which lies in close proximity to the Jordan valley rift located about 15 km to the west, is dominated by sedimentary rocks, mainly of Late Cretaceous age. These include in upward

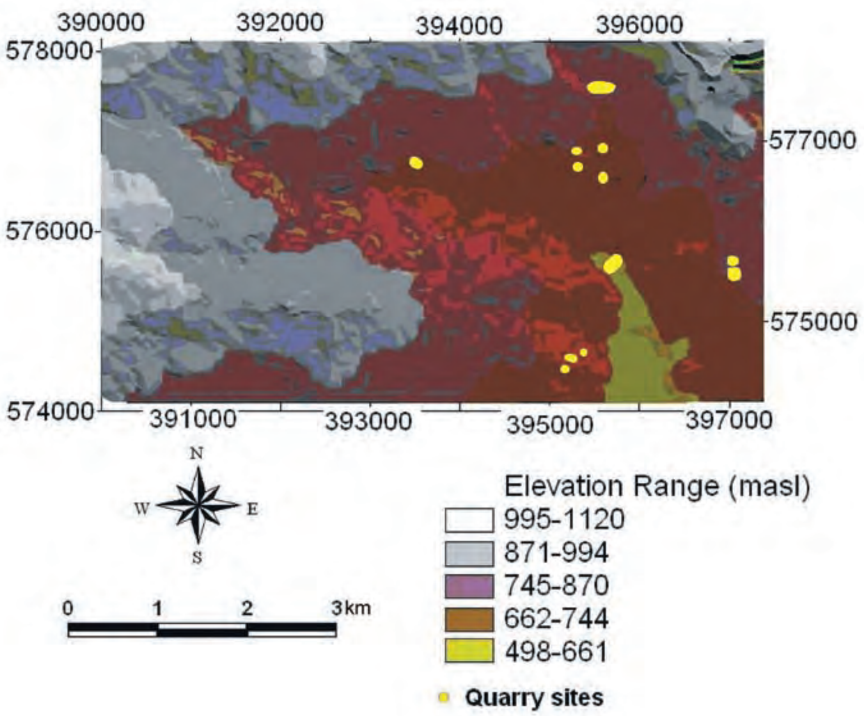

Figure 2. Elevation map of the landscape.

Table 1. The major stratigraphy found in the Jarash area (summarised from Bender (1974) and Abed (1982a, b)).

Group	Formation	Description	Thickness (m)	Has it been quarried?
Belqa	Amman Silicified Limestone	Medium- to thin-bedded, locally thick chert, silicified limestone, limestone and phosphatic chert, and a few thin phosphatic beds at the top		No
	Wadi Um Ghudran	Yellow to white grey or pink grey fossiliferous chalky limestone. Upper part typically pink to yellow grey, hard, medium- to thin-bedded, fossiliferous to coquinoidal, and with chert concretions and bands towards the top		No
Ajloun	Wadi As Sir	Thick-bedded to massive limestone with steep distinctive rocky slopes. Hard, partially dolomitised.		Yes
	Wadi Shuayb	Yellow to yellow grey thin- to medium-bedded marly limestone, commonly nodular, fossiliferous to locally shelly and coquinoidal		No
	Hummar	Hard limestone, mainly of pink to yellow grey, partly dolomitised, locally marly limestone	75	Yes
	Fuheis	Marls and marly nodular limestone	50	Yes
	Naur	Marly limestone, marl and clay, commonly grey to yellow grey limestone. It is nodular and marly, fossiliferous, medium to thick bedded	180	Yes, in a few horizons near the top.
Kurnub	Kurnub	Medium- to coarse-grained quartz arenite with a few marine intercalations of dolomite and shale		No

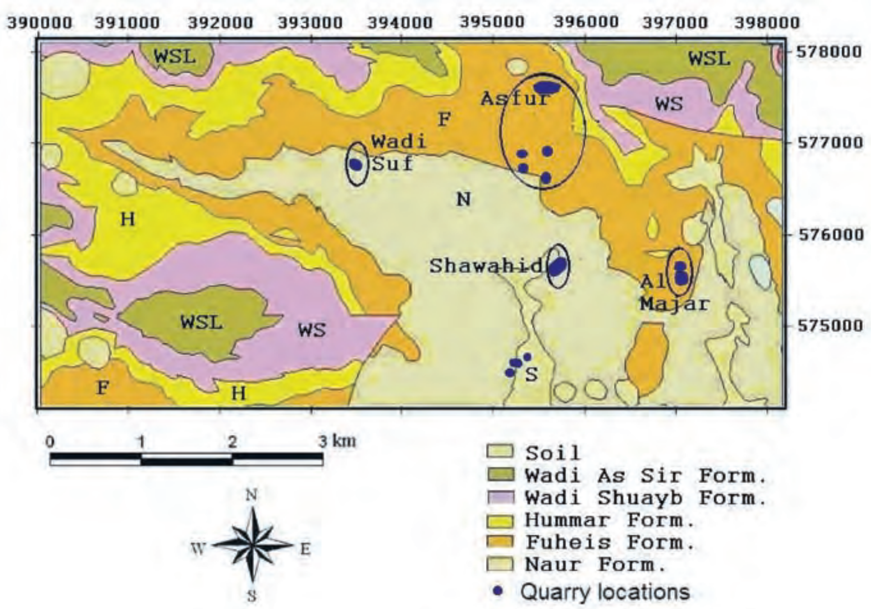

Figure 3. Simplified geological map showing the major quarry sites.

sequence the Kurnub Sandstone Group (Lower Cretaceous), the Ajloun Group (Cenomanian–Turonian) comprising the Naur limestone, Fuheis, Hummar, Wadi Shuayb and Wadi As Sir formations, the Belqa Group comprising the Wadi Um Ghudran and Amman Silicified formations (Coniacian–Campanian), and small outcrops of the Muwaqqar and Um Rijam chert limestone formations (Maastrichtian–Eocene). The characteristics of these formations as described by Bender (1974) and Abed (1982a, b) are summarised in Table 1. Figure 3 is a simplified geological map of the area.

Quaternary sediments and soil consist of brown to red and pale brown soil of varying thickness found throughout the study area. Thick caliche layers reflecting weathering in arid conditions are also found throughout the area. This caliche is easily mined and devoid of joints, making it ideal for extracting large building stones. Caliche was used in the building of Jadara as well, specifically in some of the columns of the main temple (Bashaireh 2003). The ancient quarry sites described in this paper are largely coated with thick caliche, often obscuring the original stone that was extracted at the site, and sometimes making determination of the formation from which the stone was quarried difficult.

The area contains an E–W fault system, a NNE and a NW fault, possibly of Late Tertiary age. Gentle folds are present, and are subparallel and mainly characterise the central and western parts of the sheet area. The rest of the regional structure, the Ajloun Dome, is centred near Ibbin a few kilometres NE of Ajloun to the west of Jarash. Landslides are common along the steep wadi sides in the western and southern part of the sheet area, where marly formations such as the Naur and Wadi Shuayb formations crop out.

Limestone, mainly from the Wadi As Sir Limestone Formation in the western and central parts of the sheet area, has been quarried for many years for good-quality building stone and aggregates. The majority of old sand mines in the Kurnub Sandstone in the central southern part have been abandoned. Building stones are well known historically and archaeologically due to the presence of ancient Roman and Islamic settlements, which stand as evidence of the use of limestone for building purposes. While the ancient quarry sites described herein are from the older Naur and Fuheis formations, more recent extraction has been focussed on the Wadi As Sir Formation.

Good quality micritic to spary-micritic limestone from the Wadi As Sir limestone and, locally, the Naur limestone and Hummar formations have been quarried for a long time as decorative building stones and for use as aggregates. Part of the thick-(>30 cm) to medium-(5–30 cm) bedded, milky to light grey micritic limestones of the upper Wadi As Sir formation, in the western part of the study area, could be used for ornamental purposes. Additionally, caliche has been quarried at some locations. To the west, near the Jordan valley, travertine is also mined for building and ornamental purposes (El Radaideh and Mustafa 2008). Some examples of travertine are found in Gerasa, and it is possible that the Romans used the same source as is currently extracted near Dair Abu Said.

History and archaeology of Jarash

Known as the 'Pompeii of the East', Jarash (known as Gerasa in the Classical time) is considered to be one of the best preserved and most complete Roman cities in the world. The ancient town of Gerasa, located 48 km north of the Jordanian capital of Amman, is one of Jordan's most famous archaeological and tourist sites, and visited by thousands of sightseers every year. Founded in the Hellenistic Period (332–63 BC), probably on the site of an earlier Iron Age settlement, the city was transformed in the Roman Period by the construction of an urban grid featuring paved and colonnaded streets and major monuments. Included among these are huge temples, theatres, and open public spaces, especially the famous 'Oval Piazza' in front of the Zeus temple.

From the middle of the 5th century, Christianity was the major religion and the construction of churches proceeded apace. Under the Byzantine emperor Justinian (527—565 CE) seven churches were built, mostly out of stones pillaged from the earlier Roman temples and shrines (Clark 1986).

At the time of the Islamic expansion into Syria–Palestine (635–640 CE), Gerasa conceded to Islamic leaders without any destruction being inflicted on the city. Social and economical life continued unabated, and a large mosque was built in the centre of the city.

With the destruction of the city by a devastating earthquake in 747, Gerasa's glory days passed into shadow and its population shrank to about one-quarter of its former size (Kraeling 1938, Pierobon, 1983–1984, Meyer 1988).

Apart from a brief occupation by a Crusader garrison in the 12th century, the city was completely deserted until the arrival of the Circassians from Russia in 1878, after which the site's archaeological importance was realised and excavations began.

The archaeological park at Jarash encapsulates the western half of the Graeco–Roman city as defined by the ancient city walls. Within it the remains are protected. The eastern half of the ancient city has been largely overbuilt beginning in the late 19th century when the modern town of Jarash was established.

The quarries of Jarash: current investigations

As part of the QuarryScapes project, ancient quarries in the Jarash region are documented and described by the Yarmouk University team through surveys in and around Jarash. Many quarries are found in the surrounding areas including the Asfur, Al-Shawahed, Wadi Suf and Al-Majar.

Methodology of the study

Preliminary field surveys and literature studies were conducted to locate the quarry sites and to contextualise them in the landscape. Following this, air photo, topographical, geological and archaeological data were used to construct a GIS database of the region. Later, more detailed surveys of the quarry sites were conducted using standard surveying techniques. Samples from the quarries and rubble from the archaeological site at Gerasa were collected for comparison. The materials examined in this study consisted of samples from the ancient city of Gerasa, as well as samples from the Wadi Suf, Al Shawahed, Al Majar and the Asfur areas of Jarash, where the ancient quarries were studied and documented. Limestone samples were collected and described based on their colour, mineralogy, texture and use. These samples were analysed in order to define criteria for provenance determination of ancient stone in Jarash and nearby areas.

Thin sections of the samples were made at the workshops of Yarmouk University and were investigated using a standard petrographical polarising microscope. This work aimed to define a series of parameters of significance, notably the mineralogy and texture of the rock and their value for provenancing.

Asfur quarry

This quarry was largest in terms of area. It currently lies on both sides of the street from Jarash to the Suf Refugee Camp. This area is known as 'Rubwat Al-Jundi'. This quarry shows much evidence of quarrying processes such as incomplete columns (Figure 4), traces of cutting blocks in quarries (Figure 5), and traces of industrial grooves (Figure 6). The Fuheis Limestone Formation crops out at Asfur quarry, and consists mainly of dolostone. The elevation of Asfur ranges from 746 to 871 m asl, and other nearby small quarries range from 622 to 746 m asl (Figure 2). The slope of Asfur is between 0 to 20°, but other near small quarries are 0 to 10°. Aspect of Asfur is south (112.5–247.5°) and is nearly flat (~1°).

The dimensions of Asfur quarry 77 m in width and 175 m in length, over a relief of 34 m. These dimensions show that the area is 13,475 m², and that ap-

Figure 4. Incomplete quarrying and transporting columns from the Asfur quarry landscape.

Figure 5. Traces of cutting blocks from the Asfur quarry landscape.

Figure 6. Traces of industrial grooves of column from the Asfur quarry landscape.

proximately 26,000 m^3 of stone was removed, assuming an average removal of 2 m in thickness. Unfortunately, no evidence of the logistical infrastructure for quarrying has been identified.

Al-Shawahed quarry

Another major quarry site is known as the Al-Shawahed quarry, which is set to the east of Wadi Suf. It consists of the hill faces surrounding the Suf Refugee Camp, northwest of Jarash. Evidence of the quarrying process is borne out by the many traces of cutting blocks and man-made grooves in the quarry faces. The soft and easy-to-quarry marly Naur Limestone Formation crops out at the Al-Shawahed quarry. Building blocks from this formation have been observed at Gerasa, mostly used for non-ornamental functions. The proximity and ease of extraction probably made Al Shawahid one of the more important extraction sites in the region for low-quality stone.

The elevation of Al-Shawahed ranges from 373 to 497 m asl, the slope is 0 to 10° and the aspect is flat (~1°) to southwest (202.5–247.5°). The disseminated nature of the quarrying activities here makes it difficult to determine its dimensions or estimate how much stone was removed.

The quarry site here is in danger of encroaching urbanisation, and there are no legal or practical barriers to its ultimate removal from the landscape.

Wadi Suf quarry

The elevation of Wadi Suf quarry northwest of Jarash ranges from 622 to 746 m asl, the slope is 0 to 10°, and its aspect is south (157.5–202.5°). This quarry is damaged because of natural factors (biological and chemical weathering) as well as from reclamation of agricultural lands. Farmers removed some rocks under this quarry at the northeast end, where there is a Roman cemetery cut into the rock. This was presumably for land reclamation, extraction of stone for later buildings and possibly as a byproduct of treasure hunting. In Wadi Suf there are many small quarries and damaged cut rocks. This quarry includes traces of cutting blocks, and industrial grooves as well as incomplete and unmoved columns.

Caliche covering the upper part of the Naur Limestone Formation crops out here. This is a particularly massive caliche, that seems to have been quarried for itself, and used for massive objects such as columns. Caliche enjoys the benefit of having few fractures and joints.

Al-Majar quarry

Another quarry is at Al-Majar, west of Jarash and south of the Asfur quarry. The trace blocks cut from the quarry are evidence of the quarrying process. The dimensions of Al-Majar quarry are: width 27 m, length 35 m, and height 5 m. Thus the exposed quarry area is 945 m^2, and the extracted volume is approximately 4725 m^3.

The elevation of Al-Majar ranges from 746 to 871 m asl, the slope is 0 to 10°, and aspect is southwest (202.5–247.5°) to west (247.5–292.5°). The Fuheis Formation crops out at Al-Majar quarry, and consists mainly of dolostone.

An assessment of the state of preservation and threats

Jarash quarries and quarry landscapes are under threat, chiefly from modern human activities that erase all traces of ancient use. These quarries have not been properly studied or documented, and once modern exploitation starts, there is very little chance to recover any archaeological evidence.

The greatest problem seems to be the total lack of appreciation of the value of this ancient landscape not just by the locals but even by the decision makers who are responsible for the protection and safeguarding of the country's cultural legacy. This led to damage of the ancient quarries by human activities and to lack of any initiatives from the responsible government agencies to protect these important cultural remains. The sites are not legally protected by the Antiquities Law and therefore are under the threat of urban and agricultural expansion.

The encroaching agricultural activities within the sites have been going on for ages. The fields have expanded all around the sites with the consequence of covering a substantial part of ancient stone-quarrying remains and debris.

The rapid population growth results in uncontrollable urban expansion in the area. The threat of modern buildings within and near the sites is also helping in destroying the archaeological data and the environment. The foundations of the buildings required the levelling of the bedrock with the consequence that any rock cut features were obliterated.

Petrographical study

Due to variations in depositional environment and diagenetic history of limestone, variations in texture result and can be used to differentiate limestone from different sources. Herein, petrographical characteristics of limestone from the different sources and from the archaeological sites are studied and compared in order to ascertain how useful this approach may be for provenance studies for determining which stone came from which quarry. Both the Folk (1959) and Dunham (1962) classifications for textural classification are used to describe the microtexture of the limestone samples. It is recognised that petrographical study can give a great deal of information on grain fabric, texture and mineralogy, including grain size and shape, grain distribution, sorting lithology, sedimentary and organic structure, colour variation and cement.

Sample collection

Ten limestone samples were collected and grouped according to their colour and texture from the various quarry locations. In addition, four samples of the caliche were collected, including six samples from Gerasa.

Experimental methods

Experimental methods can be divided into field methods and lab methods. Field methods include the geological surveys and sampling.

Geological surveys

Geological surveys were made in order to identify the variety of rocks present in Jarash. Areas such as Asfur to the northeast, Al-Shawahid to the north, Al-Majar to the northeast, and Wadi Suf to the northwest where surveyed, as they are believed to have been used in the construction of the ancient city.

Lab methods

Thin sections were prepared for standard petrographical analysis (Kerr 1977). The thin sections were made in the workshop of Earth and Environmental Sciences at Yarmouk University. All of the thin sections were studied using polarising microscope for the identification of the minerals, and their textures for classification of the samples. Thin sections were stained with alizarin reds to reveal dolomite present.

Results and discussion of ancient limestone quarry sources

Macroscopical analyses

Sample numbers 1, 4 and 5 show nearly identical macroscopical features. These are grey to yellow grey colour, hard, locally fossiliferous, medium-bedded to locally thin and massive dolomite and dolomitic limestone with a distinctive dark grey to grey weathering colour. These rocks belong to the upper unit of the Fuheis Formation, and the samples were taken from the Asfur quarry landscape (Table 2).

Sample numbers 2, 3, 6, 14, 15 and 16 come from the upper unit of the Fuheis Formation. These samples are light grey to white and yellow grey, hard limestone, mainly micritic to locally marly. These samples were taken form the Asfur and Al-Majar quarry landscape (Table 2).

Sample numbers 10, 11 and 17 are grey to yellow grey, frequently marly, fossiliferous, medium- to thick-bedded, locally massive sparry micrite to micrite alternating with yellow to white grey marls. These came from the lower unit of Naur Limestone Formation, taken from the Wadi Suf and Al-Shawahed quarry landscape (Table 2).

Samples 12 and 13 show features that suggest that they come from the upper unit of Naur Limestone Formation, that consists of yellow grey to pink, hard, medium- to thick-bedded, locally dolomitic, mainly micritic limestone. These samples come from the Wadi Suf quarry landscape.

Petrographical analyses

Nomenclature for the microtextural analyses of the samples described above are shown in Table 3. Samples 1, 4 and 5 are composed mainly of pelloids, intraclasts and fossil fragments (burrows, echinoids, grastropods and bivalves); generally this microfacies is character-

Table 2. Macroscopical description of the limestone and caliche samples from ancient limestone quarries context.

Sample no.	Source	Grain size	Colour
1	Asfur	Fine–Medium	Yellow grey
2	Asfur	Fine	White to light grey
3	Asfur	Fine	White and yellow grey
4	Asfur	Fine–Medium	Yellow grey with light and dark grey
5	Asfur	Medium	Yellow grey with light grey
6	Asfur	Fine–Medium	White with light and dark grey
10	W. Suf	Fine–Medium	Grey to yellow grey with grey
11	W. Suf	Medium	Grey with light grey
12	W. Suf	Fine–Medium	Grey to pink
13	W. Suf	Fine	White with light and dark grey
14	Majar	Medium	White with light grey
15	Majar	Fine–Medium	White with grey
16	Majar	Fine–Medium	White to grey
17	Al-Shawahed	Medium	Grey with white grey

Table 3. Petrographical nomenclatures and classification of rocks in ancient quarries.

Sample no.	Allochems					Petrographical classification	
	Peloids (%)	Fossils (%)	Intraclast (%)	Mud supported	Grain supported	Folk (1959	Dunham (1962)
1					*	Biosparite–biomicrite	Wackstone–packstone
2	30	70		*		Poorly-washed pelbiomicrite	Wackstone
3	50	40			*	Poorly-washed biopelsparite	Packstone
4					*	Biomicrite	Grainstone
5		50	50		*	Sparse biointramicrite	Packstone
6	20	30		*		Poorly-washed pelbiomicrite	Wackstone–packstone
10					*	Biosparite	Packstone
11		40	10		*	Packed biomicrite	Packstone
12	60	40		*		Packed biopelmicrite	Wackstone–packstone
13	30	20		*		Biomicrite	Wackstone
14					*	Poorly-washed biopelsparite	Wackstone–packstone
15	10	30		*		Pelbiosparite	Wackstone
16	30	10			*	Biopelmicrite	Packstone–wackstone
17		30	10		*	Poorly-washed biosparite	Packstone

ised by a high percentage of allochems, dominance of primary micritic matrix and diagenesis that involved recrystallisation followed by dolomitisation. This microfacies consists of fossiliferous pelloidal wackstone–packstone–grainstone. Figure 7 is a micrograph of this facies.

Samples 2, 3, 6, 14, 15 and 16 consist of a micritic matrix with bioclasts and sparite cement, with recrystalisation of calcite spar. This microfacies consists of fossiliferous (bivalves and plecypods) pelloidal wackstone–packstone.

Samples 10, 11 and 17 are composed mainly of fossil fragments (foraminifera and ostracoda), inraclasts, micritic matrix and sparite cement. This microfacies consists of fossiliferous packstone.

Samples 12 and 13 consist of fossiliferous (echinoids) with biomicrite and pelloids. This microfacies consist of fossiliferous pelloidal wackstone–packstone.

Results and discussion of archaeological context

Macroscopical analyses

Sample number 27 is from upper North Theater, and is yellow grey to pink, hard, locally dolomitic, mainly micritic limestone (Table 4).

Samples 28 and 40 are from South Theatre and Colonnaded Street, respectively. These consist of light grey to white and yellow grey, hard limestone, mainly micritic and locally marly (Table 4).

Sample number 29 is from lower North Theatre, and consists of grey to yellow grey, hard limestone, with a distinctive dark grey to grey weathering colour (Table 4).

Sample numbers 38 and 39 are from the South Theatre and Colonnaded Street, respectively. These show identical features which are grey to yellow grey, marly, sparry micrite to micrite alternating with yellow to white grey marls, these samples from (Table 4).

Petrographical analyses

Petrographical characteristics of samples from the archaeological site are summarised in Table 5. Sample number 27 consists of pelloids and fossil fragments (echinoids) with biomicrite. This microfacies consists of fossiliferous pelloidal wackstone.

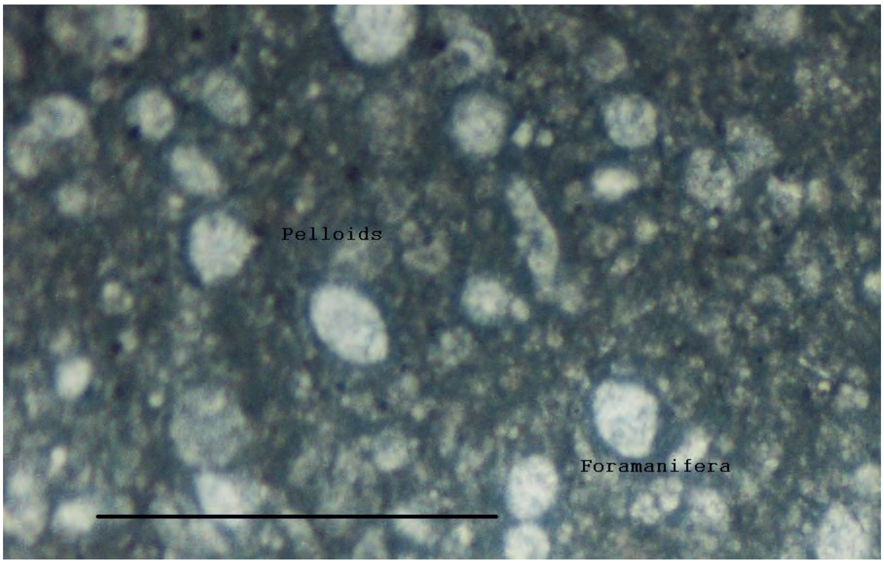

Figure 7. Photomicrograph of the Hummar Formation source rock from the area. It shows abundant pelloids and a few fossil foraminifera in a micritic matrix. Bar length is 2 mm.

Sample number 28 and 40 are composed of peloids and fossils (bivalve and pelecypods), and micritic martrix with bioclasts and sparite cement. This microfacies consist of fossiliferous pelloidal wackstone–packstone.

Sample number 29 consists of pelloids, fossilliferous (echinoid spines) and intraclasts with biomicrite. This microfacies consist of fossiliferous pelloidal packstone.

Samples number 38 and 39 are composed of fossil fragments (foraminifera and ostracoda) and micritic intraclasts, matrix and sparite cement. This microfacies consists of fossiliferous packstone.

Correlation

It is clear that that there are obvious similarities between the samples taken from the quarries and those from the ancient

Table 4. Macroscopical description of the limestone samples from an archaeological context..

Sample no.	Source	Grain size	Colour
27	Upper North Theater	Medium	Grey with light red
28	South Theater	Fine	White to light grey
29	Lower North Theater	Medium	Grey to yellow grey
38	South Theater	Fine–Medium	Grey with light and dark grey
39	Colonnaded street	Medium	White to light grey
40	Colonnaded street	Fine–Medium	White and yellow grey

Table 5. Petrographical nomenclatures and classification of rocks in the archaeological context.

Sample no.	Allochems					Petrographical classification	
	Peloids (%)	Fossils (%)	Intraclast (%)	Mud supported	Grain supported	Folk (1959	Dunham (1962)
27	60	40		*		Packed biopelmicrite	Wackstone
28	30	70		*		Poorly-washed pelbiomicrite	Wackstone
29		50	50		*	Sparse biointramicrite	Packstone
38		30	10		*	Poorly-washed biosparite	Packstone
39		40	10		*	Packed biomicrite	Packstone–wackstone
40	50	40			*	Poorly-washed biopelsparite	Packstone

city. These similarities suggest that direct correlations can be made between the sources of the stone and the sites of their ultimate consumption.

For example, sample number 5 from Asfur and sample number 29 from the lower North Theater are very similar in macroscopical and petrographical characteristics. Also, samples 2 and 3 from quarry of Asfur sites are similar in macroscopical and petrographical characteristics to samples 28 and 40 taken from the South Theater and the Colonnaded Street.

The group of samples numbered 10, 11 and 17, particularly samples 11 and 17 from quarry locations at Wadi Suf and Al-Shawahed, extracted from the Naur Limestone, are similar to samples 38 and 39 from the archaeological location, respectively. No recognisable differences can be seen between sample number 12 from the Wadi Suf quarry and sample number 27 from the upper North Theater.

The previous results suggest that the provenance of stones used as building materials in ancient Jarash is the surrounding area, and can be attributed to the ancient quarry landscapes in Asfur, Al-Shawahed, Wadi Suf, and Al-Majar locations. Therefore most building materials in ancient Jarash are local. Variations between the local sources are not great enough to assign stones at the archaeological site to specific sources at the quarries.

Conclusions

The geological-petrographical study of the quarrying sites of the ancient city of Jarash, combined with the study of the rock-cut surfaces and their tool marks, has given preliminary information about the characteristics of the main building stone of Jarash monuments and of the quarrying techniques applied there.

The volume of stone masonry acquired and the absence of material waste at the many quarries surveyed indicate exceptional stone management skills and productivity as well as the shear accuracy for calculating stone consumption with minimal waste.

It is hoped that the information granted in this paper can be of great profit for archaeological and architectural research that may provide further comprehension to the history of man's achievements of stone extraction, and share new interpretations to the ancient workings of Jarash stonemasons.

The results of this research highlight the value and significance of ancient stone quarries as a rich source of invaluable information about ancient technological achievements and socioeconomical aspects of ancient Jarash. Specifically, data on sources and extraction technology can be gleaned directly from these results. It is hoped that these findings will bring more attention and raise awareness among locals and government responsible officials about the significance and vulnerability of such sites. So far, these sites have largely gone unrecognised due to poor documentation, which has consequently led to their current indiscriminate destruction mainly by human activities such as urbanisation and agriculture. This study will be extended through further and more detailed investigation to further reveal the significance and value of these sites and to devise the necessary legal and conservation measures to ensure sustainable management of these important sites.

Acknowledgments

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Mineral fingerprinting of Egyptian siliceous sandstones and the quarry source of the Colossi of Memnon

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The two colossi that stood before the first pylon of the mortuary temple of Amenhotep III at Thebes (the Colossi of Memnon) are composed of single blocks of siliceous sandstone or quartzite, similar to that occurring in quarries near Cairo (Gebel Ahmar) and Aswan (Gebel Gulab–Gebel Tingar). In this study, mineral fingerprinting, using the method of heavy-mineral analysis, points conclusively to a Gebel Ahmar source for the two Colossi. It also identifies Gebel Ahmar as the source for the two quartzite colossi associated with the second pylon and for fragments of quartzite statues that previously stood in the peristyle court. The study has further revealed a contrast in mineral composition between the two northern colossi and the two southern colossi, indicating that they were extracted from different parts of the Gebel Ahmar quarry complex.

Introduction

The two colossal seated statues of Amenhotep III, popularly known as the Colossi of Memnon, are the most striking features of ancient Thebes on the west bank of the Nile at Luxor (Figure 1). Both statues were originally made of monolithic blocks of brown to red siliceous sandstone (quartzite). The block that forms the southern colossus is today about 14 m high (Sourouzian et al. 2006, p. 325), but would once have included a double crown of Upper and Lower Egypt. Together with their pedestals, both statues are estimated to have stood 21 m or 40 Egyptian cubits high and to have weighed some 750 metric tonnes (Sourouzian et al. 2006, p. 349). They were erected in front of a large brick pylon at the entrance of the mortuary temple of Amenhotep III, built during the 18th Dynasty of the New Kingdom (between 1390 and 1353 BC).

Each of the seated figures of Amenhotep III is flanked by standing representations of the king's mother Mutemweja

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on the north sides and of Queen Tiye on the south sides. On each statue a figure of a princess, whose name is lost, once stood between the legs of the king. The thrones are decorated by Nile gods tying the heraldic plants of Upper and Lower Egypt, thereby representing the uniting of the land of Egypt under the reign of Amenhotep III.

A devastating earthquake in the year 27 BC may have caused the broad fissure still visible today in the northern Memnon Colossus and the collapse of the upper part of statue. The colossus subsequently became famous for producing a lamenting sound, apparently produced by warmth from the rising sun acting on early morning humidity within the fissures. Greek visitors regarded this as a greeting of the Ethiopian hero Memnon (slain by Achilles at Troy) to his divine mother Eos. More than a hundred inscriptions in Greek and Latin attest to the miraculous phenomenon of the early morning lamentations. During his visit to Thebes in AD 200, Septimius Severus resolved to restore the colossus, using large blocks of sandstone believed to have come from quarries at Aswan. The work was not completed, however, perhaps as a result of the death of the emperor. A unintended result of the project was the silencing of the 'voice of Memnon'.

The rock used to form the Colossi of Memnon is technically known as 'siliceous sandstone', 'silicified sandstone' or 'orthoquartzite', but Egyptologists have long referred to it simply as 'quartzite' and it is this terminology that is used here. It must be kept in mind, however, that the geological term 'quartzite' usually refers to a metamorphic rock whereas in this case it is applied to one that is entirely sedimentary. Quartzite, which was prized for its durability and distinctive colouration, was widely used by the ancient Egyptians for small to colossal statuary, sarcophagi, *naoi* (shrines), offering tables, stelae, architectural elements (especially door frames and internal tomb linings), and occasionally barque shrines and obelisks.

The quarry source of the Memnon quartzite blocks has long been the subject of discussion, as summarised by Varille (1933), Heizer et al. (1973), Stadelmann (1984) and Klemm et al. (1984). Although earlier authors have reported the occurrence of quartzite at several localities along the Nile Valley (see Heizer et al. 1973, p. 1221), it is now clear that true quartzite is restricted to Gebel Ahmar, near Cairo, and the Aswan area (Harrell 2002, Harrell and Madbouly 2006) (Figure 2). At Aswan, quartzite was extracted from the quarry complex at Gebel Gulab and Gebel Tingar on the west bank of the Nile (Heldal et al. 2005) and from quarries near Wadi Abu Aggag on the east bank (Harrell and Madbouly 2006).

Early discussion on the source of the Memnon quartzites focussed on the interpretation of Pharaonic inscriptions and on the logistics of transporting such large blocks from distant quarry sources. In a review of the existing literature, Stadelmann (1984) concluded that Gebel Ahmar was definitely the source of the Memnon quartzites. Studies on the geology and geochemistry of the quartzites have led to diverging opinions on their quarry provenance, however.

Geological investigations initially focussed on the possibility of distinguishing between the Cairo and Aswan quartzites on the basis of their physical

Figure 1. The Colossi of Memnon on the west bank of the Nile at Luxor.

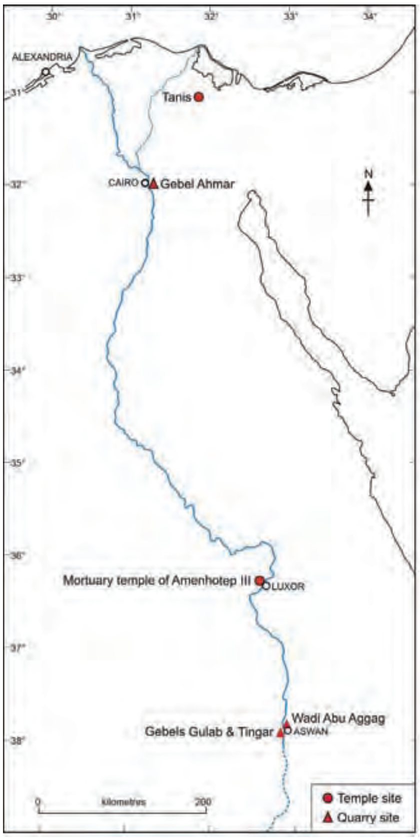

Figure 2. Location map.

and petrological characteristics. This approach seemed promising in view of the marked difference in age between the two deposits, with the Cairo quartzites being of mid-Tertiary age (Oligocene, ca. 30 Ma) and the Aswan quartzites of Late Cretaceous age (Turonian, ca. 90 Ma). However, the standard geological techniques of field examination, grain-size analysis and thin-section analysis failed to identify reliable distinguishing features. Both quartzites originated as sands deposited in fluvial channels and display a similar range of bed-forms. Also, they both possess similar, mineralogically mature, quartz-dominated detrital sand fractions. The two deposits also underwent similar post-depositional (diagenetic) changes, with cementation by silica leading to the local development of highly indurated, silica-cemented sandstone (quartzite) and impregnation by iron minerals leading to the development of a wide range in yellow, brown and red colouration. Only in the pebble fraction do the quartzites differ in their detrital composition, with pebbles of chert (finely crystalline quartz) being present only at Gebel Ahmar (Aston et al. 2000, p. 53). Since the majority of the sandstones lack pebbles, however, this distinction is of only limited applicability.

Another distinction that has been made between the two quartzites concerns the nature of the silica cement, which occurs in two forms. One type of cement, known as 'syntaxial quartz overgrowth cement', is composed of relatively large quartz crystals that have grown in crystallographic continuity with the individual detrital quartz grains that they surround (see Klemm and Klemm 2008, fig. 347). The other type of cement, here referred to as 'microcrystalline quartz fringe cement', is composed of clusters of small quartz crystals that radiate outwards from the surface of the sand grains (see Klemm and Klemm 2008, fig. 334). Shukri (1954) recognised both types of cement at Gebel Ahmar and said the fringe cement varies from normal to chalcedonic quartz. Niazi and Loukina (1987) also reported secondary chalcedony (and opal) in the Gebel Ahmar sandstone and attributed this kind of silicification to precipitation from hydrothermal solutions of volcanic origin. Klemm and Klemm (1993, 2001, 2008) state that the fringe cement is characteristic of the Cairo sandstones and that quartzites lacking it must therefore have come from Aswan. Conversely, Aston et al. (2000, p. 53) state that although fringe cement is indeed present at Gebel Ahmar, the dominant cement is of the syntaxial quartz overgrowth type, similar to that seen in the Aswan quartzites.

It is thus apparent that while the presence of chert pebbles or quartz fringe cement is indeed indicative of a Cairo quarry source, these criteria cannot be used to determine the quarry provenance of the quartzite artefacts that are pebble-free and possess only syntaxial quartz overgrowth cement. Aston et al. (2000, p. 53) indicate that a more effective method of distinguishing between the two sets of quartzites is on the basis of the degree of surface rounding displayed by the constituent quartz sand grains, with those of the Gebel Ahmar quartzites being consistently more rounded than those of the Aswan quartzites.

Because of the difficulty (as then perceived) of distinguishing between the two quartzites by conventional petrological means, Heizer et al. (1973) proposed that a better approach would be to study their geochemistry. Using the then innovative technique of neutron activation, they showed that the Cairo and Aswan quartzites differed in their contents of europium (Eu) and iron (Fe), and used this difference to identify a Cairo source for the Memnon statues but an Aswan source for the blocks used in the Roman repairs of the late 2nd or early 3rd century AD. This conclusion was also supported by a multivariate statistical analysis of Heizer et al.'s (1973) data by McGill and Kowalski (1977). A more comprehensive data set was subsequently published by Bowman et al. (1984) and Stross et al. (1988). Their findings, summarised in Figure 3, reaffirmed those of Heizer et al. (1973). A separate geochemical study by Klemm and Klemm (1993, see also Klemm and Klemm 2008) showed that the Cairo and Aswan sandstones could be distinguished by their differing contents of a wide range of elements (Co, Fe, Mn, Pb, Rb, Sr, Zn) (Figure 4) and used these differences to identify an Aswan source for the Memnon quartzites. The two geochemical studies thus came to diametrically opposed conclusions, with both sets of data plots seemingly providing conclusive support for their respective interpretations.

The present study takes the approach of establishing mineral rather than chemical fingerprints for the potential source quarries and comparing these with data for the Pharaonic quartzite artefacts. The method used is the long-established technique known as 'heavy-mineral analysis' (e.g., Krumbein and Pettijohn 1938, Milner 1962), which focusses solely on the detrital sand grain components, i.e., the material that was originally deposited as unconsolidated sand. Because the analysis is independent of variation in the proportions of mud matrix and cement minerals, obtaining a representative suite of samples is more straight-

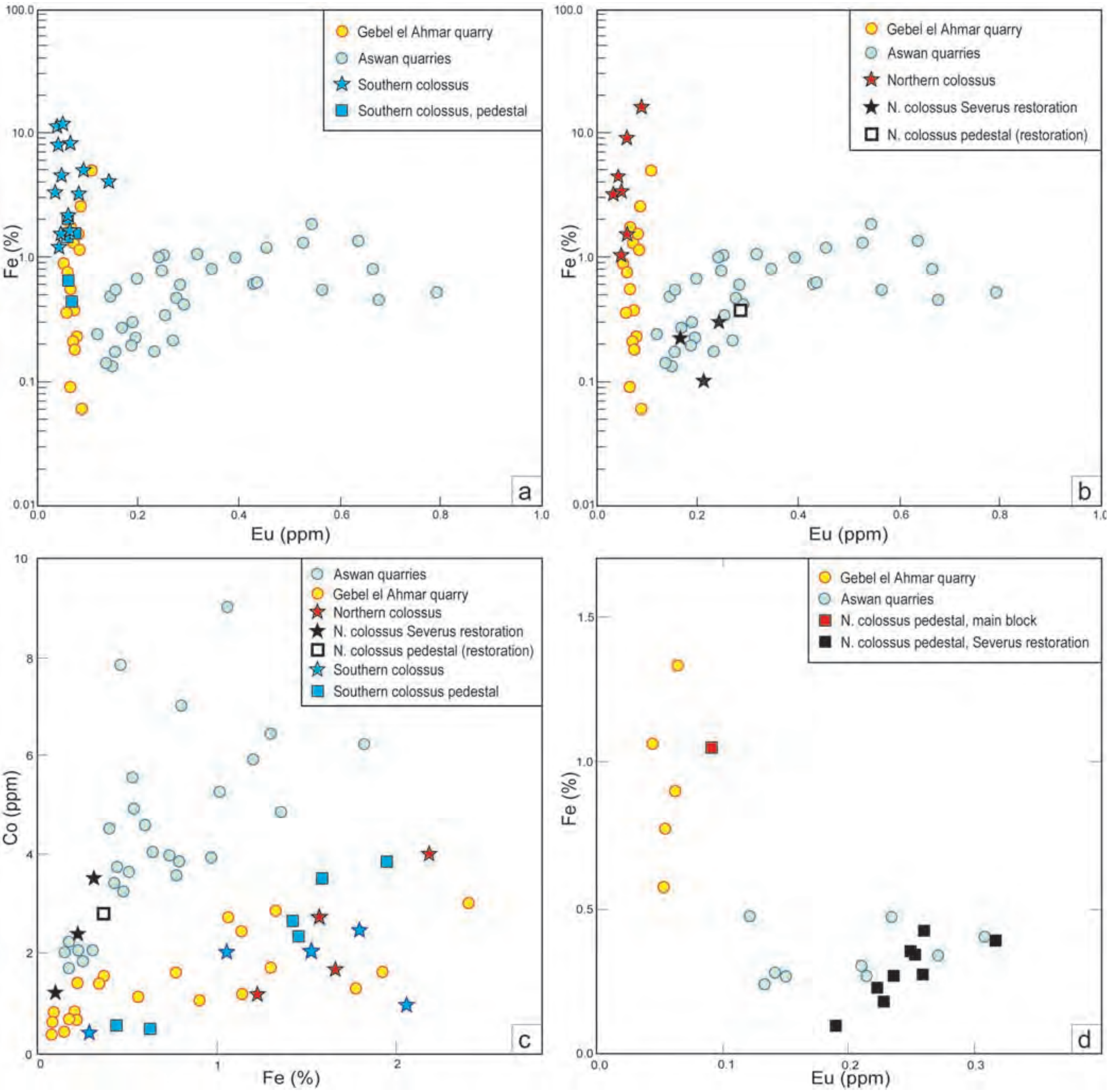

Figure 3. Geochemical data presented by Heizer et al. (1973) and Bowman et al. (1984). Iron and europium abundances for the southern Memnon Colossus (a) and northern Memnon Colossus (b) plotted with data for quartzites from Gebel Ahmar and Aswan quarries. Redrawn from Heizer et al. (1973, fig. 3 left). (c) Cobalt and iron abundances for the South and North Memnon Colossi plotted with data for quartzites from Gebel Ahmar and Aswan quarries. Redrawn from Heizer et al. (1973, fig. 3 right). (d) Iron and europium abundances for the northern Memnon Colossus pedestal. Redrawn from Bowman et al. (1984, fig. 4).

forward than for bulk-rock geochemical analysis. Heavy-mineral analysis was carried out on 8 samples from Gebel Ahmar, 7 samples from the Gebel Gulab – Gebel Tingar area, 5 samples from Wadi Abu Aggag, 8 samples from statuary at the mortuary temple of Amenhotep III, Thebes, and a single loose quartzite fragment from the ancient city of Tanis in the northeast delta area.

Method

Because of the similarity in bulk composition of the sand fraction in the two quarry areas (they are both composed almost exclusively of quartz) the study focussed on the much scarcer, but more diverse, accessory minerals. Because these accessory minerals are relatively dense, they can be separated from the bulk of the sand using a heavy (dense) liquid. For this reason, they are commonly referred to as 'heavy minerals'.

Separation of the heavy minerals from the lighter quartz and feldspar grains was achieved using bromoform, which has a specific gravity of 2.89. Disaggregation of the sandstones was achieved by impact crushing of quartzite fragments in a pestle and mortar, followed by prolonged treat-

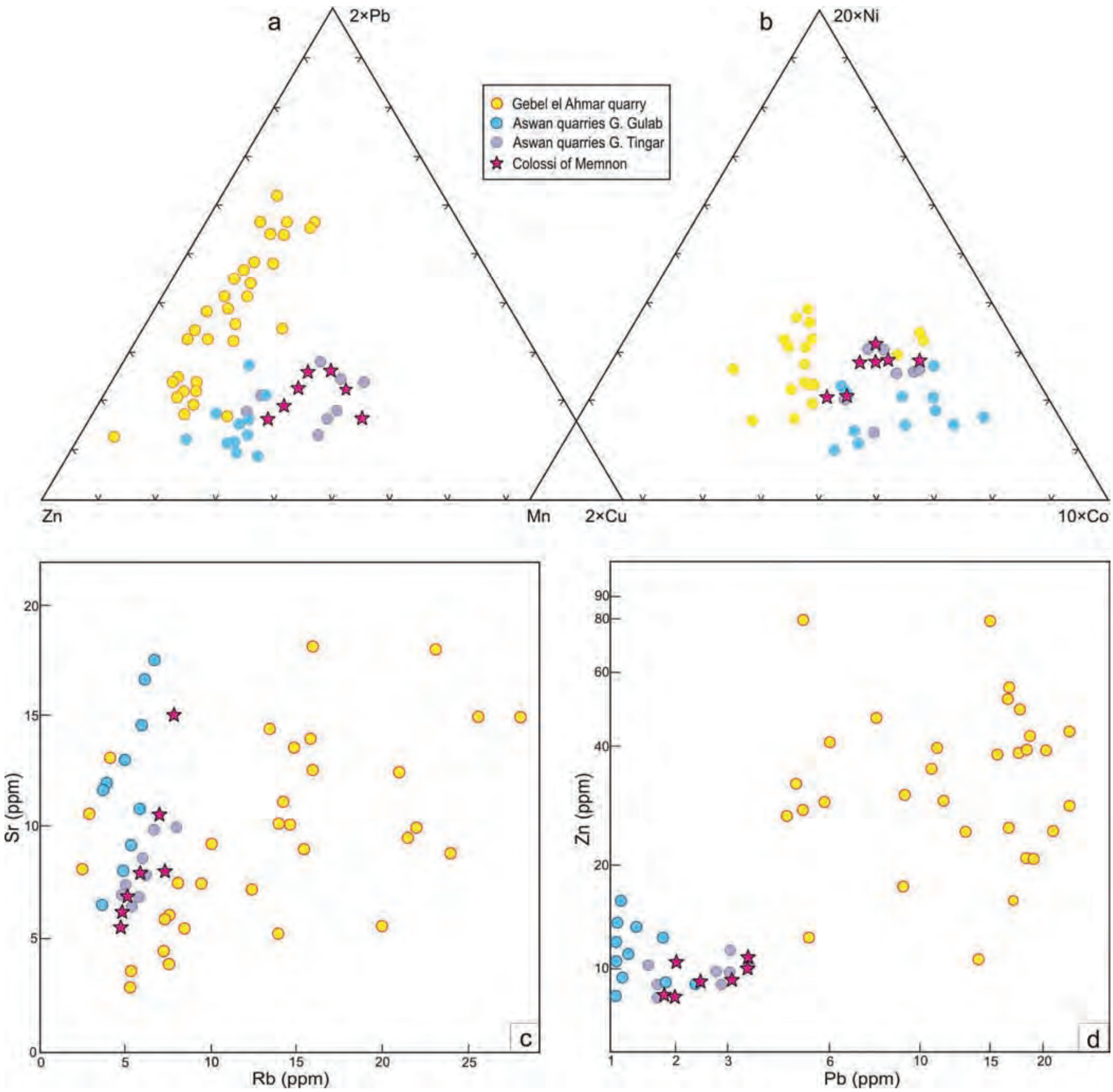

Figure 4. Geochemical data presented by Klemm and Klemm (2008). (a) Zinc, lead and copper abundances for the Colossi of Memnon plotted with data for quartzites from Gebel Ahmar and Aswan quarries. Redrawn from Klemm and Klemm (2008, fig. 351). (b) Nickel, manganese and cobalt abundances for the Colossi of Memnon plotted with data for quartzites from Gebel Ahmar and Aswan quarries. Redrawn from Klemm and Klemm (2008, fig. 353). (c) Strontium and rubidium abundances for the Colossi of Memnon plotted with data for quartzites from Gebel Ahmar and Aswan quarries. Redrawn from Klemm and Klemm (2008, fig. 354). D. Zinc and lead abundances for the Colossi of Memnon plotted with data for quartzites from Gebel Ahmar and Aswan quarries. Redrawn from Klemm and Klemm (2008, fig. 352).

ment with an ultrasonic probe to remove clay and other adhering minerals (see Morton and Hallsworth 1994). The samples were then sieved and the 63–125 micron fraction mounted on glass slides, using Canada balsam. The selection of a relatively narrow grain-size range minimises the effect that varying grain size can have on mineral proportions. Although a small proportion of the grains are fragments of larger grains that broke during the disaggregation process, the preservation of elongated grains of easily fractured grains such as kyanite indicates that such fragmented grains have had a minimal effect on the mineral proportions. The slides were examined under a polarising petrographic microscope and the percentage of each heavy-mineral variety was determined by counting grains by the 'ribbon' method.

Although heavy-mineral analysis is primarily used to identify the ultimate source of a sand population, it may also be used to differentiate one sandstone from another. The latter application is the one relevant to this study. Such comparisons may be made using the entire detrital assemblage, but this approach has the drawback that mineral assemblages can undergo substantial modification by selective dissolution of the less stable components by fluids that circulate through the sandstone during weathering and burial diagenesis (Morton and Hallsworth 1994, Mange and Wright 2007). Such mineral dissolution is often non-uniform because of variation in porosity and permeability. As a result, unstable minerals can show considerable variation in abundance, even within a single sandstone bed. In a large-scale quarry, comprising a complex succession of fluvial sandstone bodies, the potential for variation within the unstable-mineral population is even greater.

The uncertainty associated with selective dissolution is overcome by restricting comparison to minerals that were stable under the prevailing weathering and burial conditions. These include the ultrastable minerals zircon, rutile, tourmaline and monazite. Other minerals known to be stable under most weathering conditions and during shallow burial are kyanite, staurolite and sillimanite, all of which have been encountered in this study.

Results

The results of the heavy-mineral analysis of quartzites from Gebel Ahmar, the Gebel Gulab–Gebel Tingar quarry complex and Wadi Abu Aggag are shown in Table 1. The minerals are arranged into two groups: those known to have been stable under the prevailing conditions of weathering and diagenesis and those that are likely to have been unstable. It is evident that the latter minerals display substantial variation within each of the three quarry groups. They thus have little potential for mineral fingerprinting of quarry sources.

Among the stable minerals, kyanite, sillimanite and staurolite are clearly more abundant in the Cairo quartzites than in the Aswan quartzites. Sillimanite is the least abundant of the three minerals, but is notable for its absence from the Aswan quartzites. Since the grains of all three minerals show no sign of significant surface etching, the contrast cannot be attributed to differing degrees of post-depositional dissolution but must reflect differences in composition of the original detrital sand assemblages. The relative abundance of kyanite, sillimanite and staurolite, both individually and as a group, can be therefore be used to distinguish between the Cairo and Aswan quartzites. Their abundance relative to the three principal ultrastable minerals (rutile, tourmaline and zircon) is expressed by the index KSi (see caption to Table 1 for formula).

Significant variation also exists in the relative proportions of the ultrastable minerals themselves. However, since tourmaline possesses a much lower specific gravity than the remainder, variation in the relative abundance of tourmaline may in part be the result of density fractionation during river transport. The effects of such density fractionation can be minimised by comparing the relative abundance of rutile and zircon, which have comparable density and shape. This ratio is expressed by the index RuZi (see caption to Table 1 for formula).

The values of the two mineral indices KSi and RuZi are plotted graphically in Figure 5. In addition to showing a clear separation between the Cairo and Aswan quartzites by virtue of their KSi values, the plot also reveals a significant difference in the range of RuZi values between the quartzites of the Gebel Gulab–Gebel Tingar area and those of Wadi Abu Aggag. Apart from one sample, the former quartzites display lower RuZi values. Further study will be required to determine whether this compositional difference could be used to identify quarry provenance for the Aswan area. Also apparent from Figure 5 is the much wider range in composition displayed by the Gebel Ahmar quartzites compared with those from Aswan. A consequence of this wide range in composition is that it is more difficult to obtain a representative set of samples for the Gebel Ahmar quarries than for those of Aswan.

Also plotted on Figure 5 are data for quartzite statues from the mortuary temple of Amenhotep III at Kom el-Hetan

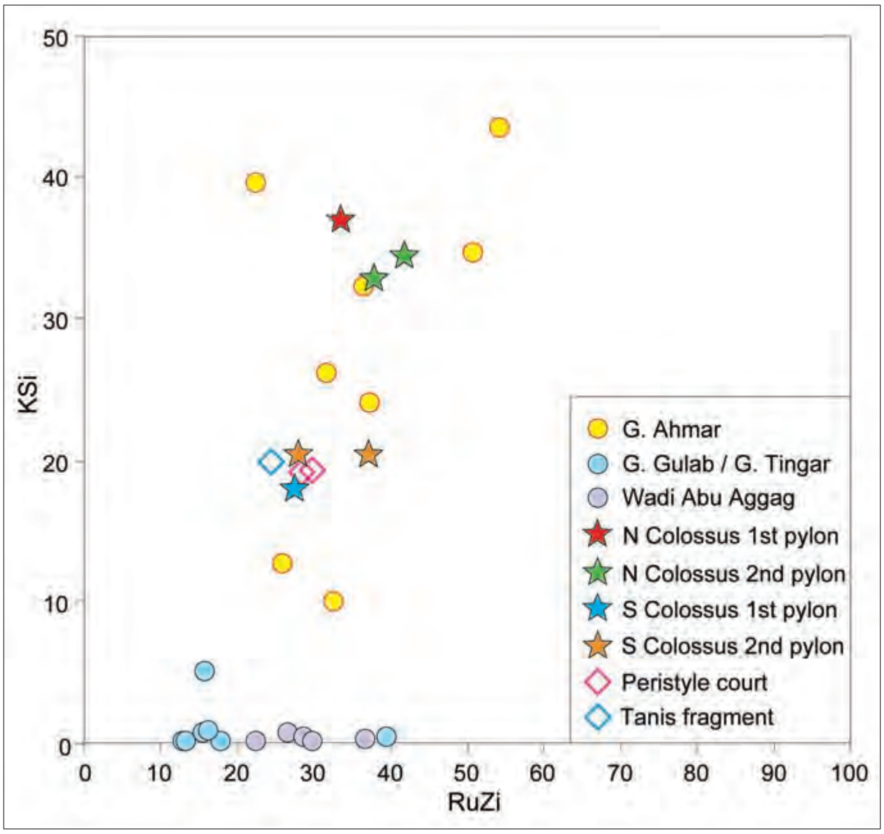

Figure 5. Heavy-mineral data for quartzite artefacts in the Amenhotep III temple, West Bank, Thebes, compared with data for quartzites from Gebel Ahmar and Aswan quarries. KSi = ratio of kyanite, sillimanite and staurolite to the ultrastable minerals rutile, tourmaline and zircon. RuZi = ratio of rutile to zircon. See caption to Table 1 for details of formulae.

on the West Bank at Thebes (Stadelmann and Sourouzian 2001, Sourouzian 2006, 2008). These include samples from the north and south colossi of the first pylon (the Colossi of Memnon) and from the remains of the north and south colossi of the second pylon (see Figure 6). Also included are fragments of quartzite statues that previously stood in the peristyle (solar) court. All of these quartzites plot within the field for Gebel Ahmar. A quartzite fragment from Tanis (for location see Figure 1) also falls within the Gebel Ahmar field, as might be expected for a site in the Delta area. The mineral composition of all of the quartzite statues studied thus favours a Gebel Ahmar source. In addition, some heavy-mineral grains from the southern Memnon Colossus possess well-developed fringes of microcrystalline quartz cement (Figure 7), which is generally agreed to be found only at Gebel Ahmar (see above).

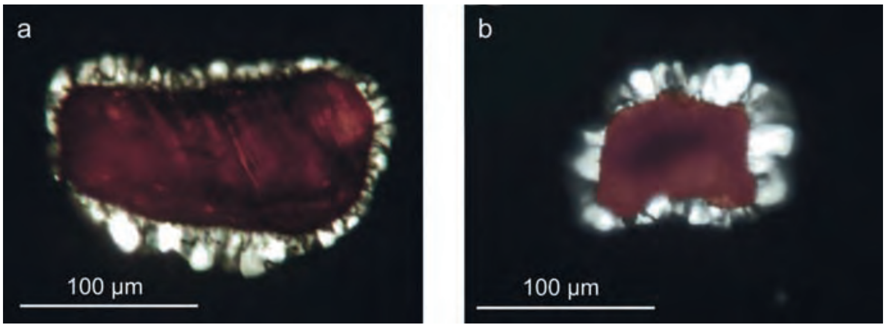

Figure 7. Photomicrograph of microcrystalline quartz fringe cement adhering to heavy-mineral grains from the southern Memnon Colossus. (a) Rutile grain as nucleus. (b) Hematite grain as nucleus.

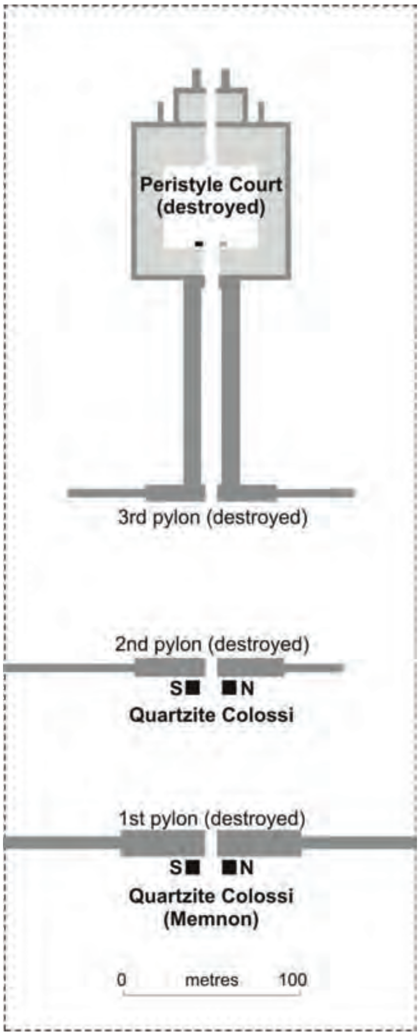

Figure 6. Plan of part of the mortuary temple of Amenhotep III, showing location of the quartzite colossi and Peristyle Court quartzite fragments analysed in this study.

An additional feature of these plots is that the temple samples fall into two compositional groups, each with a limited range of index values. This is in marked contrast to the wide range in composition of the samples collected at Gebel Ahmar in recent years. The most likely explanation of this feature is that extraction for monumental and architectural purposes will have focussed on those parts of Gebel Ahmar that contained the most massive and uniform bodies of quartzite. These are most likely to have occurred within the lower parts of major fluvial channel fills. Since the best stone will have been extensively worked, it is likely that the quartzite sampled at outcrop in recent times is not representative of the high-quality quartzite that was worked in ancient times. This conclusion is supported by the contrast in grain size between the recently collected samples (fine grained) and the artefacts (coarse grained). Most probably, the recently collected samples represent the upper part of the fluvial succession, deposited at a time of relatively low energy within the river system.

The main compositonal group of Pharaonic quartzite samples includes those from the two southern colossi and those from the peristyle court. The close similarity in composition of this group suggests that their host blocks were extracted from a specific part of the Gebel Ahmar site. Since the sample from the city of Tanis (20th to 22nd dynasties: 1190–716 BC) has a similar composition, it may be that this compositional field represents a major, long-term quarry site within the Gebel Ahmar complex.

The subordinate compositional group consists of samples from the two northern colossi. Again, the limited compositional range suggests extraction from a specific site at Gebel Ahmar, but evidently not the same site that supplied the main group of samples. Whether this represents a deliberate selection of different quarrying sites for the two northern and the two southern colossi is not clear, but the possibility of symbolic extraction from northern and southern parts of Gebel Ahmar cannot be ruled out.

Conclusions

This study has demonstrated that the Colossi of Memnon and other quartzite statues within the mortuary temple of Amenhotep III were quarried at Gebel Ahmar, as previously inferred from epigraphic evidence. Data acquired for the quartzites from the Aswan area indicate that it may be possible to distinguish between quartzite quarried on the west bank of the Nile (Gebel Gulab–Gebel Tingar) and quartzite quarried on the east bank (Wadi Abu Aggag).

The proposed Gebel Ahmar source for the Colossi of Memnon is in agreement with the conclusion reached by Heizer et al. (1973) on the basis of chemical analysis. It is counter to the conclusion of Klemm et al. (1984), who proposed an Aswan source, also based on chemical analysis. It seems likely that the discrepancy between the two sets of chemical analysis stems from the original sampling. As pointed out by Klemm

Table 1. Heavy-mineral data and indices for quarry and temple quartzites.

			Unstable minerals %						Stable minerals %									Mineral indices			
Location	Sample No	Details	Ap	Ca	Cp	Ep	Gt	Ti	Ky	Mo	Ru	Si	Sp	St	To	Zr	count	RuZi	count	KSi	count
Gebel Ahmar	GA1		0.0	1.9	0.5	0.5	0.9	0.0	18.3	0.0	20.2	1.9	0.0	10.8	16.4	28.6	213	36.5	96	32.2	205
	GA2		0.8	0.0	0.0	0.0	3.9	0.0	1.6	0.0	19.4	1.6	0.0	6.2	7.0	58.9	129	32.6	43	9.8	122
	GA3		0.0	0.7	0.0	3.3	0.0	0.0	9.8	0.0	24.2	9.2	0.0	14.4	15.0	23.5	153	50.7	73	34.7	147
	GA6		1.8	0.9	1.8	0.0	0.9	0.0	24.6	2.6	9.6	5.3	1.8	7.0	10.5	33.3	114	22.4	49	39.6	106
	GA7		0.0	0.4	0.0	0.0	1.1	0.0	19.2	0.2	16.9	3.6	0.0	20.0	24.3	14.3	474	54.1	148	43.5	467
	GA8		0.4	0.4	0.0	1.2	0.4	0.0	13.4	1.6	20.2	2.0	0.0	8.1	17.8	34.4	247	37.0	135	24.1	241
	CD1		0.0	0.2	0.0	0.0	0.0	0.0	8.2	0.0	21.6	0.6	0.0	3.9	3.3	62.3	514	25.8	431	12.7	513
	CD2		0.0	0.3	0.0	0.3	0.6	0.0	15.7	0.0	19.6	3.2	0.0	7.1	10.9	42.3	312	31.6	193	26.3	308
Gebels	ASW1		0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.9	17.1	0.0	0.0	0.0	1.7	80.0	350	17.6	340	0.0	349
Gulab/Tingar	ASW2		0.0	0.0	0.6	0.9	0.0	0.0	0.0	1.8	12.2	0.0	0.6	0.0	3.0	80.9	329	13.1	306	0.0	322
	ASW31688		0.7	1.4	2.1	0.7	0.0	0.0	0.0	0.0	12.6	0.0	0.0	0.7	16.1	65.7	143	16.1	112	0.7	136
	ASW31689		0.0	1.3	6.0	11.3	1.3	0.0	2.0	0.7	11.3	0.0	0.0	2.0	4.0	60.3	151	15.7	108	5.0	121
	ASW31690		0.0	1.9	1.9	4.3	0.0	0.0	0.5	0.3	13.6	0.0	0.0	0.0	2.7	74.9	374	15.4	331	0.6	344
	ASW31695		0.0	0.2	0.2	0.0	0.2	0.0	0.2	0.0	33.1	0.0	0.0	0.2	15.2	50.9	643	39.4	540	0.3	640
	ASW31696		0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	12.5	0.0	0.0	0.0	2.2	83.9	360	13.0	347	0.0	360
Wadi	HSWA1		0.4	0.0	0.1	0.0	0.6	0.0	0.0	0.3	27.8	0.0	0.1	0.1	22.0	48.4	672	36.5	512	0.2	663
Abu Aggag	HSWA2		0.0	0.0	0.0	0.0	0.1	0.0	0.1	1.1	25.9	0.0	0.1	0.1	7.9	64.6	735	28.6	665	0.3	733
	WAA1		0.8	1.5	1.5	2.3	0.8	0.8	0.0	0.0	19.2	0.0	0.0	0.0	6.2	66.9	130	22.3	112	0.0	120
	WAA2		0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	24.6	0.0	0.0	0.3	6.1	68.4	329	26.5	306	0.6	328
	WAA4		0.0	0.4	0.4	0.0	0.8	0.0	0.0	0.8	27.5	0.0	0.0	0.0	5.7	64.4	247	29.6	226	0.0	242
	WAA5		0.0	0.7	0.0	0.0	0.7	0.0	0.7	0.0	23.6	0.0	0.0	0.0	8.9	65.6	305	26.5	272	0.7	301
Mortuary	HST1	Pylon I N Colossus	1.4	2.8	5.6	1.4	2.8	0.0	9.7	0.0	13.9	9.7	0.0	12.5	12.5	27.8	72	33.3	30	37.1	62
Temple	HST3	Pylon I S Colossus	0.0	11.1	12.5	13.4	2.8	0.9	6.9	0.0	12.0	1.9	0.0	1.9	4.6	31.9	216	27.4	95	18.0	128
	HST4B	Pylon II N Colossus	0.4	3.5	2.7	5.5	1.1	0.5	15.1	0.4	19.3	3.4	0.0	11.2	9.9	27.0	741	41.7	343	34.4	639
	HST4C	Pylon II N Colossus	0.6	0.7	0.2	1.4	0.6	0.2	17.8	1.2	19.6	4.8	0.2	9.0	11.4	32.4	1259	37.7	655	32.8	1211
	HST5A	Pylon II S Colossus	0.3	0.8	1.0	0.8	0.5	0.3	10.5	0.0	25.2	3.4	0.0	5.8	8.6	42.6	591	40.6	424	20.4	568
	HST5B	Pylon II S Colossus	0.8	9.3	5.6	9.3	0.8	1.3	7.7	0.0	14.6	2.9	0.0	4.2	5.6	37.9	377	27.8	198	20.4	275
Tanis	CD3	Loose fragment	0.0	0.9	0.0	0.0	0.0	0.0	13.7	0.0	18.8	1.7	0.0	4.3	2.6	58.1	117	24.4	90	19.8	116

Unstable minerals: Ap = apatite; Ca = calcic amphibole; Cp = clinopyroxene; Ep = epidote; Gt = garnet; Ti = titanite (sphene).

Stable minerals: Cr = chrome spinel; Ky = kyanite; Mo = monazite; Ru = rutile; Si = sillimanite; Sp = spinel; St = staurolite; To = tourmaline; Zr = zircon.
RuZi (rutile:zircon index) = 100xRu/(Ru+Zr), KSi (kyanite-sillimanite-staurolite index) = 100x(Ky+Si+St)/(Ky+Si+St+Ru+To+Zr).

and Klemm (2008, p. 231), Heizer et al. (1973) were able to collect samples from the northern Memnon Colossus itself, whereas Klemm et al. (1984) had to rely on loose quartzite fragments, raising the possibility that they were in fact analysing material from the Roman restoration of the northern Colossus, not from the original blocks. Since the restoration blocks are believed to have come from Aswan (Heizer et al. (1973) and Bowman et al. (1984), this would explain the anomalous results obtained by Klemm et al. (1984).

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Granite quarry survey in the Aswan region, Egypt: shedding new light on ancient quarrying

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In the QuarryScapes project, a detailed survey of granite quarries east of the Aswan region was made by the Supreme Council of Antiquities (SCA), Egypt, being one of the partners in the project. Localising and recording the ancient granite quarries were the main goals of the survey work. During the survey, key material remains associated with ancient quarrying were found and studied, such as inscriptions, graffiti, unfinished objects, roads, shelter areas and transportation ramps. In addition, a detailed investigation to define the boundaries of the remaining parts of the ancient granite-quarry areas was made as a necessary step in preparing plans for their immediate protection. Due to the urgent threats to the ancient quarries, some of the modern dimension stone quarries have to relocate to other granite-deposit areas, in particular in the Alaki region further to the south.

Introduction

The 'Aswan Granite' was the third most important stone used in Egyptian civilisation, after sandstone and limestone. Its use for vases, stelae, statues, sarcophagi and buildings commenced from at least the Early Dynastic Period (Aston et al. 2000). In terms of quantities, its largest use was during the Old Kingdom, particularly associated with the 4th Dynasty pyramid complexes at Giza, and again during the New Kingdom for obelisks and colossal statues (Röder 1965, Habachi 1984). The stone was also extensively used during the Graeco–Roman Period, and even today several companies are exploiting different varieties as dimension stone.

Although 'granite' often is used as a collective, 'industrial' term for the plutonic rocks in the area, it is slightly misleading. They constitute a range of granitoid rocks, varying from granitic to tonalitic in composition (Brown and Harrell 1998, Klemm and Klemm 1993, 2008, Harrell and Storemyr 2009). The most widely used type is the Aswan red or pink granite, which is essentially coarse grained to very coarse grained,

Kelany, A., Negem, M., Tohami, A. and Heldal, T. (2009) Granite quarry survey in the Aswan region, Egypt: shedding new light on ancient quarrying. *In* Abu-Jaber, N., Bloxam, E.G., Degryse, P. and Heldal, T. (eds.) *QuarryScapes: ancient stone quarry landscapes in the Eastern Mediterranean*, Geological Survey of Norway Special Publication,**12**, pp. 87–98.

but porphyritic and gneissic varieties are occasionally found. The so-called 'black granite' is essentially of granodioritic to tonalitic composition, medium- to coarse grained and commonly porphyritic, containing large, pink to white phenocrysts. A third type is red to grey, fine-grained granite ('Younger granite' by Klemm and Klemm 2008). In-between these types there are transitional varieties, making the outcrop area a source of a wide range of different subtypes. For simplicity, we have, however, chosen to apply 'granite' as a collective term when speaking of such quarrying in general.

The ancient Egyptians called
the pink granite

 *m3t*,

which was the general term for this stone throughout all periods. Later it was used as a special term for the red granite after the word

 *m3t rwdt*.

On the other hand, the black granodiorite and tonalite were called

 *inr km*.

Sometimes the Egyptians added the place name to the term of the stone. For example, the granite from Elephantine was called

 *m3t 3bw*

(Harris 1961).

The importance of the quarrying activity over such a long period has given Aswan its unique character. Key locations of granite quarrying can be found along the east bank of Aswan and islands within the First Cataract (Figure 1). The publication from the Napoleon Campaign refers to these large areas of quarries, starting from the modern town to Philae and thus covering most of the east bank of Aswan (Jomard 1809). Over the last four years the Joint Swiss and Egyptian Archaeological Mission has discovered some new extensions of the ancient quarries, dated to the Old and Middle Kingdoms, to the north of the ancient city of Aswan (von Pilgrim, in press).

Previous research of the Aswan granite quarries

The Unfinished Obelisk and the colossal statue at Shallal are the most attractive sites in the granite quarries on the east bank of Aswan. Many researchers and travellers have paid attention to these two sites, in particular Engelbach (1922, 1923) who was the first person to excavate the Unfinished Obelisk quarry. He turned the direction of the archaeologists and Egyptologists to become more interested in ancient quarry sites, especially after his work at the Unfinished Obelisk and at Chephren's quarry in Lower Nubia (Engelbach 1933, 1938). Important research in the Aswan region was also undertaken by De Morgan et al. (1894), who described the quarries and

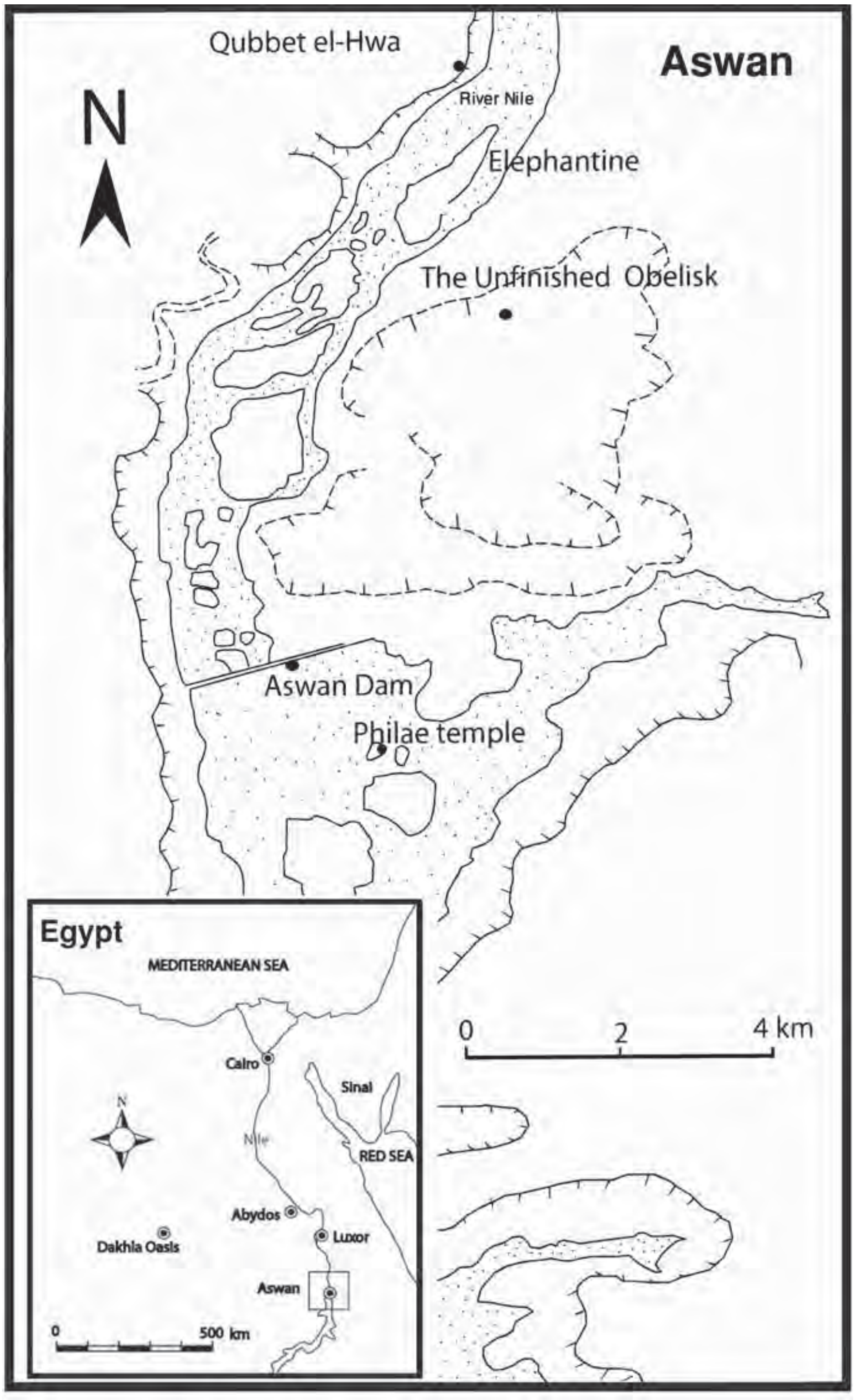

Figure 1. Map of the Aswan area.

the inscriptions, as well as Ball (1907), who published several studies of the first cataract region, including the ancient quarries.

More recently, important studies of the Aswan granite quarries include Röder (1965) and Klemm and Klemm (1993, 2008), providing the most comprehensive geological and archaeological surveys of the granite quarries. Many archaeological features were found, from inscriptions to ancient fortifications that have subsequently attracted many researchers. Although not directly connected with quarrying activity, the study of such diverse material culture has been needed to understand the greater story of the Aswan region (Jaritz 1981, 1993).

In 2002, the Egyptian Supreme Council of Antiquities carried out an extensive excavation of the Unfinished Obelisk quarry. This has enabled us to gain a greater understanding of ancient techniques used in the quarrying of granite (Kelany 2003). This, in turn, encouraged us to commence the demanding task of surveying the rest of the granite quarries as discussed in the present paper.

Surveying the quarries

In recent years, modern quarrying and urbanisation have caused destruction of a large number of ancient quarry sites (Storemyr 2009), even many of which were described by Klemm and Klemm (1993). The main objectives for the survey of the granite quarries were thus to identify remaining quarry areas, characterise them and delineate them on the map, in order to ensure future protection of the last remains. Our survey first focussed on the high-risk areas in the northeastern part of the quarries. This was later extended to the central and southern parts. The area under investigation is located between the southern parts of the modern houses of Aswan city in the north, to the southern part of Shallal village in the south. The Nile River borders the survey area to the west, and the road between Mohmoudiya and Shallal to the east (Figure 2).

As developed during the QuarryScapes survey of the Aswan west bank (Bloxam et al. 2007) we used hand-held GPS (with an accuracy of approximately 5 m) together with satellite images such as IKONOS and QUICKBIRD to locate the quarries. In addition, we used survey maps of Aswan no. NG 36 B3b (scale 1:50,000), Aswan map sheet 15/810 and 15/795 (scale 1:25,000), compiled by the Egyptian Geological Survey 2007, as well as maps made by Klemm and Klemm (1993), to locate the sites.

Data recorded during the survey will be put into the main database of all ancient quarries of Egypt, as developed by EAIS (Egyptian Antiquities Information System, see Shawarby et al. 2009) and subsequently into a GIS system to use for both analysis and as a planning tool in terms of protecting ancient quarries from modern activities. This work aims to demonstrate a transferable method of documenting and protecting sites of archaeological significance, in terms of conservation strategies.

Geology and quarries

The geology of the Aswan area and the connection between the geology and ancient quarrying have been the subject of numerous studies since the early 20th century by scholars such as Ball (1907), Engelbach (1923), El-Shazly (1954), Röder (1965), Klemm and Klemm (1993), and Brown and Harrell (1998). The outcrops of igneous rocks are found where the younger, sedimentary rocks of the Nubian Group (Whiteman 1970) have been removed by erosion, essentially on the east bank of the Nile (between Aswan and the Shallal district) as well as on the islands in the river. Spheroidal weathering of the granitoid rocks caused the formation of so-called woolsack morphology, where the terrain is covered with a layer of in situ, rounded boulders of various sizes. Such morphology is a common phenomenon in the region, and the boulders, which can measure up to hundreds of cubic metres, are considered to be valuables sources for granite blocks even

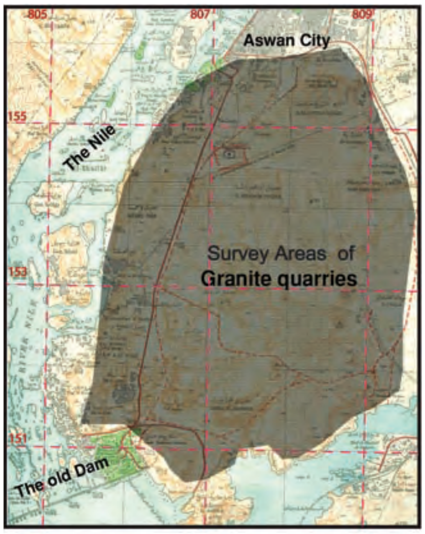

Figure 1. Map of the Aswan area.

by the modern stone industry. At present time, such morphology is seen only in parts of the Aswan outcrop area. As mentioned by Klemm and Klemm (1993) it is likely that these 'missing' boulders were the main source for the ancient quarrying. Only when they were too small (as in the case of the obelisks) or when the quarrying technology became more efficient for bedrock quarrying (as in the Roman Period) was it favourable to target the solid bedrock. Hence, the natural terrain has been strongly modified by the ancient quarrying, but largely this modification implied removal of surface boulders, leaving few and scattered remains from the quarrying activity. In modern times, quarrying and urbanisation have demolished many of these remains, and more are under urgent threat.

The chemical and mechanical weathering causing the formation of the boulders initiates along natural joints in the rock mass, commonly occurring in granitic rocks in three directions perpendicular to each other. Thus, the spacing of such joints determines the size of the boulders. Similarly, the spacing of joints is important when quarrying in bedrock, determining the maximum achievable block size. The main quarrying areas were therefore most likely situated in places where the jointing was most favourable, whilst outcrops displaying more closely spaced joints were left. This could also explain why the finer-grained 'younger' granite was rarely used, due to closely spaced fractures (Engelbach 1923, Arnold 1991, p. 37, Aston et al. 2000, p. 36).

Quarrying techniques

During the Pharaonic Period, quarrying largely involved the extraction of loose boulders. They were worked with hammer stones (pounders) of dolerite originating from dykes in the granitoids, or (less common) aplitic granite. Such pounding is among most scholars considered to be the only technique involved until the stone block reached the rough shape of a statue or other object. In the Unfinished Obelisk quarry (S1 in Figure 3), channels were made directly into the granitic bedrock. The massive amounts of dolerite hammer stones found in the quarry lead Röder (1965) to the conclusion that the channelling was made by pounding only. However, in recent excavations (Kelany 2003) massive amounts of charcoal, ash and burned mud bricks were found, suggesting that heat must have been an important agent in one or more steps of the quarrying process. Later, from the Ptolemaic Period onwards, iron tools took over in the granite quarrying. According to Klemm and Klemm (2008) chiselled channels were introduced in the Ptolemaic Period, whilst splitting with iron wedges quickly became the dominant extraction method in the Roman Period.

Transport of granite objects

There were two aspects in the transportation of granite objects from the quarries to their places of use: land transport and river transport. Here, the discussion mainly concerns land transport, in terms of transporting objects from the quarries to the Nile.

Transport of large objects from the granite quarries usually involved two steps: first, from the quarry pits out of the actual extraction area, and second, from the quarry areas to the main branch of the Nile. The first step was relatively easy when the quarrying targeted stone boulders which were normally close to the surface.

But when quarrying deep into the granite bedrock, it became more difficult to remove large stones from the quarry pit. Evidence from the excavations undertaken at the ‘Unfinished Obelisk quarry’ suggested that another large quarry operation was needed to remove remaining granite on the north side of the Unfinished Obelisk, before the actual piece could be moved (1168 tons). When clear, a pillow of sand would

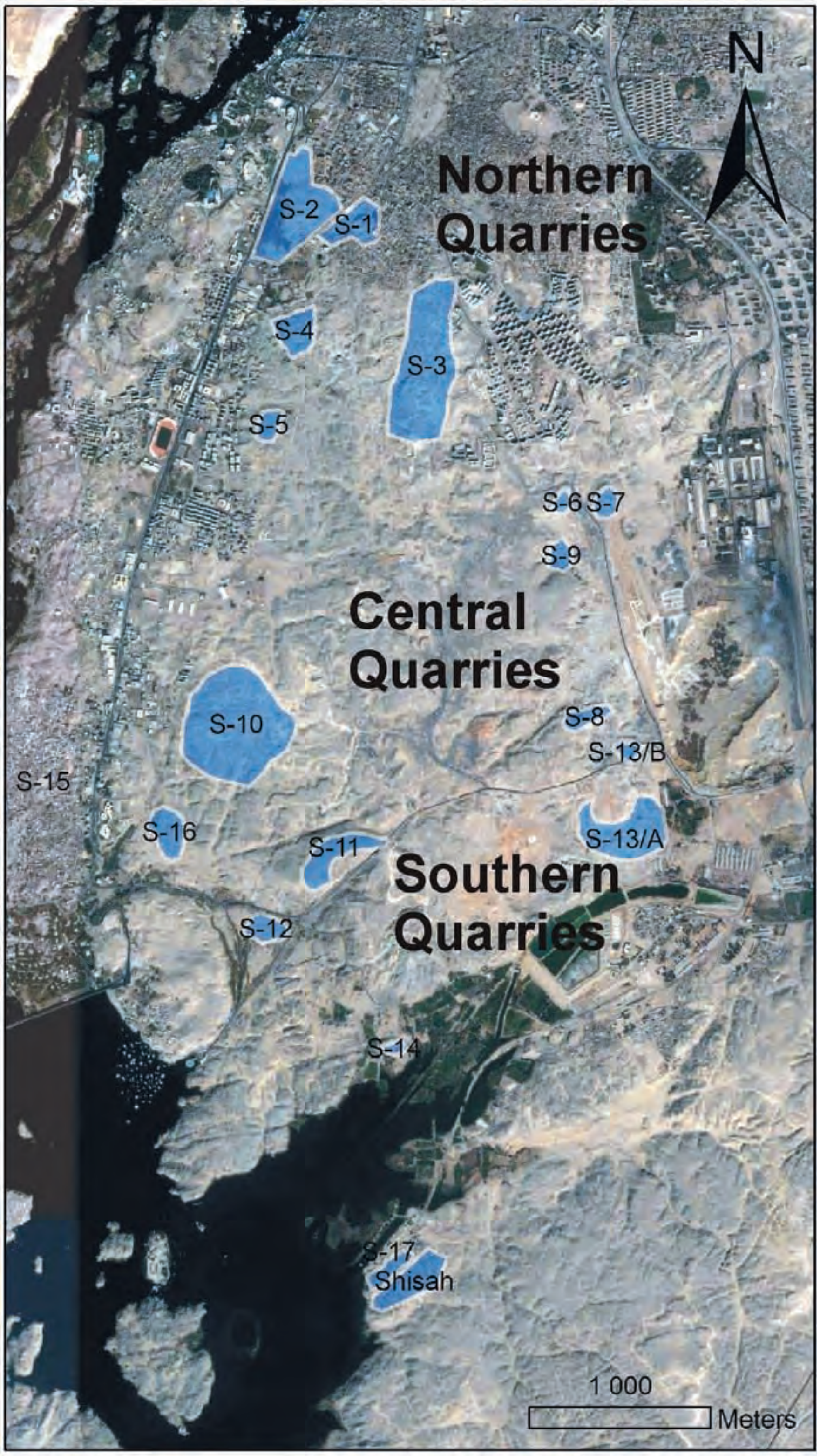

Figure 3. The quarry areas, S1–S17 as described in the text. Background satellite image from Google Earth.

probably have been used to protect it from hard surfaces and for evening out the slope. Sand, probably from dry wadis nearby and from wind action, was found within the quarry debris (Kelany 2003). In other cases, ramps were built to transport stones from the quarries down to lower levels. In the quarries at the Aswan west bank, there are many well-preserved examples of this type of ramp, connected to stone-paved roads, creating a wide stone transportation network (Heldal et al. 2005, Bloxam et al. 2007). Many similar ramps were documented in the granite quarries, although limited in comparison with the west bank. The reason for this may be poor preservation of most of the Northern quarries, which was the main area for the production of large objects, or the prevalence of dry wadis in-between ancient quarries which were used as canals for the transport of stones (Kelany et al. 2007).

Many kilometres of paved quarry roads were made using local rubble stones in one or several layers, similar to the roads found at the Aswan west bank quarries. These roads are largely built in quarries located deep into the granite hills, or on the plateau, where they are far away from wadis or canals. Most of these roads were made in connection with the New Kingdom quarries and later reused during Roman times.

The longest known road in the granite quarries, constructed with local granite, is 350 m long and leads from a New Kingdom quarry on the top of the plateau to a lower level towards the northwest (Figure 4a–c). Another paved road was found in the eastern part of the Northern quarries, built of 2 to 4 levels of rubble stones (Figure 4d–f) and associated with an area of large-object quarrying. A short, paved road, comprising only built stone edges with nothing in-between, was found in the western part of the Northern quarries (Figure 4g), crossing a small, sandy wadi, leading to a small work area. The same type of cleared tracks aligned with stones on both sides is found at the Aswan west bank, but the function of the alignments is not yet completely understood.

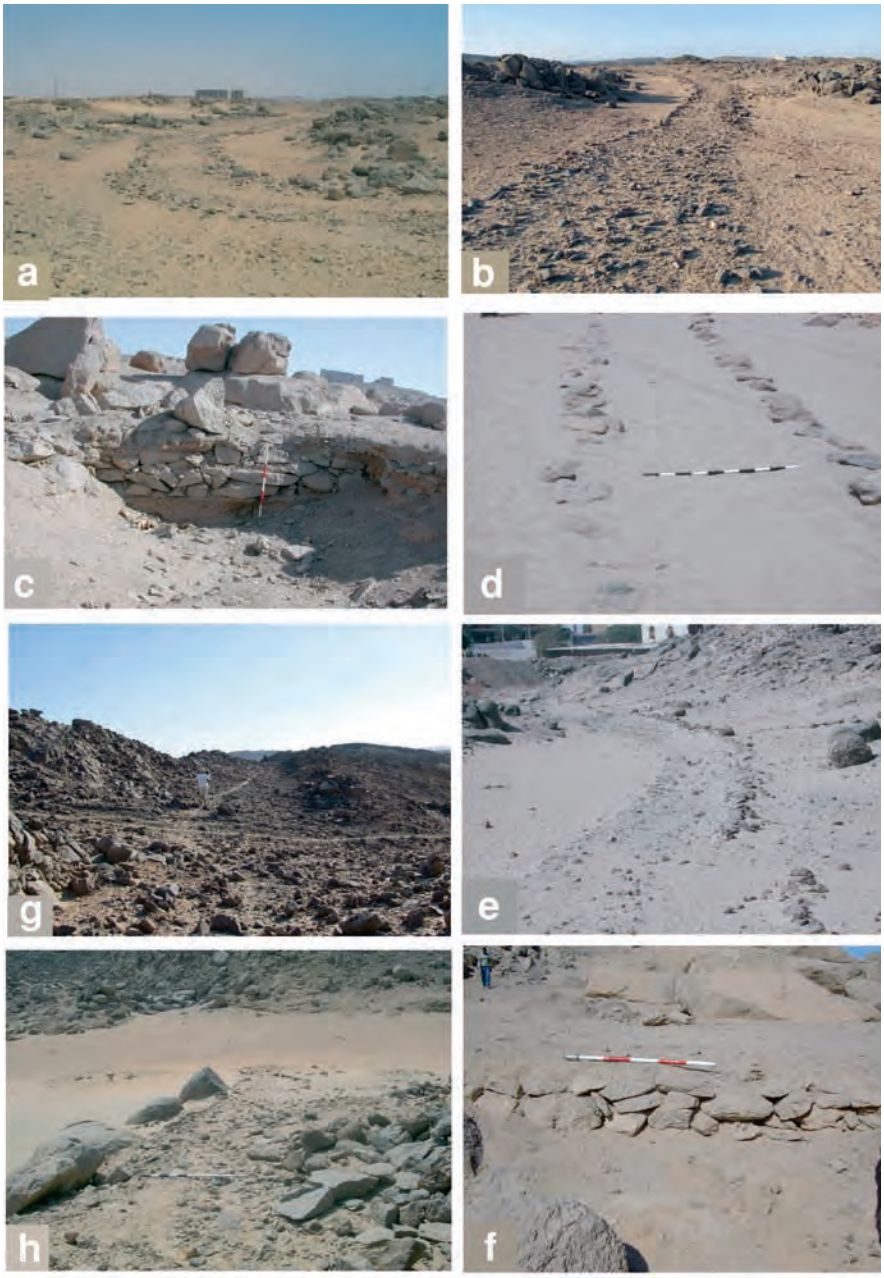

Figure 4. Different types of stone transportation roads (New Kingdom and Roman Periods) in the granite quarries. (a,b,e) paved roads, (c,d) built-up roads, (d) track with stone alignments, (g) footpath, (h) ramp.

Another type of transport method used for small objects from granite quarries, in the New Kingdom and Roman Period, was via footpaths or animal paths. There are only a few places where these ancient paths can be clearly seen (Figure 4h), given the overprinting by modern quarry activities.

The Northern quarries

Most of the Northern quarries (Figure 3) have been heavily affected by modern activities, except the Unfinished Obelisk site (S–1) and the quarries at the Fatimid cemetery (S–2), which are under the protection of the Egyptian SCA. The rest of the ancient quarries now remain as islands surrounded by modern activity (Figure 3). Our survey identified three main quarry areas (S3, S4 and S5, Figure 3) in addition to the above mentioned. Essentially, the boulder layers have been the target for extraction. Numerous large and small objects were quarried from this area during the New Kingdom and Graeco–Roman Period, as well as in small scale during Islamic times.

Ashy layers with charcoal mixed with

the quarry debris suggest that fire setting was widely applied in the quarrying process during the Pharaonic Period, also outside the Unfinished Obelisk quarry. In addition, dolerite stone tools were found scattered across these areas, suggesting their use in pounding and trimming of extracted blocks. Pottery shards found in the quarries dated to both the New Kingdom and Graeco–Roman times.

Many large unfinished objects were found inside the quarries, probably left behind because of cracks or other features that made the blocks unusable. These included a circular base from the New Kingdom (according to the quarrying techniques and pottery shards found in the quarry debris) (Figure 5h) and a large square base, probably of an obelisk (Figure 5c). Several reused, unfinished granite stelae were found inside a modern blacksmith's workshop (Figure 5a). Unfortunately, we could not find out from which quarry they were extracted. Column capitals and bases, as well as large millstones, all from the Graeco–Roman Period, were found at several locations in the area (Figure 5b, d, f, g).

In the northwestern corner of the Northern quarries (S–3) there are several trenches in the granite bedrock, in particular connected to dykes of dolerite and/or aplite. Beside these trenches there are roughly shaped pieces of rock mixed with quarry debris. These pieces have a more or less uniform size, compatible with the sizes of discarded pounders found in the quarries. Thus, these trenches seem to represent quarries for the production of stone tools in the Pharaonic Period. Pottery shards around the trenches indicate more specifically a New Kingdom age. Such tool quarries have previously been documented by Klemm and Klemm (2008) in the western and southern part of the granite outcrop area. However, the ones in the Northern quarries are the first to be found in this area, and so far the closest ones to the Unfinished Obelisk quarry. Thus, the area may be of significant importance for revealing more knowledge about the Pharaonic stone technology.

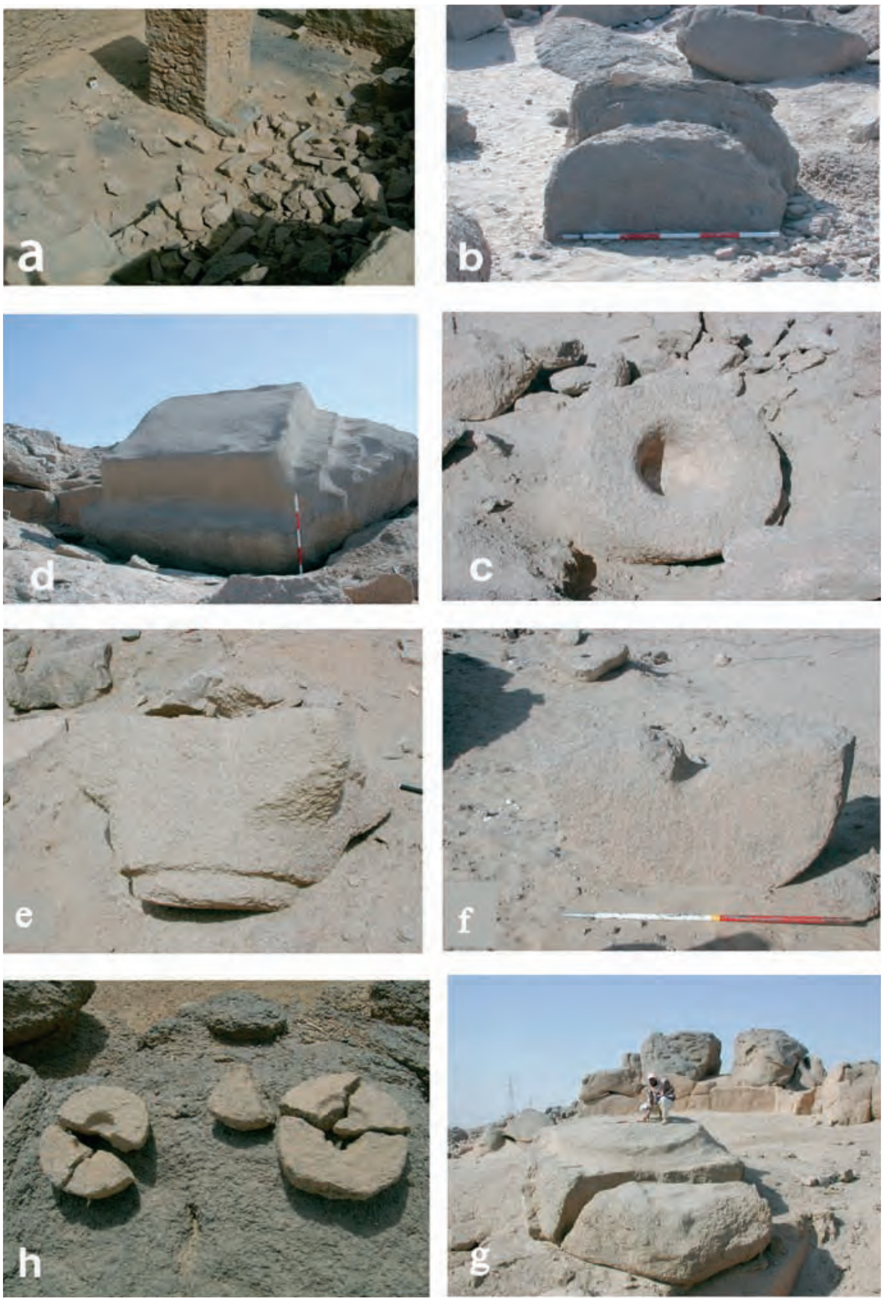

Figure 5. Unfinished objects from the Northern quarries. (a) Unfinished granite stele reused in modern blacksmiths' room, (b, d, f, g) different types of unfinished rotary millstones, (c) unfinished granite object base, (e) granite-column capital, (h) large circular granite object base.

In the southern part of the area, a granite quarry (100x100 m) designated for the extraction of rotating millstones was found. Many pieces of discarded millstones are found in the quarry (Figure 5g). The rotary hand mills came into use in the Roman Period in the area, and are commonly found in settlements from that period.

We documented a few stone shelters inside the ancient quarries, although these are probably not associated with the large ancient quarrying activities. The absence of shelters or dwellings for the ancient quarries may be because places of more permanent settlement, for instance at Elephantine Island and Aswan, were very close by. Hence, the workmen may have travelled daily from these places to the quarries. A similar situation is also found in the quarries at the Aswan west bank (Bloxam and Kelany 2007).

The Central quarries

This quarry area is located south of the Northern quarries (Figure 3) and includes

Figure 6. Unfinished Roman Period granite baths, Southern quarries.

five identified quarry sites (S6–S10). Some of the quarries have previously been described by Klemm and Klemm (1993, Map 355). The survey work started from the northern part of these quarries, which is located directly south of the Mahmoudiya Houses (S–6).

There are two sandstone hills on top of the granite at quarry sites S6 and S7. Quarries within the sandstone unit most likely date to the Roman Period (based on pottery shards and marks from typical Roman wedging techniques) and the target for quarrying was probably ashlar blocks for buildings in Aswan. Some small granite quarries were also found in the same areas (S9), which were mainly for extraction of small granite objects in the Pharaonic Period, such as stelae and stone tools.

The Hatshepsut quarry (S8) correspond to Quarry No. 11 of Klemm and Klemm (1993, Map 355). The name of the quarry relates to inscriptions found above it (see below). Two unfinished baths from the Roman Period are found here, left in the quarries because of flaws in the stone blocks (Figure 6b, c). One of these baths is of particular interest, as it shows us how the quarrymen split and shaped large granite boulders (Figure 6b). Although the most visible objects are from the Roman Period, these quarries were clearly heavily exploited also in the New Kingdom, illustrated by massive layers of quarry debris containing stone-tool fragments and ash as well as pottery shards from that period.

Of particular interest in these quarries is the occurrence of numerous pounders of coarse-grained granite (Figure 7). Such are not common in any of the other quarry areas, and in general one believes that the granite was less suitable for pounders than dolerite and aplite. The reasons for the common occurrence of such pounders in this particular area is, however, not clear. The surfaces of these tools clearly show marks and wear from their use as pounders.

The most important discoveries made in these quarries were the hieroglyphic inscriptions. These were found on a sandstone cliff, quite high above the granite quarries (Figure 8). Stone walls from possibly a small shrine or chapel, built for a high official, were also found beside these inscriptions. Beside the walls we observed a large area of quarry debris containing fragments of dolerite tools and pottery shards dating to the New Kingdom.

There are a total of seven small inscriptions found on this sandstone cliff. Importantly, one of these inscriptions can be clearly identified as giving the name of Queen Hatshepsut of the New Kingdom (Figure 9). This is a highly


Figure 8. The location of the hieroglyphic inscription (red arrow) in sandstone cliff, Central quarries.


Figure 7. Used granite pounders, Central quarries.


Figure 9. Hieroglyphs giving the name of Queen Hatshepsut of the New Kingdom, Central quarries.

significant finding in terms of locating where quarrying of granite was undertaken during her reign (Porter and Moss 1937, Habachi 1984).

The other inscriptions found on the sandstone cliff are still under study, but it is important to mention that they mostly contain titles linked to quarry activities. Graffiti of obelisks and ostriches were also found here. These inscriptions and graffiti will be published in detail after further study.

The location of the inscriptions and the small shrine is significant. From this point, one can get a good view of the granite-quarry landscape. This situation is quite similar to the inscriptions and graffiti found in the Khnum Quarry on the west bank of Aswan (Bloxam and Kelany 2007). Possibly it had a function as a place of worship, and/or a site for overseeing the quarrying activity.

To the west of the Roman-bath quarries and the New Kingdom inscriptions many small quarries were recorded. In one of them, two unfinished objects are found. One looks like an unfinished granite statue (Figure 10f), whilst the other may represent an intended altar or boat base from the New Kingdom (Figure 10e). The other small quarries display evidence of limited, Roman activities.

Beside the cliff edge at el-Aquad, a paved road, 350 m long, leads to a small quarry area—*the long-road quarry* (S10 in Figure 3, see also Figure 4a and b). This paved road is the longest we have seen in the granite quarries in Aswan and is discussed further below. The quarry area displays evidence of the extraction and removal of at least some large blocks, and numerous smaller, initial workings on others. On the quarry face in front of the site, where the largest block was extracted, there is a hieroglyphic inscription, which could have been a mark for the quarry team (Figure 11a). The debris from quarrying here contains pottery shards dating to the New Kingdom and Roman Periods, many dolerite pounder fragments, charcoal and ashy debris. In addition, we observed many oval-shaped stone tools which came from aplitic veins in the granite, and several small quarries for such. This type of tool is characteristic of the area.

Figure 10. Colossus and large unfinished granite objects of the New Kingdom from the Southern quarries. (a) Shallal colossus, (b) Tlaina colossus, (c) possible base of Tlaina colossus, (d) tool quarry on the top of Tlaina colossus mountain, (e) unfinished block, possible alter or boat base, (f) unfinished seated statue.

Many stone shelters were found in these quarries. Some of them were highly deteriorated, others better preserved. This may suggest the same as the pottery shards, namely the presence of people in the area both in the New Kingdom and in the Roman Period.

The *Karor Quarry* and the surrounding area as mapped by Klemm and Klemm (1993, quarry number VII, p. 307, Map 355) is now largely destroyed by modern development (Figure 3, S–15). Out of its original quarrying context, the only object remaining in this quarry area is a Roman bath (Figure 5d). To the north, several small quarries were located in an area largely disturbed by modern development. Production remains here suggest that large objects were extracted. This makes sense logistically due to their proximity to the main road from Aswan to Philae.

The Southern quarries

This is the richest quarrying area in terms of archaeological evidence related not only to ancient quarrying, but also to an ancient wall (see below) and many rock inscriptions. The quarry landscape is generally well preserved and can be divided into several small sites.

The Shallal Quarry (S13, Figure 3) is one of the most famous quarrying areas after the Unfinished Obelisk quarry. Egyp-

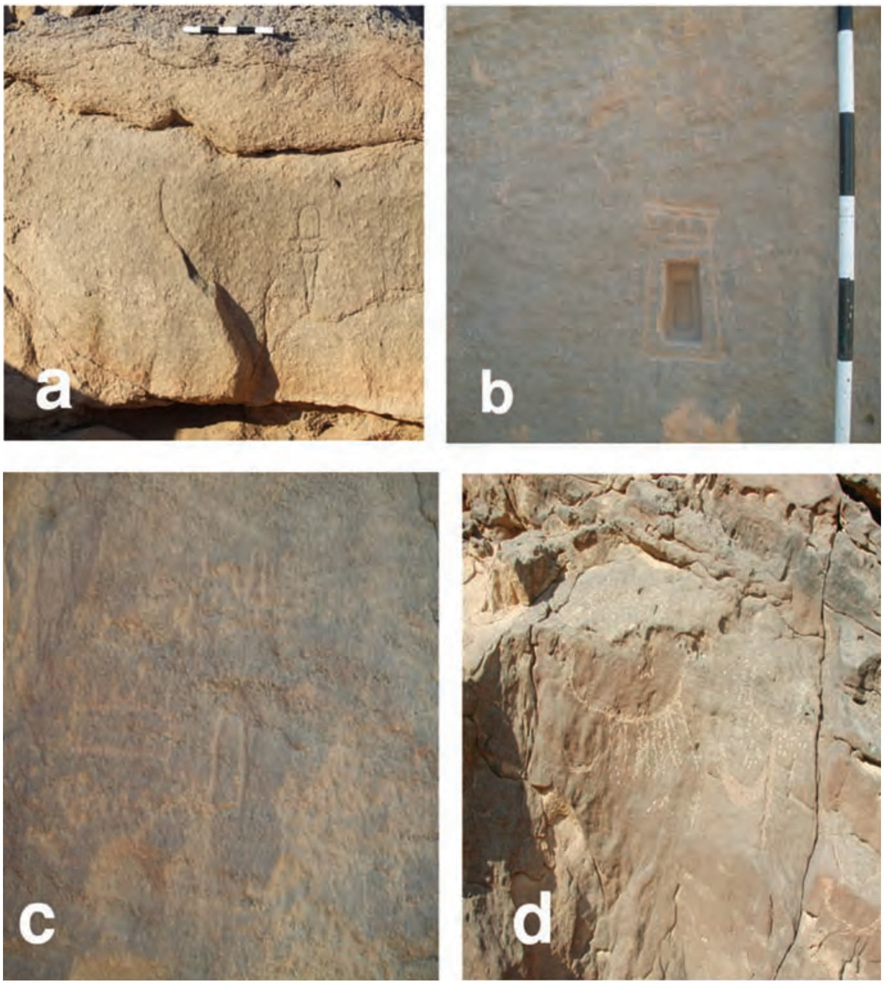

Figure 11. Epigraphic data from granite quarries. (a) Inscribed hieroglyphic mark, (b) hieroglyphic signs depicting a shrine façade, (c) inscription on stone boulder with name of Imn*, (d) Predynastic rock art of a boat.*

tologists usually call this area 'The Southern Quarry' or 'Ramses II Statue Quarry' given the large statue that is lying here. Yet, there is no specific archaeological evidence that confirms such a connection with the reign of Ramses II. Today, this area of quarrying is now split in two by a modern asphalt road. In addition to the statues, many other unfinished objects, such as four Roman baths, are found across the landscape. Encroaching modern quarrying is gradually eating away these quarries, with the loss of archaeological remains that were earlier described by de Morgan (1894).

During our recent archaeological survey many new findings were made, such as inscriptions and graffiti and elements of the infrastructure related to the ancient quarrying here. A small sandstone quarry was found located just to the north of the unfinished statue in the sandstone layers that cap the granite. A limited number of sandstone blocks were quarried here, probably used for building the large transport road beside the unfinished statue and for building workers' shelters.

On the quarry face of the sandstone quarry there is some graffiti depicting the hieroglyphic sign *cnh* and a stone jug with a handle sign which refers to the god Khnum—one of the local triad of cataract gods. This type of sign has been found in many other places in west bank quarries (Bloxam et al. 2007, p. 212). Another graffiti found beside these hieroglyphic signs depicts a shrine façade, this type of shrine being found on New Kingdom papyrus (Clark and Engelbach 1930, Badawy 1968). In the sandstone quarries at Gebel el-Silsila, a similar graffiti of a rock-cut shrine was made on a quarry face dating to the New Kingdom reign Amenhotep III (Klemm and Klemm 1993, p. 247). The purpose of such shrines in ancient Egyptian quarries, especially during the New Kingdom, was worship and commemoration (Caminos 1963, p. 2).

Another inscription, although difficult to interpret, was found just beside the unfinished statue. Inscribed on a boulder that has fallen down from a sandstone layer capping the top of a hill, only the name of *Imn* could be read (Figure 11c). The location of this inscription and the methods by which it was engraved suggest it was the work of a lower rank of craftsman. In addition, two small shelters that utilised existing natural holes in the sandstone cliff were documented. Many small dolerite fragments were found on the floors of these shelters, with one unfinished (but broken) dolerite stone bowl. The type and technique of manufacturing this bowl indicate that it dates to the Roman Period, when the quarry was reopened for producing granite baths.

The Tlaina Quarry is located to the west of the Shallal quarry and approximately 100 m north of the SCA magazine, which was the earlier camp of the Italian mission who relocated the Philae temple (Figure 3, S–14). It is a small quarry with an abandoned colossus left close to the top of a granite hill (Figure 10b) (Klemm and Klemm 1993). Between the foot of this hill and the colossus, a cleared ramp has been made for transporting the colossus down from the quarry. Close investigation of the colossus shows a crack in the shoulder region, suggesting that this could have been why the object was abandoned.

At the foot of the granite hill, about 75 m from the colossus, an unfinished, square granite base was found during our survey work which was not documented by Klemm and Klemm (1993) (Figure 10c) The size, shape and location of this granite base may suggest that is was intended to be the base for the colossus. This is suggested particularly because we have not seen any other quarrying activities here, except for a limited amount related to the roughing out of small granite blocks and tool making (Figure 10d).

The Shisah Quarry (Figure 3) is located at the southern part of the Shallal area. The position and function of Shallal village has made it difficult to save archaeological remains here, especially the ancient quarries. It seems likely that the small Roman Period quarries, located between the modern houses, were used for the production of building stone and other granite objects associated with the Philae temples opposite (Arnold 1999). One important unfinished object, a stele, was found at the foot of the granite hills (Figure 12).This type of stele was usually used for funerary, votive and commemorative purposes and found all over Egypt in a range of dynastic contexts (Shaw and Nicholson 2002).

A sandstone quarry was also located close to the southern boundary of the Central quarries, on the top of a hill (Figure 3, S–11). Chisel marks, pottery shards and graffiti suggest this to be a Roman Period quarry. In addition, on the northeastern slope of the hill, we found what we believe to be the first recorded Predynastic rock art in the granite quarry area, a depiction of a boat (Figure 11d).

Figure 12. Unfinished granite stele from the Shisah quarry.

Figure 13. Section of the ancient fortification wall between old Aswan city and Philae temple (built late Middle Kingdom and reused/rebuilt during Graeco–Roman times) showing granite and dolerite stone interior.

Quarries along the ancient wall

In the southern part of the quarries, the famous ancient fortification wall, which dates to the Middle Kingdom, crosses the granite outcrops. (Figure 13 and Figure 3, S16) The outer face of the wall is built with mud bricks, with the interior filling comprising granite pieces probably quarried from nearby outcrops. These quarries probably represent the earliest quarrying in this particular area. Considering the length of the ancient wall, starting from the opposite side of Philae temple to the ancient Aswan city, this type of construction would have needed massive quarrying nearby. The recent investigation of the wall shows three phases of development and repairing. The last two phases belonging to Graeco–Roman times (von Pilgrim, in press). This later quarrying has largely destroyed evidence with respect to determining where the Middle Kingdom quarries might be.

Dolerite tool quarries

The dolerite tool quarries mentioned by Klemm and Klemm (1993) on the Aswan east bank have been extremely difficult to locate. In the Northern quarries, these have been completely destroyed by modern building, and in the Southern quarries, it was difficult to find traces of where the tools were manufactured. In addition, the dolerite dykes here did not appear to be of suitable quality for making such tools. However, a possible new tool quarry was found very close to the entrance of Philae temple (S–12), where a dolerite layer of high-quality stone is located. The quarries are represented by small stone heaps with associated New Kingdom and Roman pottery (Figure 14a–d). In the lower area of the quarry, chisel and wedge marks on stone flakes suggest these being representative of Roman Period or later activities (Figure 14c) (Kelany et al, in press).

Risks and threats

In the last 20 years, the ancient granite quarries have suffered much from urbanisation and modern quarrying, but most of all from ignorance; not recognising the significance of these quarry landscapes and the rich archaeological remains therein. Many modern granite quarries are situated in ancient quarries, especially in the area with the best quality of granite (Northern quarries). Not surprisingly, the modern stone industry has the same quality measures as the ancient quarrymen—uniform colour and large blocks. Most of the ancient quarry landscape in these northern areas has been obliterated by modern quarrying as well as house building. Hence, our main survey work in this area focussed on investigating and protecting the last ‘surviving’ ancient sites left inbetween these activities. The Middle and Southern quarries are, however, still in a relatively good condition, and our focus here is to relocate and/or stop modern quarrying activities in order to protect the quarry landscape. In addition, we are working on the last phase of setting up a site-management plan for the Southern quarries so that they can be opened to visitors.

The building of houses has greatly affected the Northern quarries, especially around the ‘Unfinished Obelisk quarry’. Most of the buildings were erected in the last 15 years, without any control or intervention from the SCA. Learning from this, the SCA now supervises the area with respect to new building and other activities. Other areas affected by house building linked with the growth of Aswan city can especially be seen in the Nubian areas close to the Nile on the east bank, such as at Karor Tagog, Soheil island and others close by.

Conclusions

The purpose of the presented survey was to investigate the remains of the ancient granite-quarry landscape in Aswan, in order to get an idea about their signifi-

Figure 14. Possible dolerite tool quarry, New Kingdom and Roman Periods. (a–b) Work area in the dolerite layers, (c) wedge mark on stone fragment, (d) stone heap, perhaps tool blanks.

cance and preservation. Moreover, to obtain knowledge of how much of the quarry landscape described by previous scholars has actually been destroyed over the last 20 years. For obvious reasons, the Unfinished Obelisk quarry is a site of tremendous importance, being one of the most impressive quarries in the world and a monument over ancient Egyptian technology, yet not completely understood. The other remaining sites are at first sight far less impressive, but on the other hand also less disturbed, and may provide the largest potential for future research, also for obtaining better knowledge about the obelisk site itself. Thus, the survey has helped in highlighting the significance of all these smaller quarry sites and uncovered many questions for future research.

Unfortunately, the survey also revealed an alerting degree of destruction of quarry sites, particularly in the Northern quarries. Urbanisation and modern quarrying have demolished most of the ancient quarry landscape in a short period of time. On the other hand, the Southern quarries are still in relatively good condition, but in desperate need of protection, representing the last 'unbroken' part of the ancient granite quarries in Aswan. The first step towards long-term protection of the sites has now been taken, and in the continuation we see that with such a survey, delineating the most important sites, a fruitful cooperation with the many stakeholders in the area may take place.

The newly found inscriptions and other new features of the granite quarries, described above, have also shown how easy it is to miss important elements of such sites, even in an area that has been crowded with scholars for the last centuries. Clearly, the future will reveal more discoveries in the same areas. Another important outcome of this work, in terms of professional development, was the building of our experience, knowledge and practices for SCA inspectors (inside and outside Aswan) in the recognition and documentation of ancient quarries through training courses given during this fieldwork.

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Preservation and promotion of the Sagalassos quarry and town landscape, Turkey

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At the Hellenistic–Roman town of Sagalassos most natural building stones used in the ashlar architecture originate from local lithological units, both in the immediate vicinity of the city and on its territory. Imported white limestone and white and coloured marbles represent only a small fraction of the total amount of building stones used. The proximity of the stone quarries supplying Sagalassos to the monumental centre of the town, offers great potential of contextualising this quarry landscape as part of the extended urban landscape. When the quarries of the city of Sagalassos are seen as an integral part of the monumental town, their significance can be easily demonstrated to the public and the need for their conservation becomes evident. As Sagalassos is an archaeological site where guided tours are offered and where the excavation and reconstruction of the town and its environs can be directly observed, the local quarries and their history can be disclosed to the broader audience. Although the number of people reached is moderate, such a model may hopefully serve as an example for making other similar monumental cities and their associated quarries accessible to a wider public, hence ensuring their long-term preservation.

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Introduction

At the Hellenistic–Roman town of Sagalassos (near modern Ağlasun in SW Turkey, Figure 1), natural building stones used in ashlar architecture include limestone, conglomerate, breccias, travertine and sand- to siltstone of different qualities (Degryse et al. 2008). The provenance of this stone can be related to local lithological units, both in the immediate area of the city and on its territory. Throughout the history of the city, local beige and pink, good-quality limestone remained the most important building stone (Figure 2). However, high-quality white limestone from just outside the territory of Sagalassos, some 25 km away, and white and coloured marbles imported from a distance of at least 200 km away, represent a small fraction of the total amount of building stones used (Figure 2).

As for local extraction, the nature of the quarry evidence at Sagalassos allows a tentative chronology to be proposed (Figure 1, Degryse et al. 2008). The first building stones of Sagalassos were quarried at the site proper. The quarrying of the local bedrock can be traced to the Mid-Hellenistic Period. This beige limestone from the limestone nappe near monumental Sagalassos continued to be extracted throughout the Julio–Claudian and Hadrianic to Severan Periods. The unique (single occurrence of radiolarian mudstone) limestone of the Sarıkaya quarry (Figure 1c), four kilometres to the west of the city, seems to have been used only in Late Hellenistic buildings. This quarry may have been one of the main suppliers of building stone during that period. The local pink limestone was only identified in the Ağlasun Dağları quarry (Figure 1), two kilometres northwest of the monumental town. This quarry was at least contemporary to the Sarıkaya quarry, and was still supplying building stone to Sagalassos during the 1st and 2nd centuries AD. Some of the beige and possibly pink limestone used at Sagalassos was likely brought in from just outside the southwestern territory of the town, along with the high-quality white limestone. This import can be considered a trend from the Trajanic Period (AD 98–117) onwards, at the same time as Pamphylian monuments gave up the high-quality Pisidian limestone of the 1st century AD in favour of the now massively imported cheap white (and grey veined) Proconnesian building marbles. Yet, this cheap stone never seems to have reached the Sagalassian construction sites. A keyword for quarrying the local limestone in the city area seems to be proximity. In the immediate vicinity of important stone-consuming activities, there are quarries which in size fit the required volumes. This view is also supported by the integration of possible quarries in buildings, where the (older) quarry walls or steps are used as an integral part of a (new) construction. Another interesting aspect of the quarries is the lack of well-organised quarries and systematic channelling typical of the Greek and Roman Periods. This relates

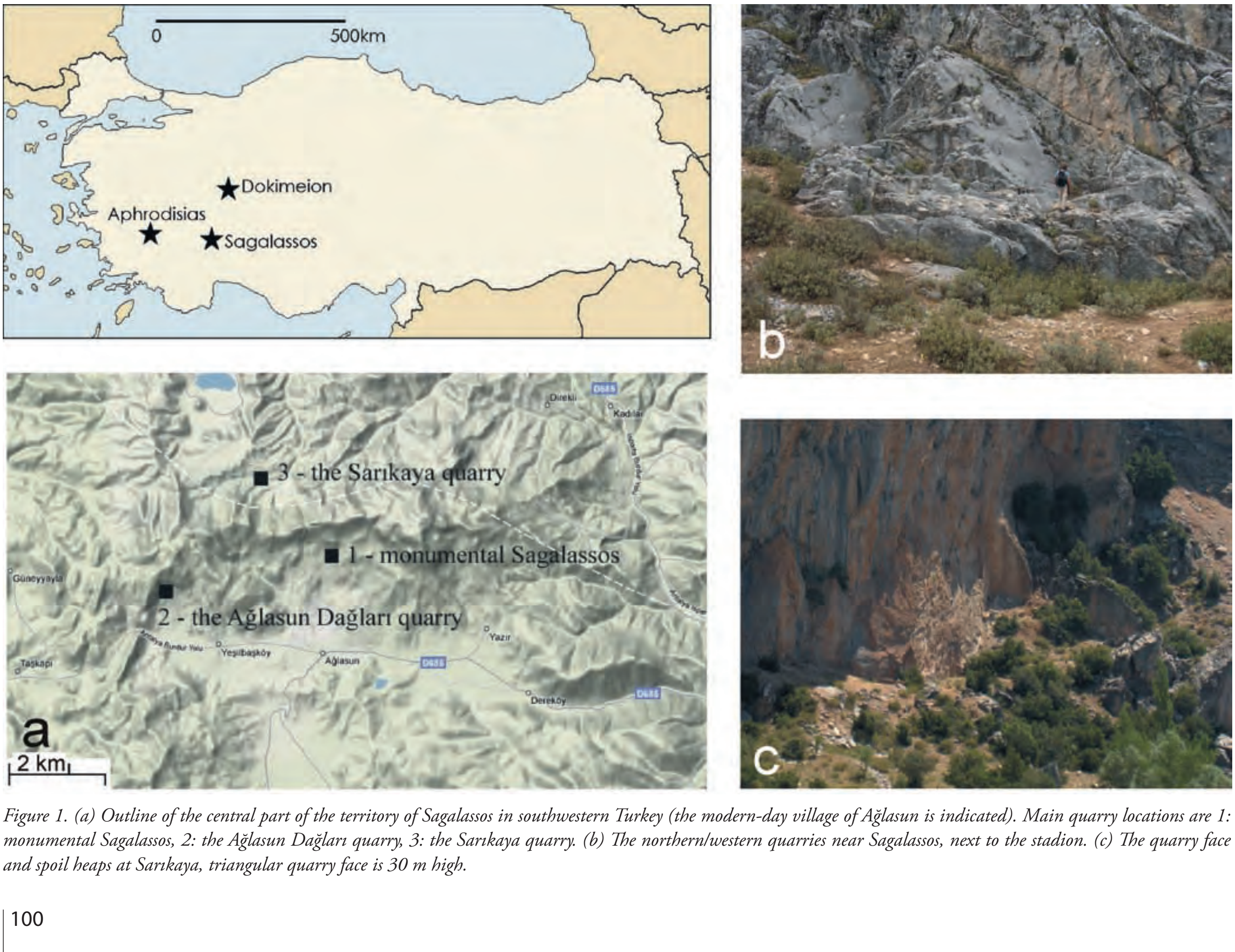

Figure 1. (a) Outline of the central part of the territory of Sagalassos in southwestern Turkey (the modern-day village of Ağlasun is indicated). Main quarry locations are 1: monumental Sagalassos, 2: the Ağlasun Dağları quarry, 3: the Sarıkaya quarry. (b) The northern/western quarries near Sagalassos, next to the stadion. (c) The quarry face and spoil heaps at Sarıkaya, triangular quarry face is 30 m high.

to the stone quality, as the abundance of natural fractures in the limestone deposits forced the quarrymen to follow the natural features as best they could.

The excavations at Sagalassos have also generated tens of tons of *crustae* and s*ham architecture* fragments in different imported coloured stones and marbles. Very expensive white marbles from Dokimeion (near Afyon) for sculpture were imported into the city already in Augustan times. From the 2nd century AD onwards also high-quality white marble from Aphrodisias was brought in for the same purpose. Apparently the high expense of both marbles, which could be more easily transported towards Sagalassos despite a distance of several hundreds of kilometres, formed a smaller obstacle than the transport towards the site of cheap white Proconnesian marble through the Pamphylian coast. From at least the 2nd century AD onwards, Docimian white to yellowish and purple veined (*pavonazetto*) marble also reached Sagalassos as wall veneer and floor coverings. The second most common stone type is green *cipollino* from Euboia in Greece, also used as wall veneer and floor pavements. Other marbles and coloured stones positively identified at Sagalassos include *rosso antico* (quarried in Peloponnesus, Greece), *verde antico* (quarried in Thessaly, Greece), *porfido rosso* and *porfido verde* (quarried in Mons Porphyrites, Egypt), *bianco e nero tigrato* (probably quarried in Asia Minor), *granito del foro* (quarried in Mons Claudianus, Egypt) and *giallo antico* (quarried in Simitthus, Tunisia). As most of these exotic marbles only occur in very small quantities, they probably reached Sagalassos not directly but as leftovers from building projects in the larger cities, where the shaping of architectural elements must have produced such smaller fragments as used in the Sagalassos *opus sectile* floors and wall veneer.

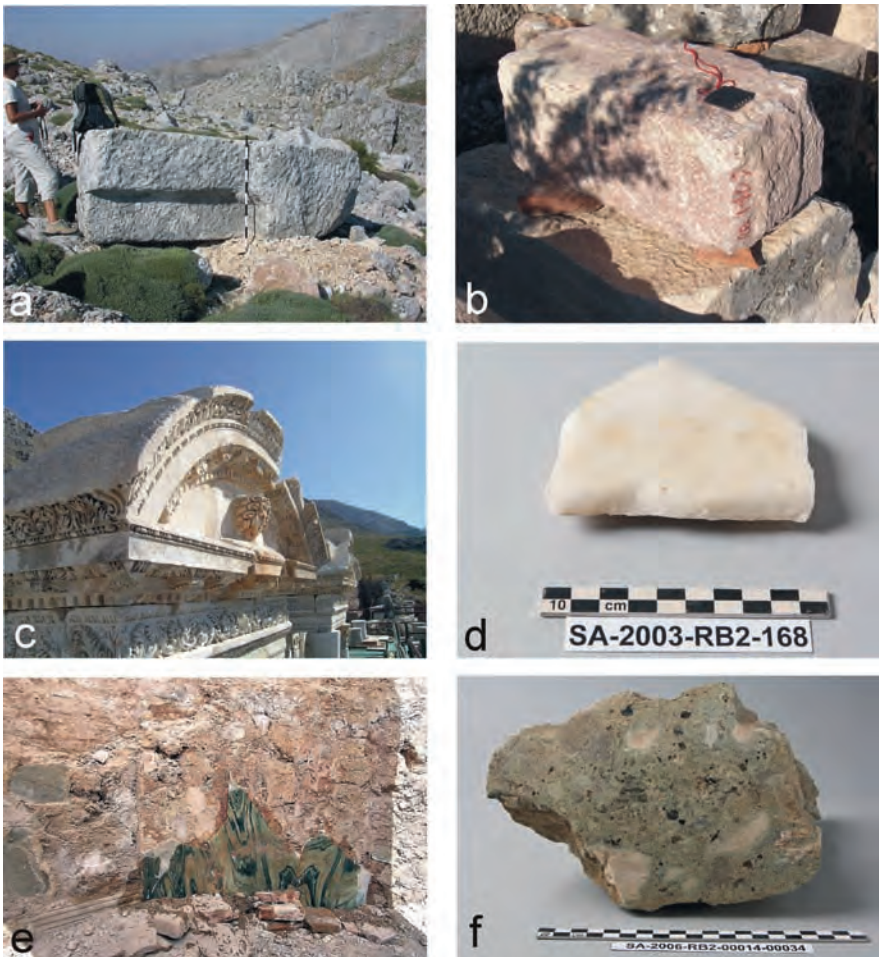

Figure 2. Photographs of the natural building stone used at Sagalassos. (a) Local beige limestone ashlar. (b) Local pink limestone ashlar. (c) White recrystallised limestone cornice block. (d) White marble wall veneer. (e) Euboian cipollino wall veneer. (f) Verde antico column part.

The Sagalassos story

The Sagalassos quarry landscape has a large potential of contextualising the quarries as being a part of the extended 'urban landscape' of Sagalassos. It illustrates the use of predominantly local stone for large building activities in antiquity. The selective exploitation of usable local stone in a natural landscape differs from ancient 'industrial' quarry landscapes, which significantly reshaped the natural landscape. At Sagalassos, we are confronted with a landscape consisting of many small quarries which are often hard to recognise. It is important not to see these smaller extraction locations only as individual 'dots' in this cultural landscape.

Since quarries may be difficult to promote to a lay audience (Storemyr 2006), in the QuarryScapes case-study areas (see other contributions in this volume) each of the studied landscapes has, for example, been characterised according to the special 'stories' they may convey (Bloxam et al. 2007, Bloxam and Heldal 2007). The obvious relationship between quarrying and nearby use of the stone in a monumental city can be considered as the theme in the 'Sagalassos story', to be used for promotion of the significance of this quarry landscape to the wider public. It is a story about life in and development of the town. Moreover, it illustrates the importance of local building materials in Hellenistic–Roman times to construct a monumental centre, even if the raw material is not of excellent quality (like granite or marble), is not of an exceptional aesthetic importance (like multicoloured stones or marbles) or does not serve the purpose of regional use or even trade and export.

When the quarries of the city of Sagalassos are seen as an integral part of the monumental town, their conservation becomes self-evident and their significance, through a 'story', as argued here, can be demonstrated to the public. Also, the use of more distant quarries is an important issue. For instance, the significance of the

Sarıkaya and Ağlasun Dağları quarries in the territory of Sagalassos is inseparably connected to the city. They are providers of special stone types for building projects throughout several periods of construction. Even when in the case of the regional quarries (e.g., Yarışlı) the obvious connection to the ancient city of Sagalassos is lost, such quarry sites are of socioeconomic importance as the stone was transported over long distances. Moreover, this is certainly true for stone from remote sources at Sagalassos, like marbles and granites, based on the sheer number of occurrences known throughout the world. However, in such cases, the quarry sites of these types of stone are more easily seen as important through their impact on so many sites, and the industrial nature of their 'quarry landscapes'.

Man-made risks and their mitigation

In practice, the local quarries in and close to the centre of the city of Sagalassos are part of the archaeological site and town, and are not only protected by law but also by guards present throughout the year. This is not the case for the quarries situated farther away from the monumental centre. It can hence be stated that the greatest danger posed to the quarry sites in the territory lies in not being identified as ancient quarry sites, and thus of value.

Therefore, recognition of an archaeological quarry as a cultural resource associated with the local cultural heritage is a key aspect to the conservation and promotion of such sites. Local inhabitants may be the natural and most evident custodians of the cultural resources at hand when engaged in the history (and story) of their own town, region or general background. At Sagalassos, a considerable local workforce (up to 100 workmen) is engaged in the annual excavations, having a significant impact on local life. The relationship between the foreign excavation team and the local community has been very good since the beginning of the scientific research at Sagalassos, 20 years ago. However, this relationship has so far not allowed to share its aims and results with the local public and to get feedback from it. For that reason a community archaeology project is being prepared by the Sagalassos team in order to reach the wider public of Ağlasun and even of the province of Burdur.

The latter project aims to activate the potential for development in rural areas by making the local youth aware of their natural/cultural heritage, thus ensuring the long-term conservation of these resources. The target group is the youth of Ağlasun and the students that come to the town from different parts of Turkey, to study at the Vocational High School. Using active learning and involvement methods, the local youth will be encouraged to discover the natural/cultural values at hand, and the need for their preservation and sustainable use as resources for development. This not only means creative ways of education and dissemination of information, but also aims at encouraging the young people to start an NGO (non-governmental organisation) that would work as a cultural 'portal' for Ağlasun, not only over the web but also physically by running a heritage centre in town. We also plan to integrate this 'heritage consciousness' into the education programme of the secondary schools and the High School, creating a cycle of learning among the students, where older ones 'teach' the younger classes. In the experience of the excavations at Sagalassos, local people could become custodians of their cultural heritage, and would therefore participate in its protection. During this process, incorporating quarries into a 'common heritage awareness' for local inhabitants rather than knowledge being exclusively focussed on its monumental aspects, can significantly enhance the protection and promotion of quarry landscapes.

Bringing the story forward—the quarries and the tourist

Independent of the framework of protection, physical preservation and promotion, it is usually the quality of the site itself, practical presentation and visitor management that will determine whether people want to come back to a site (Storemyr 2006). In extension, the presentation of a site will also determine the success of any attempt to raise awareness on quarries and quarry landscapes to the public.

Sagalassos presents an archaeological site where excavations and reconstruction of the town and its environs can be observed. Although Sagalassos attracts about 10,000 tourists per year and constitutes a place where these activities can be seen 'in action', this number is not impressive compared to other Turkish archaeological sites. Due to the mountainous location of the ancient city, it is covered by snow for at least four months per year and due to the oro-Mediterranean climate, weather conditions are harsh (frost, rain, wind and storms) for about seven to eight months of the year. This leaves the site realistically accessible to visitors for a maximum of six months per year, between May and October, with most of the tourists coming in July and August. Yet, taking into account the distance of 110 km to the nearest tourist resort at Antalya, and the lack of promotion of the ancient city as a tourist attraction, the aforementioned number of visitors to Sagalassos is considerable.

To accommodate the people who take the effort to visit the site during the excavation season in July and August, members of the Belgian excavation team offer free guided tours to groups and even to individuals in multiple languages. The guides active in Sagalassos are volunteers, mainly teachers and pensioners, who come with the excavation team to the ancient city during their summer holidays and spend four to six weeks on the site. Hence, thousands of people every year visiting Sagalassos in the summer get professional first-hand explanations about the history and evolution of the town, the scientific work in progress and the facts and figures of the ongoing excavations and surveys. The response to these guided tours is massive and the evaluations are extremely positive, mainly thanks to three factors. Firstly, the information provided is correct and up to date, provided by (volunteer) members of the team, active in the excavations for years on end. Moreover, during the months of July and August, the tourists can witness the excavations in progress from a few metres away. Secondly, the information is offered for free. Thirdly, the visitors have a personal choice which part of the city or excavations they want to visit and how much time they want to spend for this visit. The duration of the tours offered may vary from 1 hour to a full day. In this way, everyone coming to the site, from individual visitor to tour operator has custom-made access to all information regarding every aspect of the city, its environs and the ongoing activity. The financial investment made by the Belgian scientific team to offer this information and service is minimal (travel and subsistence for four to six guides for on average four weeks), but still cannot be neglected.

Another service offered by the Turkish government, through the guards present year round at the site, is the sale of affordable brochures that explain the city and its history. The information in these brochures is written by the Belgian excavation team in cooperation with the museum authorities of the province of Burdur, responsible for the excavation at Sagalassos. This provides information available to anyone visiting the site on an individual basis, in addition to the possibility of guided tours during the excavation months.

The relationship between quarrying of local stone and nearby use of it in the monumental city provides opportunities for the promotion of the Sagalassos quarry landscape as an integral part of the Sagalassos cultural landscape. Although visually obscure and often perceived as dots in the landscape, the quarries can come into focus when presented as an integral part of the extended ’town landscape’ of antique Sagalassos. The guided tours are an enormous asset in this regard. When tourists are willing, on the suggestion of the guides present, selected quarries can be visited and an explanation given.

An ideal location for a guided quarry tour, easily accessible to any group, is the eastern quarries (Figure 3, Degryse et al. 2008). This area of Sagalassos is already visited by guided tourist groups because the industrial quarter or potters’ quarter of Sagalassos is situated there. At this location, an explanation on the exploitation of the natural resources in the territory of Sagalassos is offered. This has so far mainly focussed on the extraction of ores and clays. However, it is easy to include the extraction of stone for building and funerary purposes in this story. In the eastern part of Sagalassos, the extraction of local stone is obvious from quarry faces, spoil heaps and from quarry marks and trenches. These can be visited and on-site customised explanations can be offered. Moreover, the importance of these extraction sites in the cultural (monumental) landscape of Sagalassos can be immediately demonstrated in the nearby necropolis ashlar architecture.

Besides the guided tours, which can not be given outside of the excavation season, the quarries can be integrated into trekking tours that should be designed for the surroundings of the site. Trekking route maps can be produced where information about the flora and fauna of the area, the location of the natural springs, the distant necropolises

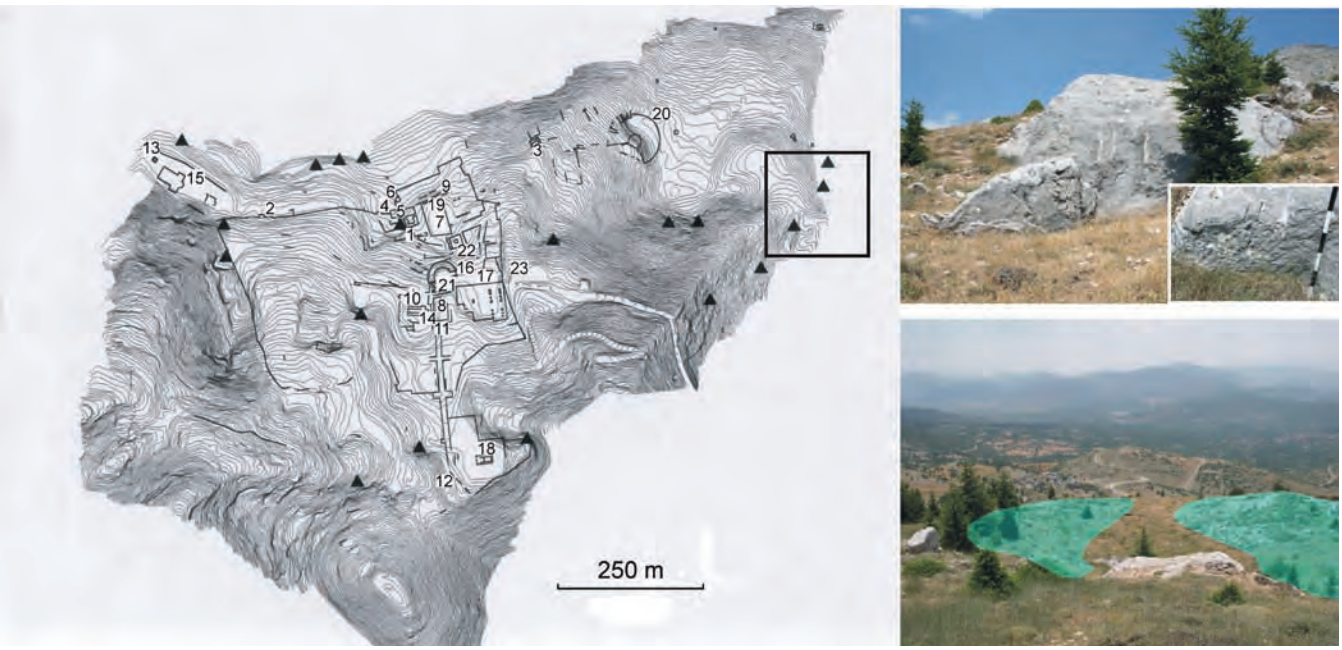

Figure 3. Map of Sagalassos (top is north) with the main buildings (numbered) and the quarries (triangles) located in the vicinity of the city, as defined by Degryse et al. (2008) (1: the bouleterion, 2: the late Hellenistic city wall, 3: the late Hellenistic fountain house, 4: the Doric temple, 5: the propylon of the Doric temple, 6: the Heroon, 7: the upper agora, 8: the lower agora, 9: the northeast building, 10: the temple of Apollo Klarios, 11: the gateway on the lower agora, 12: the south gate, 13: the monument of Claudia Severa, 14: the west portico of the lower agora, 15: the temple of Dionysos, 16: the odeion, 17: the bath building, 18: the temple for Antoninus Pius, 19: the nymphaeum on the upper agora, 20: the theatre, 21: the nymphaeum on the lower agora, 22: the macellum, 23: the gate near the bath building). To the east of the city lie the ‘eastern quarries’ (indicated by the square). Photographs show an example of the local quarries, with a quarry face (top) and the spoil heaps in front of the quarry (green, bottom).

and the quarries are indicated. A first effort to produce such a map was initiated within the community archaeology project (cf., supra).

Concluding remark

It is realised that the impact of the efforts made at Sagalassos to disclose the local quarries and their history to the broader audience and to demonstrate their importance as integral to the monumental town, will only reach a few thousand people per year. However, it shall certainly help create awareness among the local public about the significance of the quarries as related to the remains of the ancient city, and their potential as a cultural resource that can be a tool for the local development, e.g., with regards to tourism. This may hopefully serve as a model for making other similar monumental cities and their associated quarries, e.g., in the eastern Mediterranean in general and Turkey in particular, accessible to a wider audience, hence ensuring their long-term preservation.

Acknowledgements

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Whatever else happened to the ancient Egyptian quarries? An essay on their destiny in modern times

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Through selected case studies, this essay describes the fate of ancient Egyptian stone quarries over the last 50 years. It focusses on the many-sided causes of destruction and neglect of these important archaeological sites in an attempt at raising key conservation issues. Such issues are particularly related to how to deal with modern development, such as urban growth and quarrying, which are expected to remain the largest threat for the ancient quarries also in the future.

Introduction

This essay will examine what has happened to Egyptian stone quarries over the last 50 years. Why is this important? It is no secret that Egypt's archaeological heritage in general suffers tremendously from the adverse effects of modern development as well as from neglect, looting and natural decay. This is, of course, not just an Egyptian phenomenon, but Egypt's heritage is particularly vulnerable because of the huge amount of archaeological sites and the special geography of the country. Much of the deterioration has taken place over the last 50 years or so—a period that has brought unprecedented change to the country. Looking at how ancient quarries have fared in this period may aid conservation because this has to target the many-sided causes of damage and destruction—causes closely linked with political, economic and social issues.

The core part of the essay deals with selected case studies undertaken within the QuarryScapes project and aims at describing the fate of some important ancient quarries when cities have expanded and modern quarrying has occurred. These case studies have been previously presented in a comprehensive report (Storemyr et al. 2007, including primary references, see also bibliography and other sources at the end of this essay), and are reworked here for the purpose of trying to answer the main question, as seen from the perspective of an interested outsider: is there any hope for ancient Egyptian quarries in the future?

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A vibrant country in trouble

In 2000 professor of economics at the American University in Cairo, Galal Amin, published the English version of *Whatever Happened to the Egyptians?;* a critical but entertaining account of the profound changes, not least in social structure, that have taken place in the country from the 1952 revolution to the present. The book became a bestseller, and in the follow-up *Whatever Else Happened to the Egyptians?* from 2004, Amin took another bemused look at the 'quantitative' changes in Egyptian society throughout the same time span—a period in which the population grew from some 20 to nearly 80 million. Amin's books and many others portraying modern Egyptian society, from novelist Alaa Al-Aswany's bestseller *The Yacobian Building* (2004) and historian John R. Bradley's highly critical *Inside Egypt* (2008), to Ibrahim and Ibrahim's geographical textbook *Ägypten* (2006), give a picture of a vibrant and multifaceted country, but also a country facing many political, economic and social problems. Large population growth, massive poverty, a widening gap between rich and poor, nearly three decades of emergency law, inflated bureaucracies, endemic corruption and people's profound dissatisfaction with governing elites are some of the many issues taken up by the authors mentioned above.

Simultaneously, over the last 50 years, tremendous changes in land use have taken place, guided by president Nasser's (1956–1970) socialist reforms, Sadat's (1970–1981) 'open-door policy' and Mubarak's (1981–present) continued liberalisation in the economic sector. The profound changes are the results of attempts at relieving population pressures by building new cities and villages, expanding the amount of cultivable land, and making room for industrial and technological development. The High Dam at Aswan (completed in 1971) is the best-known enterprise—a project that wiped out Old Nubia by creating Lake Nasser but secured the agricultural and energy needs of the country. New, celebrated and criticised projects followed in the wake of the High Dam, such as the 'New Valley' and Toshka projects, which ultimately aim at turning the Western Desert green across a huge area west of Abu Simbel and beyond.

The use of the fringes of the Nile Valley and even the remote desert is symptomatic of the current land-use development policies. In this partially hyperarid climate, the Delta, the narrow stretches along the Nile River and the environs of a few Western Desert oases are the only places where agriculture could traditionally be undertaken. This special geography implies that 99% of the population uses only about 5% of the total land area of the country. Driven by population growth, there thus seems to be little else to do than put the desert to use, though critics would maintain that Egyptians may never be willing to move into the desert in great numbers. Crowded Cairo, one of the world's largest cities with an estimated population of some 20 million, has expanded 35 km into the Western Desert in the course of 30 years, but (for many reasons) outlying areas still remain virtual ghost towns. Also substantial cities, such as New Minya, New Asyut and New Aswan, pop up in the desert adjacent to Nile Valley and agricultural schemes expand into almost every sizeable flat-lying tract of land outside the fertile Nile floodplain. Mining, quarrying, petroleum production and new roads round off the picture of a country in which the desert is no longer as serene as it used to be. It is also increasingly traversed by some of the almost 13 million tourists that visited the country in 2008 (an all-time record), though most of these spent resort holidays along the Red Sea coast or visited mainly the classical monuments in Giza, Luxor and other places. Tourism is the most important source of foreign revenue and sprawling new hotels and resorts litter the Red Sea coast, the Mediterranean shoreline and main tourist centres in the Nile Valley. A mixed blessing, the tourist industry means work for many, but also increasing differences between rich and poor and an undermining of traditional ways of life. Also, the sprawling luxury resorts are an immense contrast to the harsh realities of everyday life for most Egyptians.

Heritage management and ancient quarries

What has all this to do with ancient quarries or, for that matter, any other type of cultural heritage in Egypt? A simple, general answer is that the destiny of cultural heritage, or its status in terms of condition, legal protection and conservation, reflects the political, economic and social development of a country, including the rapid changes in land use. First, Egypt has a staggering amount of archaeological sites—the entire Nile Valley, its desert flanks and many remote desert areas are practically a continuous series of archaeological landscapes, which almost everywhere include ancient quarries, some of very great lateral extent. This means that there is an almost unavoidable conflict between preservation and modern development, and that the poorer-known (and, hence, unprotected) sites may be destroyed or their environs at least heavily impacted by almost any kind of development project.

Second, though the problems of destruction of archaeology generally is thoroughly recognised by the Supreme Council of Antiquities (SCA, the cultural heritage authority of Egypt, part of the Ministry of Culture), conservation and management efforts have traditionally been directed towards monumental heritage (pyramids, temples, tombs, some settlements), which are admittedly also much needed. Non-monumental sites, where tourists seldom venture, are given lesser priority, which is not surprising because it is often difficult to recognise, let alone communicate, the significance and value of such sites. And most have little potential for tourist revenue, at least in comparison to a pyramid. Hard to 'see', such sites may be large, complex and sometimes remote, which implies that their conservation demands special competence and is often costly in terms of survey, monitoring and management. Such competence and basic resources (e.g., survey equipment, cars) are generally lacking at the local/regional heritage preservation offices, and thus foreign missions usually aid in such matters, but of course, only at those sites where they have special interests.

Third, most Egyptians have considerably more acute everyday problems than caring about such archaeological sites. At the bottom line, comparatively well educated heritage inspectors are so underpaid (like elsewhere in the state sector) that many are more concerned with making ends meet by taking or seeking additional jobs than monitoring threatened sites, for which there is anyway few incentives at the local level.

In consequence, a significant proportion of poorer-known archaeological sites, including ancient quarries, remain more or less neglected. In theory, for all sites older than a hundred years, there is strong protection under the Antiquities Law (last revised in 1983), but in practice there is often little or no control in terms of directing developers (and looters) away when they enter an area of archaeological remains with picks and shovels, bulldozers and dynamite. This is certainly not to say that the authorities are doing nothing. There have been many positive changes in recent years, including compulsory conservation of excavated sites by those responsible for the digging, a ban on new excavations (except rescue excavations) in the Nile Valley (this as a way of putting a higher focus on archaeology in the Delta and on conservation), promotion of field schools and training courses, and the building of new storage facilities for excavated artefacts and construction of new museums. In addition, there is a stronger tendency than before on 'nationalising' the heritage or encouraging greater professional Egyptian involvement with it, which also includes a focus on the return of (stolen) artefacts from abroad. This is, in the end, a heritage that traditionally, as a result of the colonial era, has been the playground for foreign expeditions and adventurous collectors.

However, many of these initiatives are not particularly helpful for conservation and management of little-visited ancient quarries and other non-monumental sites spread across the landscape. Therefore, for such sites the establishment of the EAIS (Egyptian Antiquities Information System, a part of the SCA) for making, maintaining and publishing an official country-wide site inventory, as well as a small SCA department for actually putting the ancient quarries on the conservation agenda, have been of greater importance. To this we shall return later.

Overall condition of ancient Egyptian quarries

A recent QuarryScapes analysis showed that among the approximately 200 known ancient quarries of mainly Pharaonic to Roman date about 10% are entirely or largely destroyed (including those now under Lake Nasser), 20% are partially destroyed, 38% are largely intact and 26% are still in relatively good condition, with the state of the remaining 6% unknown. Those still in good condition (except for minor or, in some cases, major looting) are principally located in the Eastern Desert, including Mons Porphyrites and Mons Claudianus, and in some places along the Nile in Middle Egypt (Figure 1). Not surprisingly, the main reason for destruction—and probably the greatest direct future risk—is modern quarrying (good stone doesn't change its location!), to which about 40% of the quarries have been subjected. About 11% are directly influenced by urban and rural development, with agricultural development accounting for a mere 2% since ancient quarries are normally situated in elevated places that cannot be used for agriculture. However, the latter threat is a main risk for prehistoric quarries (pre-3,000 BC), especially Palaeolithic ones used to produce flint tools. For a number of quarries the exact nature of modern impact could not yet be specified.

These figures may not at first glance seem particularly dramatic. However, they do not consider developments that have taken place in the immediate environs of the quarries, which in many cases have thoroughly obscured their archaeological and natural context. Moreover, bearing in mind that only about 6% of the quarries have a secured, legal protection status as owned or supervised by the SCA, the situation can be regarded a great deal worse, notwithstanding the fact that >10% are part of other legally protected archaeological sites, many more are known by the heritage authorities, and that three quarries are developed (or under development) for visitors. Typically, the latter are some of the most 'monumental' ancient quarries in Egypt: the Unfinished Obelisk in Aswan, Gebel el-Silsila near Kom Ombo and Serabit el-Khadim in Sinai. The failure to properly register ancient quarries, and thus to make public that 'this is archaeological land', is understandable in view of the developments in the country and the authorities' lack of resources; but clearly one of the greatest risks facing this group of cultural heritage sites is the ignorance of developers who do not recognise the historical significance of a place that is marked on no map and not communicated as being of special value. For legal protection measures to be undertaken, inventories first need to be made and this has been a high-priority task in the QuarryScapes project. Though there is a long way to go from a record in a database to efficient protection and conservation, all known ancient quarries are now listed in the SCA/EAIS databases.

Natural hazards and erosion may seem of minor importance compared to the man-made risks. And this is certainly true for most quarries along the Nile Valley, with the exception of spectacular, deep gallery quarries that have already collapsed or may collapse in the future. Also weathering away of tool marks and inscriptions is problematic at some places. But perhaps the greatest natural risks are connected with rare rainstorms and flash floods, especially in the Eastern Desert where quarry infrastructure such as habitation sites, slipways and roads are frequently washed away. Moreover, the occasional earthquake has taken its toll at some sites.

Three areas with numerous ancient quarries, spanning the entire course of Egyptian history (and parts of its prehistory), are under particularly high pressure from modern development. These are the greater Cairo area, and the environs of El-Minya and Aswan. In these areas it is

The State of the Stone Quarries of Ancient Egypt

Figure 1. Overview of known ancient Egyptian quarries and their tentative condition. The quarries mainly date from the Early Dynastic (ca. 3100 BC) to the Roman Period, with a few Islamic Period quarries also included. Map: the QuarryScapes project/Per Storemyr and James A. Harrell.

industrial, urban and agricultural development, which spark off chain reactions of secondary developments such as quarrying and road building, that are responsible for the critical situation, as seen from the perspective of ancient-quarry protection. Some of these developments are presented as case studies below.

From ancient quarry to swimming pools and football stadiums

Flying over Cairo on a smog-free day is an experience. Coming in from Upper Egypt one may skirt the green Faiyum, enjoy all the pyramids from Hawara to Giza, turn east over the Nile, pass the Citadel and, if lucky, see a red spot surrounded by sports stadiums and swimming pools in the urban jungle before landing close to Heliopolis in the eastern outskirts of the city (which are not the outskirts anymore, given that the city now extends halfway to Suez). The red spot is Gebel el-Ahmar (meaning 'the red mountain'), once an extraordinarily important ancient quarry (Figures 2–6). From here, hard, red and brown silicified sandstone (or quartzite), with strong symbolic connections to the solar religion of ancient Egypt, was procured for fine statues and architectural elements.

Gebel el-Ahmar is not marked on maps of Cairo anymore. It has been renamed Gebel el-Akhdar, meaning, quite ironically, the 'green mountain' and obviously referring to its now terraced slopes. It is now squeezed between Medinet Nasr to the east, where building of residential areas commenced under Nasser's regime, and Manshiet Nasser to the west, where 600,000 people live in Cairo's largest squatter settlement initiated in the 1960s within and around the ancient, medieval and modern Moqattam Hills limestone quarries. Gebel el-Ahmar itself is entirely built over by Arab Contractors, a most influential construction company established in the 1950s and at times the largest of its kind in the Middle East. It also built the High Dam at Aswan. The area was formerly used by the military, but the company's hospital was established here in the 1970s. A large sporting club followed (Figure 5), and today one may join tens of thousands of fans watching Arab Contractor's Premier League football club play at their own stadium here. Or one may sip a Turkish coffee in the café at the highest point of the hill by a prominent modern building (apparently a casino completed already around 1980) clad with the fine quartzite from the quarries, which were also active in modern times (according to Baedeker's 1885 travel guide providing stone for e.g., millstones and road construction). Many more companies reside in the environs; there is another large stadium nearby and construction still continues within the boundaries of the former quarry.

The ancient quarry was occasionally visited by scholars throughout the 20th century and though important finds were made (Figure 6), it was never really surveyed and documented. There seems to be no reports on efforts at protection and conservation, and it would be difficult now to properly reconstruct what really happened back in the 1950s and 1960s when plans for the use of the area must have been originally laid down. And it would by all means have been hard for any kind of cultural heritage authority to save this prominent hill with non-monumental archaeology in such an incredibly sought-after area. Whether archaeological traces remain at Gebel el-Ahmar is unlikely, but since the area still awaits a survey there may be surprises by the swimming pools and tennis courts.

Basalt for pyramids and railway construction

As an archaeological site Gebel el-Ahmar may be dead, not only because the quarry itself is largely gone, but also since its context has drowned in the urban jungle. Turning to the other side of Cairo,

Figure 2. Ancient Gebel el-Ahmar silicified sandstone quarry (red circles) around 1825 and by the 1880s as the city of Cairo had not yet started its modern expansion. Maps from the online version of Description de l'Egypte by Bibliotheca Alexandrina *(http://descegy.bibalex.org) (left) and Baedekers 1885* Handbook for travellers for Lower Egypt *(online at http://scholarship.rice.edu/handle/1911/9163) (right).*

Figure 3. Cairo and its eastern outskirts in 1965 (above) and 2000 (below) with approximate outline of the ancient Gebel el-Ahmar silicified sandstone quarry. Satellite images: 1965–US declassified (Corona); 2000–Landsat.

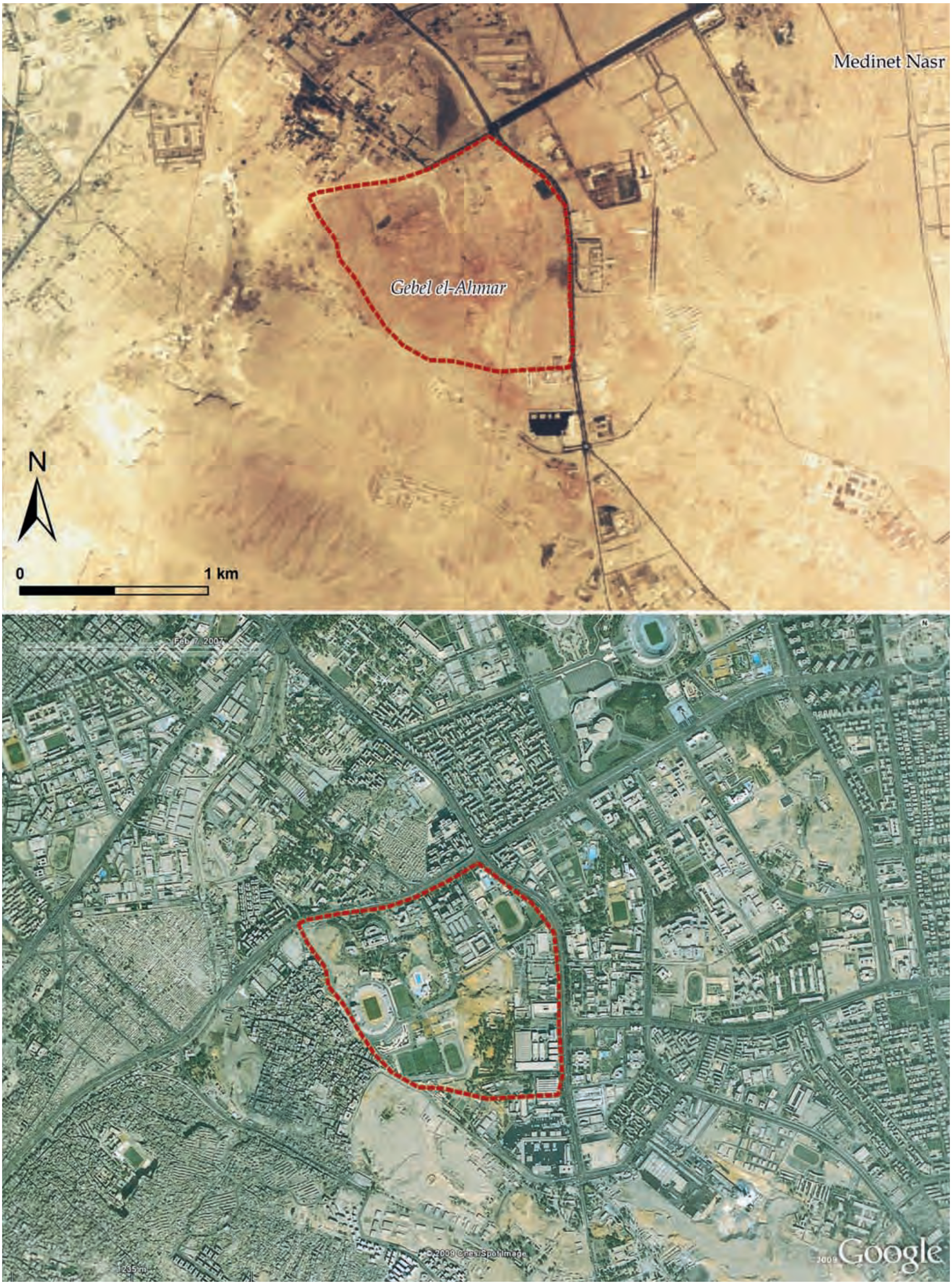

Figure 4. Ancient Gebel el-Ahmar silicified sandstone quarry in 1965 (above) and 2007 (below). Quarry outline is approximate. Satellite images: 1965–US declassified (Corona); 2007–Google Earth (Spot).

Figure 5. View from the top of Gebel el-Ahmar, looking south towards part of the Arab Contractor's Sporting Club. Note the red rock which gave the hill its original name. Photo: Per Storemyr 2005.

Figure 6. Gebel el-Ahmar: Excavation of an abandoned colossal statue in 1989. The insert picture shows the situation in 1991. Photos: James A. Harrell.

in the Western Desert 50 km beyond the pyramids of Giza, the situation is still very different (Figure 7). On Gebel Qatrani, at 350 m above sea level and on the highest point in northwestern Egypt, lies Widan el-Faras, a basalt quarry which in a sense can be regarded as the 'sister quarry' of Gebel el-Ahmar; the two quarries are the only known heavily exploited ancient sources of hardstone relatively close to (but outside) the Nile Valley between the Mediterranean and Aswan—and they both rose to prominence in the pyramid age of the Old Kingdom. Until a few years ago Widan el-Faras, strikingly located on a black-coloured escarpment with views to the Faiyum, had been untouched since antiquity. This is not to say its environs had remained unexploited; since the basalt deposits between Gebel Qatrani and Giza are suitable for building purposes, and are unique in the region and considered a national strategic resource, they were put to use as sources of crushed stone for railway and road construction, probably around 1960. A large project for which the stone was used was the 350 km-long railroad, finished in the early 1970s, between the iron-ore mines in the Bahariya Oasis and the prestigious iron and steel factory at Helwan near Cairo. The factory was established with Soviet aid in the late 1950s and in the early years was supplied with ore from Aswan. The railroad runs just to the north of Gebel Qatrani.

State-owned and private basalt-quarry companies (that also deliver blocks for coastal erosion protection) gradually closed in on the ancient quarries. In 2002, work aiming at establishing a new quarry in the midst of the Pharaonic workings was underway, and since then about 30% of the old quarries have been eradicated (Figure 8). However, large-scale modern production has not yet commenced. This is because of intervention by the heritage authorities reacting to pressure from scholars (mainly QuarryScapes) who have surveyed the quarries, as well as others involved with nature conservation. Gebel Qatrani is part of Lake Qarun Nature Protectorate, which was established in 1989 and is administered by the Egyptian Environmental Affairs Agency (EEAA). In theory, it is forbidden to undertake modern quarrying, mining and the like inside a nature protectorate without a special permit. Moreover, because of its fossil deposits—and its archaeology—this area is now forwarded as a potential World Heritage Site. For the time being, quarry companies have retreated from the ancient quarries (extraction licences have not been renewed by the responsible governorate), but heavy activity is going on as before in the immediate environs. A call has been made for permanently securing the protection of the quarries by the SCA, but the outcome is still uncertain.

The ancient road from the quarries—4500 years old and thus the oldest paved road in the world—traverses a still rather pristine part of the Northern Faiyum desert and ends at an ancient harbour, now on dry land, by Qasr el-Sagha, 12 km to the south. In this area other problems of modern expansion start, as the attractive northern shoreline of nearby Lake Qarun is planned for upscale residences and tourism. Accompanying this development will be destructive road building, the churning up of unregistered archaeological sites due to construction activities, and a massive influx of people into this fragile environment—notably within the Lake Qarun Nature Protectorate Much is already destroyed a few kilometres further east in the archaeologically exceptionally important Kom Aushim area, where several archaeological missions work, but where extensive modern clay mining and land reclamation for agriculture have gone on for decades. The agricultural development appears to be slow in this area, but is moving northwards and may in the future threaten the Umm es-Sawan Old Kingdom gypsum quarries.

Then there are the desert tourists. With the Northern Faiyum desert becoming increasingly squeezed between the western outskirts of Cairo and the development zone of Kom Aushim, modern roads and tracks now criss-cross the area and make it easily accessible for day-trip tourists in their 4WDs. The ancient quarry road from Widan el-Faras is being adversely affected by this traffic and some people do not seem to refrain from stealing whatever kind of artefact they come across, from flint tools to pottery fragments. This is a trend that affects large parts of the Western Desert and, in consequence, will make it difficult for professional archaeologists to interpret sites in the future.

Fortunately, attempts at counteracting the adverse effects of desert tourism

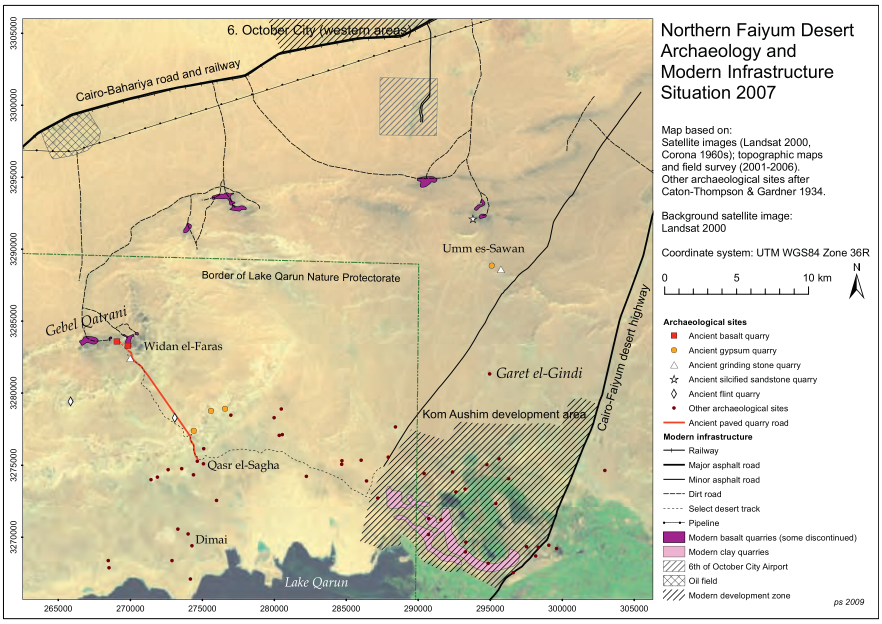

Figure 7. Archaeology and modern infrastructure in the Northern Faiyum desert as of 2007. Map: the QuarryScapes project/Per Storemyr. Background satellite image: Landsat 2000.

Figure 8. Part of the ancient Widan el-Faras basalt quarry in 2001 (above) and 2007 (below), after initial work to open a modern quarry. Photos: Per Storemyr.

on both archaeological and fossil sites in the Northern Faiyum are currently underway by the local EEAA office responsible for the Lake Qarun Nature Protectorate. For example, the office has marked access tracks and natural/cultural sites, aiming at informing visitors and in this way reducing the risk of destruction by looting and careless desert driving.

Chephren's quarry and the Toshka project

Increased looting has also been observed a thousand kilometres to the south, at Chephren's quarry in the Western Desert, 60 km west of Abu Simbel. This is, however, rather unimportant as compared to other threats facing these 50 km^2 of flat desert with 700 small Old Kingdom quarries that produced a beautiful bluish gneiss. Chephren's quarry is in the midst of the Toshka megaproject (Figures 9–10), second only to the High Dam at Aswan in ambition and cost. The project is part of a decades-old vision of making a Nile-parallel 'New Valley' (Wadi el-Gedid) running from Toshka through the Western Desert oases almost to the Mediterranean, using water from Lake Nasser and groundwater from the Nubian aquifer. This, according to its supporters, would relieve Egypt from many problems with overpopulation and food production. Sceptics, on the other hand, point out that the project will lead to severe environmental impacts and may fail due to increased use of Nile water in Sudan and Ethiopia.

Hyperarid and burning hot, this area was remote and pristine until the 1970s when the water level of Lake Nasser began to rise after the completion of the High Dam. Like hundreds of archaeological sites along the new lake, part of the ancient track from Chephren's quarry to the Nile drowned in this period. In the late 1970s, construction began on the Sadat Canal, a spillway draining into a series of large, natural depressions in the desert. Following exceptionally high water levels, overflow from Lake Nasser through this canal was first observed in the late 1990s and since then three large lakes (the Toshka Lakes) have formed. They have shrunk in recent years, but still occupy an area of more than 1000 km^2.

The Sadat Canal did not have great impact on Chephren's quarry itself, but the nearby Stele Ridge carnelian quarry of Middle Kingdom date was adversely affected. However, it was not before the construction of the new asphalt road to distant Uweinat in the 1990s that this gemstone quarry became severely damaged during digging for gravel. Similar destruction took place in Chephren's quarry; the road passes right through an associated settlement site and literally divides the ancient quarry area into two parts. The Uweinat road is an element of the Toshka project, for which the first concrete plans were presented in the early 1990s. Construction commenced in 1997 and the first phase has involved the excavation of a more than 150 km-long canal network for supplying the planned agricultural schemes. These canals, two of which are now in operation (Canal 1 and 2), are fed through the 50 km-long Sheikh Sayed Canal and the giant Mubarak pumping station at Lake Nasser. According to the original plans, the whole of Chephren's quarry and Stele Ridge should already have been bulldozed, covered with topsoil and now producing cash crops for the international market. Moreover, the planned Toshka city should have been the home of thousands of people coming from the Nile Valley. However, apparently due to economic problems, since 2003–2004 the project has come to a partial standstill. By Canal 1 and 2 a few farms have sprung up, but the unfinished Canal 4, which cuts through marginal areas of Chephren's quarry, as well as Canal 3, are left as huge scars (several hundred metres wide) on the desert surface. This means that many parts of the quarry landscape, though surrounded by roads and unfinished canals, remain reasonably well preserved (as observed in 2007).

In the late 1990s there were some attempts by heritage authorities at putting Chephren's quarry and the nearby Nabta Playa Neolithic sites (60 km west of Chephren's quarry) on the agenda for conservation and associated desert-tourist development—attempts partially related to the influx of tourists that come to see the famous Abu Simbel temples, less than an hour's drive away from Toshka. For unknown reasons, these attempts were not followed up and since then practically nothing has happened in terms of protection. The archaeological missions that have recently worked at Chephren's quarry in 2002 called upon the heritage authorities to take action and officially protect the quarry area, but in 2007 it was learned that the plans developed had *'disappeared within the bureaucracy'*. Following new requests, further plans for action may be underway but, again as with Widan el-Faras, the outcome is uncertain. Evidently, if no action is taken, there is an acute risk that a unique archaeological site will be wiped out as soon as (or if) canal building and land reclamation resume.

Ancient quarries, modern industries and a new city

By the first Nile cataract and the High Dam are the Aswan quarries, an assemblage forming one of the largest, longest-lived and most complex quarry landscapes in the world. Exploitation was based on two easily available, special resources—hard silicified sandstone (quartzite) and granite (plus the closely related granodiorite)—but also on normal, soft sandstone. Spread out across more than 100 km^2 on both banks of the Nile, the quarry landscape covers almost the entire history of humankind, featuring everything from Palaeolithic tool workshops, massive grinding-stone industries, quarries for sculpture and building stones, to the most famous of all quarries in Egypt, the Unfinished Obelisk quarry of New Kingdom date (Figure 11). This is the only officially protected quarry in the Aswan area and it is also part of a World Heritage Site, the 'Nubian monuments from Abu Simbel to Philae'. There are also ancient iron and ochre mines, and presumably ancient clay mines in addition to, of course, many other archaeological sites in this traditional border- and trade region between Upper Egypt and Nubia.

The complex ancient quarry landscape has an equally complex history of modern impact (Figures 12–14). There is minimal place for agriculture along the narrow Nile floodplain, and with some justification one may portray Aswan as an ancient industrial region that over the past century has been revitalised. Throughout the Middle Ages and early modern era Aswan lost much of its former importance, but was 'rediscovered' by tourists and developers, gaining momentum from the building of the original Aswan Dam (or Old Dam) between 1897 and 1902, subsequently raised twice until 1934, and finally being developed into a modern industrial, tourist and administrative city over the last 50 years. Still, population grew slowly in the beginning, from less than 15,000 a hundred years ago to about 30,000 before President Nasser started the building of the High Dam (completed in 1971). Now there are somewhere between

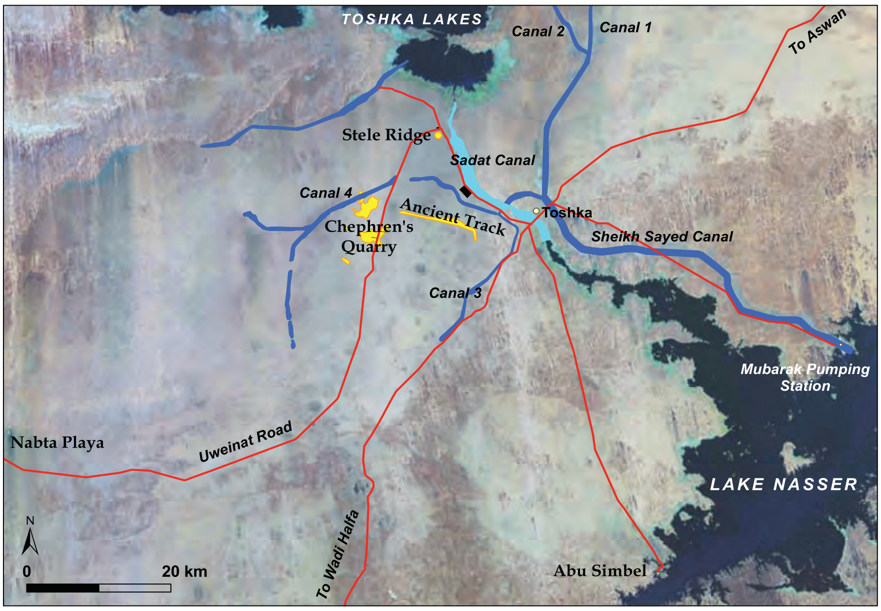

Figure 9. Chephren's quarry and the Toshka project area with modern roads (red) and canals (blue). Status in late 2007. Map: the QuarryScapes project/Per Storemyr. Background satellite image: Landsat 2000.

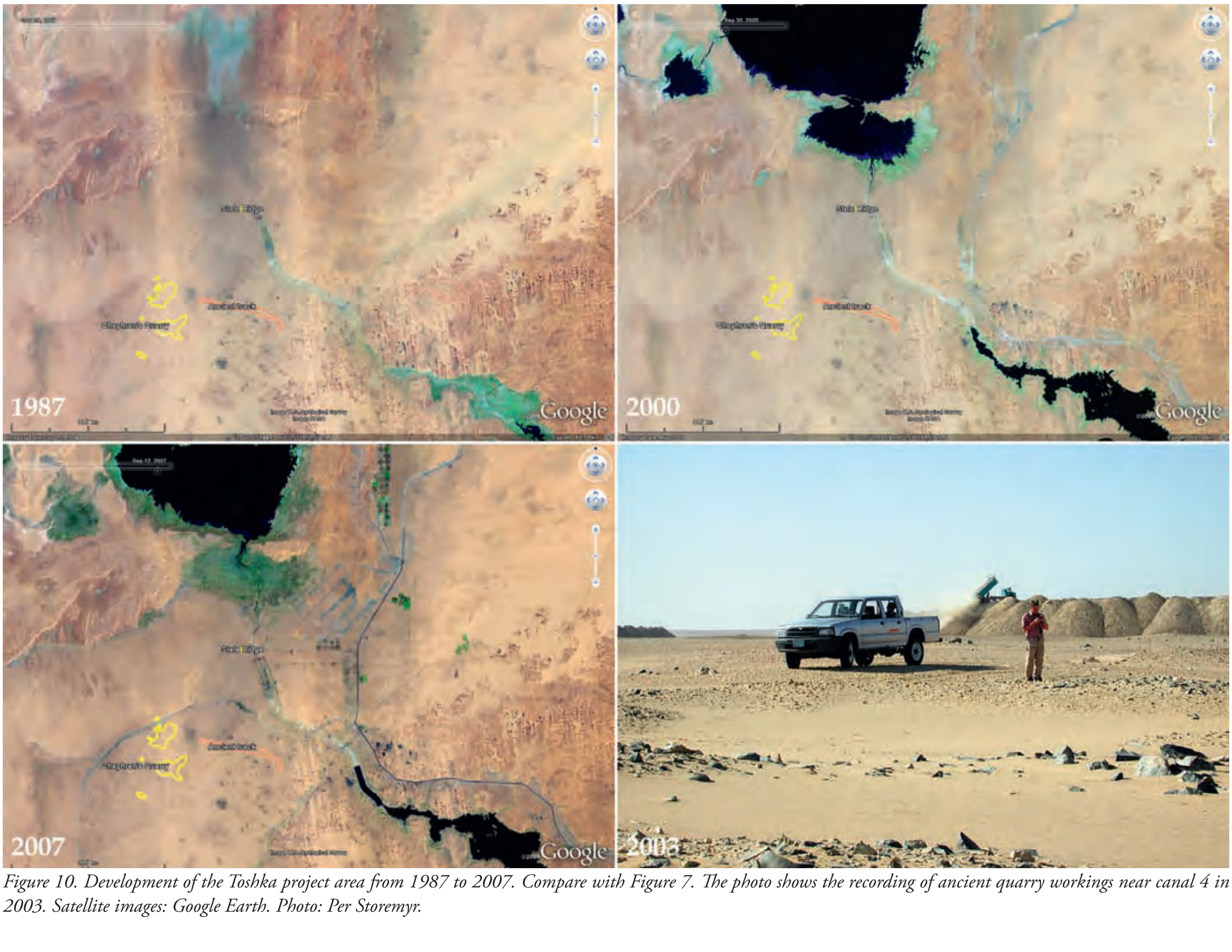

Figure 10. Development of the Toshka project area from 1987 to 2007. Compare with Figure 7. The photo shows the recording of ancient quarry workings near canal 4 in 2003. Satellite images: Google Earth. Photo: Per Storemyr.

300,000 and 500,000 people living here. Depending on counting procedures, this is a growth rate that is up to three times higher, or more, than the Egyptian average for the same period.

The old granite quarries between Aswan and Shellal were the first to be affected by the modern development. The Old Dam was built from enormous amounts of locally quarried granite, an undertaking that sparked off a bustling modern stone industry in the heart of the old quarries. Now, a hundred years later, there are dozens of companies operating here, producing for the domestic and international markets; and although ancient remains still exist (such as the Unfinished Obelisk), the context and integrity of the ancient landscape is entirely gone. This is also a result of massive urban expansion, which partially takes place within the ancient quarry areas because there is little available space elsewhere.

Expansion now touches the other ancient east bank quarries, in silicified sandstone, stretching 12–13 km from Aswan to Wadi Abu Aggag and Wadi Abu Subeira in the north. In the early years of the new industrial era after the 1952 revolution, this area north of Aswan City saw large-scale iron-ore mining for the steel plant at Helwan. However, iron-ore production ceased already by the 1970s when the higher-grade mines in Bahariya took over. Presently it is the massive clay mining for the Egyptian ceramic industry that dominates the hills and wadis in the area and destroys ancient quarries and other archaeological remains. The mouth of Wadi Abu Subeira is, furthermore, a place for large-scale modern sandstone quarrying, which has completely eradicated the ancient Gebel el-Hammam quarries. Ironically, the best preserved ancient quarries on a plateau north of Wadi Abu Aggag, where ornamental stone was procured in ancient times, are within a military area where development is banned (except, of course, for the military's own activities).

About 10% of the people in the Aswan area live in the extensive Nubian villages on the west bank (Figure 15). Except for the gradual expansion of these villages, some road building and mainly small-scale artisan quarrying of sandstone for housing, this serene area with golden sand dunes was, in stark contrast to the east bank, until recently largely untouched by modern development. Consequently, the widespread, ancient silicified sandstone quarries and other archaeological remains had hardly changed their character for hundreds, even thousands of years. However, behind this picturesque scene power lines from the dams and new roads had literally cut off the area from the rest of the Western Desert already by the 1960s. And, alas, other developments are under way. Originally planned in the late 1970s, 1999 marked the start of the construction of New Aswan City, one of the so-called third generation, national urban development schemes, designed to be the home for 70,000 people. Following the now ongoing building of the city, a new bridge, inaugurated in 2002, has also been built across the Nile. This bridge not only serves the new city, but is a major link in the expanding road network in Upper Egypt, especially as regards transportation needs for the Toshka project. As for other large construction programmes, the building of the new city proceeds comparatively slowly and people have yet hardly begun to move in.

Conservation in Aswan

Notwithstanding the current pace of construction, it is likely that New Aswan City marks the beginning of the end of the west bank as a rather quiet zone in terms of modern expansion. There will be further needs for housing and development, and this now easily accessible desert flank of the valley offers valuable space. If archaeological remains are to be protected and managed, they thus have to be included in the overall land-use planning. Although compulsory in the realms of the Antiquities Law, as the construction of the new city began the local cultural heritage was given no consideration whatsoever. After intervention in 2005–2006 by the local SCA office, called for and supported by the QuarryScapes project and other missions working in the area, it thus came as a surprise that the Governorate and the New Urban Communities Authority (a part of the Ministry of Housing, Utilities and Urban Development) seemed to welcome conservation of the main archaeological sites, a task that has implied serious replanning of land use. There may be many reasons behind this positive attitude, but a key issue is that the planners formerly simply did not know that the area itself and its neighbourhoods are full of archaeology. This failure of the local heritage authorities to properly inform and take action before it is too late is at the bottom line of conservation in Egypt. And one explanation is that the poorer-known, non-monumental sites of obscure significance are often unknown to the authorities themselves.

Clearly, it is now only possible to save isolated islets of archaeological remains, including ancient quarries, in the construction zone of New Aswan City. On other parts of the west bank there are considerably better opportunities to protect, manage and present archaeology within its landscape context through the participation of the local Nubian people, who for a long time have operated a small desert tourist 'industry' in the area, a welcome source of income. These environs, across the Nile from renowned Elephantine, are the only ones left along the valley in the Aswan area that have not yet become the focus of heavy modern development (Figure 16). There is a chance, indeed, for preservation to take place here, not only as seen from the positive attitudes in the New Aswan City case, but also in relation to other activities that may, hopefully, be the start of a greater focus on conservation in the region.

First, jointly with the SCA, the Swiss archaeological mission has for about 10 years undertaken rescue excavations in Aswan, by Egyptian standards a very special and successful archaeological

Figure 11. The Unfinished Obelisk quarry in Aswan from 1851 to 2008. Until Engelbach's excavation in 1922 hardly anything had happened at the site since antiquity, and even until the late 1960s the area around the quarry was little used (compare with Figure 10). Over the last decades modern Aswan has closed in on the quarry, and large-scale archaeological excavation and museum development has also taken place over the last several years. The lower picture shows the current situation: a quarry and museum 'island' in the midst of modern Aswan. The quarry is in the middle of the picture, whereas the area in front is the Islamic Fatimid cemetery. Photos: 1851–Félix Teynard (Library of Congress' Prints & Photographs Online Catalog, http://hdl.loc.gov/loc.pnp/cph.3c27936); 1900–1920–American Colony in Jerusalem, Dept. photographer (Library of Congress' Prints & Photographs Online Catalog, http://hdl.loc.gov/loc.pnp/matpc.01591); 1922–1923–from R. Engelbach The Problem of the Obelisks, T.F. Unwin, London, 1923; 1989–James A. Harrell; 2005 and 2008–Per Storemyr.

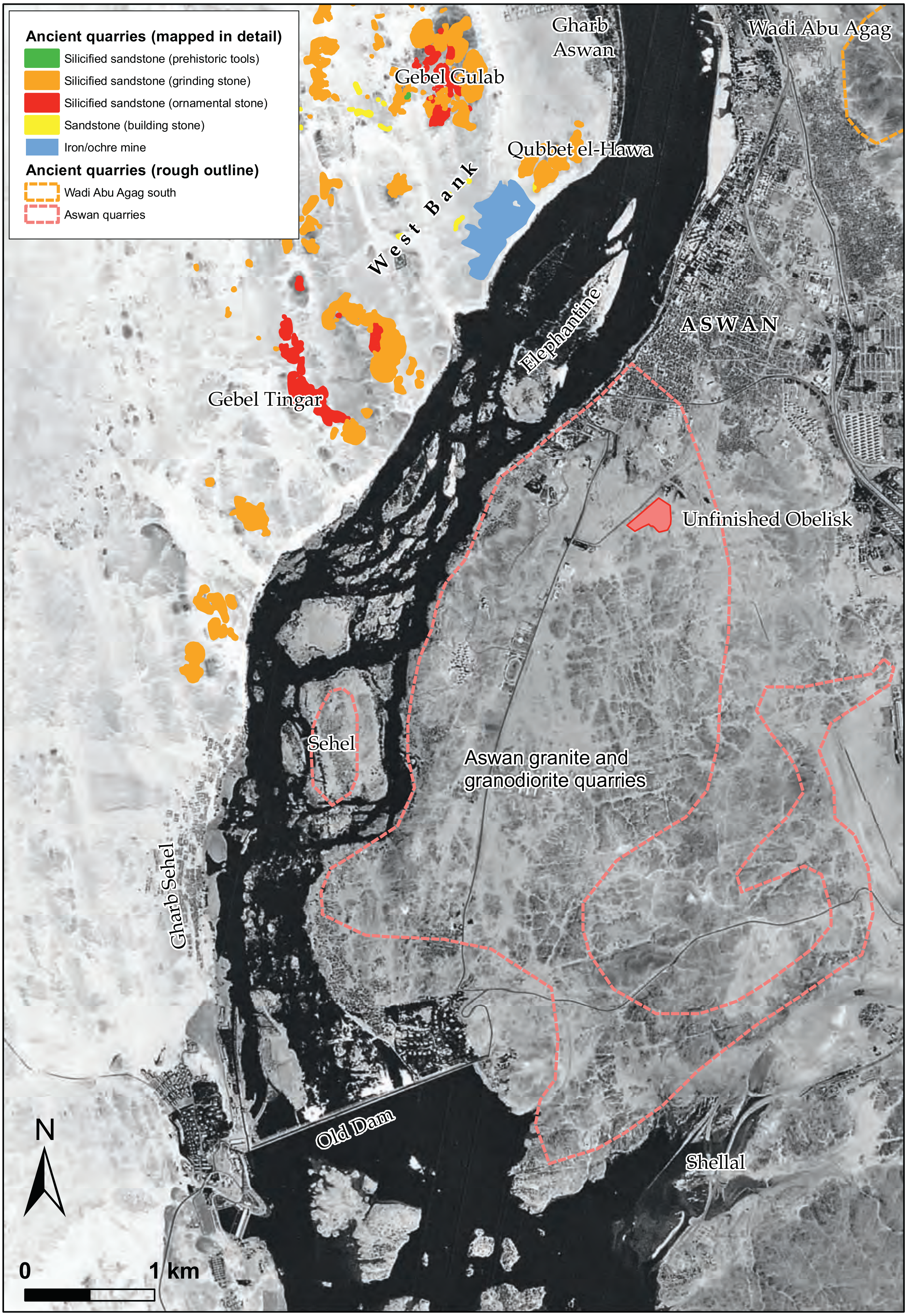

Figure 12. The first Nile cataract area and Aswan in 1965 with ancient quarry areas on the east and west banks, and the now-protected area of the Unfinished Obelisk quarry and museum. Map: the QuarryScapes project/Per Storemyr. Background satellite image: US declassified (Corona/KH7).

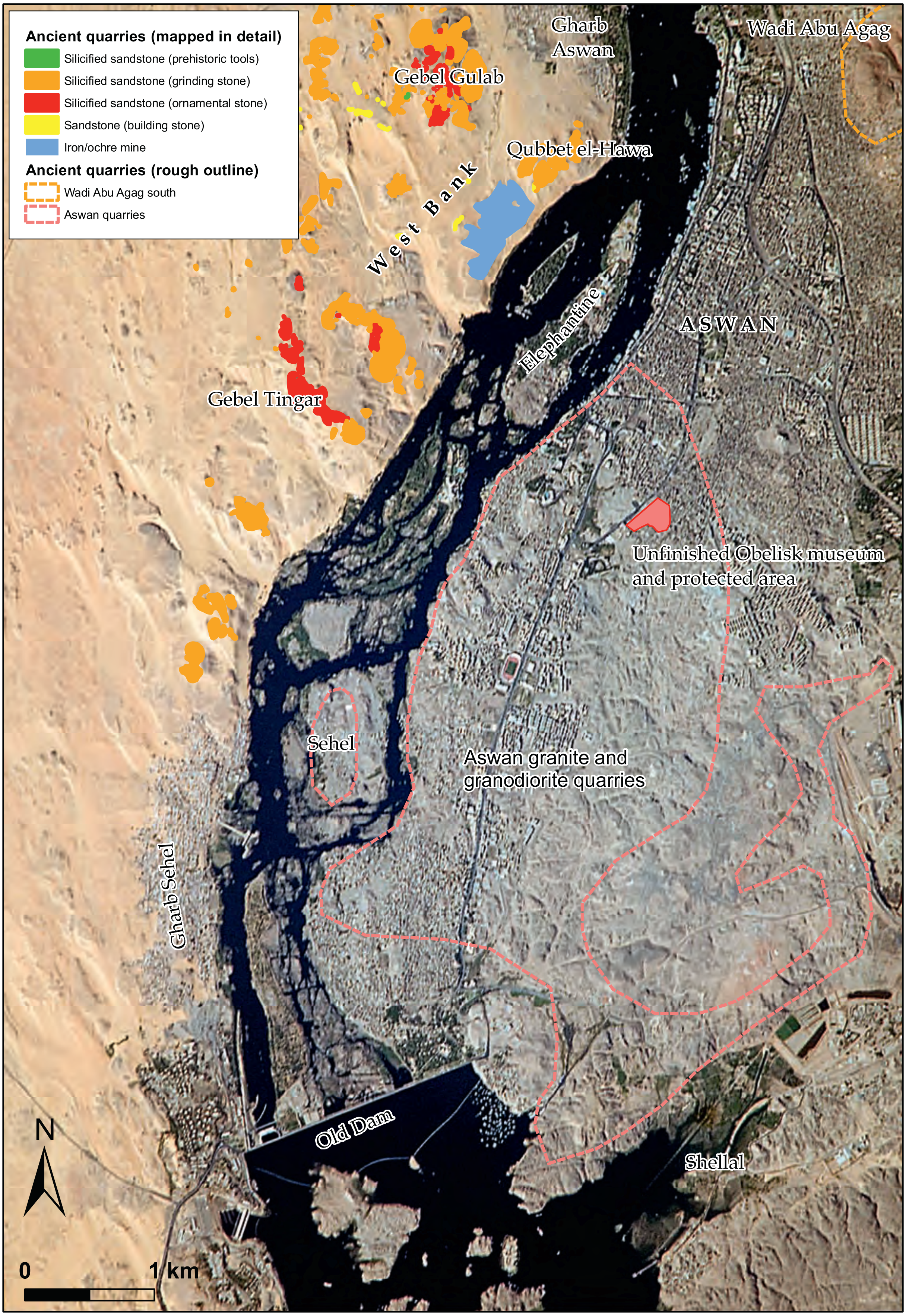

Figure 13. The first Nile cataract area and Aswan in 2008 with ancient quarry areas on the east and west banks, and the protected area of the Unfinished Obelisk quarry and museum. Compare with Figure 10. Map: the QuarryScapes project/Per Storemyr. Background satellite image: Astronaut photography (Image Science and Analysis Laboratory, NASA-Johnson Space Center. "The Gateway to Astronaut Photography of Earth." http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=ISS017&roll=E&frame=20971).

Figure 14. An unfinished Roman granite bathtub among modern quarry waste in the southeastern part of the Aswan granite quarries (close to the Kima fertiliser factory). Photo: Per Storemyr 2005.

programme that has brought to light the early history of the city. Second, centred on the Unfinished Obelisk quarry museum, and backed by the central SCA Cairo office, a few dedicated inspectors have created a milieu for recording and protecting ancient quarry remains in the urban and industrial jungle on the east bank (in particular within the ancient granite quarries). What makes this project unique is the direct and friendly cooperation with local quarrying and mining companies, which, like the developers in New Aswan City, have minimal knowledge of the ancient quarries they are blasting away. The companies are encouraged to join archaeological investigations in the areas where they are active and are given options in terms of other suitable deposits if it is decided that they must stop exploitation at the original place. Furthermore, in cooperation with governorate authorities, the companies are offered long-term quarrying licences at the new places since one of the greatest problems in the Egyptian quarrying sector is haphazard planning due to the frequent issuing of short-term licences. Not without backlashes, this bottom-up programme has been able to protect a great deal of important archaeology in an area that is extremely high pressure in terms of demand.

The future

Current and future conservation of ancient Egyptian quarries (and other heritage resources) are, in many ways, faced with the effects of large-scale development schemes of national importance, originally planned decades ago with minimal reference to archaeology. As the case studies have demonstrated, the Toshka project and the building of new cities are two important examples. But also modern quarrying can at places be viewed similarly, for example in the Northern Faiyum where the basalt deposits are regarded a national strategic resource with exploitation pursued from the 1960s onward. At other places, modern development may have been planned in a less centralised manner or, in many cases, is simply haphazard, but still it is often undertaken in the wake of grand schemes, again with negligible reference to poorer-known archaeological sites. Aswan, with its modern stone and clay industries, as well as its urban encroachment following the building of the dams, is a particularly vivid example of this kind of development. And the total destruction of Gebel el-Ahmar (and other ancient quarries) in Cairo, goes back to the urban development plans laid down in the 1950s and 1960s.

In addition to such large-scale, 'age-old' projects with a negative influence on ancient quarries, there are dozens of less extreme cases of more recently planned

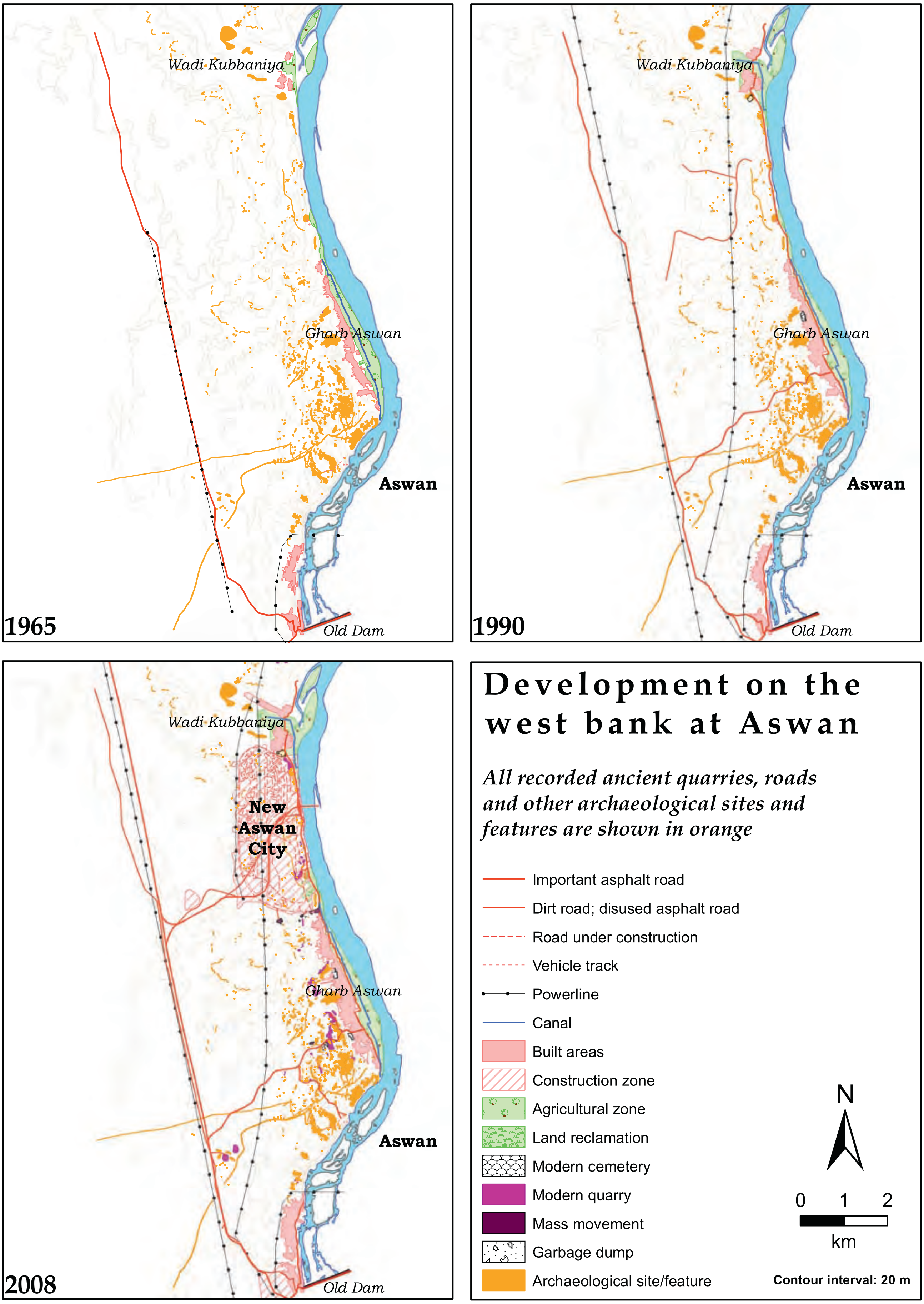

Figure 15. Development on the west bank of the Nile at Aswan between 1965 and 2008. Compare with Figures 10 and 11. Maps: the QuarryScapes project/Per Storemyr.

Figure 16. The 'industrial' Aswan east bank as seen towards the still well-preserved west bank with its sand dunes. Both places feature ancient quarries. Photo: Per Storemyr 2007.

or expected developments across the country. For example, modern quarrying in the Eastern Desert and along the flanks of the Nile Valley is already a key issue expected to become increasingly problematic in the future. This is because of the generally rapid and, in terms of long-term planning, haphazard expansion of these industries.

Without urgent protection measures and (re)planning that considers archaeological resources, all indicators point to continued heavy loss of heritage values and, at several places, the almost total disappearance of ancient quarries in the not-too-distant future. The recent attempts at saving bits and pieces, as reported here for the case study areas, are undoubtedly just a drop in the ocean in view of the challenges ahead. It is thus extremely welcome that the heritage authorities have recognised the need for more concerted actions and, as a result of the activities around the Unfinished Obelisk in Aswan, in 2006 decided to establish a special SCA department for conservation of ancient quarries (and ancient mines) throughout Egypt. A main intent of this small department is to undertake education and training for regional SCA offices, enabling their inspectors to recognise and protect this group of archaeological remains. The new department is in no way exempt from the endemic lack of resources, yet it has been able to carry out field-training courses and make plans for the development of an 'ancient stone centre' on the precincts of the Unfinished Obelisk quarry.

In such a department there is hope for the future. Nonetheless, any kind of favourable, long-term institutional development is dependent not only on dedicated individuals, but also on national and international support—and perhaps on the general political course troubled Egypt may take in the future. Given that the department will become more than a transient phenomenon, it will have to work in several arenas simultaneously. First, in high-pressure areas (like Aswan) it simply has to survey, excavate, document and save as much as practically viable. Second, in a longer-term perspective it has to pursue the nation-wide inventory (mentioned above), which also needs to address the relative significance of the ancient quarries. Third, since it is not possible to save everything, selected quarries must be targeted for conservation on different levels, sometimes in alliance with other bodies, for example with environmental authorities responsible for nature protectorates within which several ancient quarries are located. Some quarries are important, even unique, in a global context while others may hold significance on a regional (e.g., Eastern Mediterranean) level, whereas many must be regarded as of primarily national, provincial and local value. The latter group is probably the largest, encompassing many of the 140 limestone and sandstone quarries along the Nile; thus a special challenge is to select representative candidates for conservation. For the quarries of global significance there can be no doubt that they all in one way or another should be saved for the future (for example most of those mentioned in the case studies above).

The making of such survival 'lists' is, of course, not straightforward because it is profoundly dependent on methods for assessing significance, whether from an archaeological, a contemporary socio-cultural or economic perspective. Moreover, the condition of the quarries, or their integrity, as expressed in the 'Operational Guidelines for the Implementation of the World Heritage Convention', will heavily influence assessment. When a quarry and its context are largely destroyed, all one can do, regardless of past importance, is to document the sad remains and leave the place to the bulldozers. Like Gebel el-Ahmar such a site is gone and only interesting for the devoted quarry researcher.

To avoid too many similar destinies, the perhaps most important task is to promote ancient quarries, gaining public attention and securing that well-managed samples will be accessible as showcases for local residents (and developers), Egyptian visitors and foreign tourists. If nobody is interested in these places or understands their 'basics', there can be few incentives for carrying out all the work needed to safeguard them. Getting public attention is certainly not an easy task when competing with pyramids, temples and mummies in a country where most people are suffering badly from political, economic and social problems. The recently established quarry conservation department will need all the help it can get—from local people that may identify with 'their' quarry and take part in its management and presentation, to international institutions that may see the significance of the quarries in a world heritage perspective and grant the resources needed.

Sources and acknowledgements

Information about the case studies and the general condition of ancient Egyptian quarries can be found in a comprehensive QuarryScapes report by Storemyr et al. (2007), which includes primary references. Additional relevant material for the Aswan case is available in Bloxam et al. (2007) and methods for assessing significance are discussed in Bloxam and Heldal (2008) and Bloxam (2009). A general overview of ancient Egyptian quarries is presented by Harrell and Storemyr (2009). See Shawarby et al. (2009) who discuss research activities undertaken by The Egyptian Antiquities Information System (EAIS) now the GIS Center of Excellence within the Supreme Council of Antiquities (SCA) concerning the digital documentation of the Egyptian Quarry Landscapes undertaken during QuarryScapes. For a sober account on overall development trends in Egypt, including important data relevant to all the case studies, see Ibrahim and Ibrahim (2006). Fagan (2004) gives an accessible history of the fate of the Egyptian heritage at large, from antiquity to the present, see also Jeffreys (2003) and Wilkinson (2008) on related subjects. The brief description of the modern heritage sector and SCA is based on my own experience and conversations with inspectors and archaeologists over the years as well as media reports (e.g., in *Al-Ahram Weekly). The Valley of the Kings Site Management Masterplan* (Weeks et al. 2006) provides a very useful reference to cultural resource management in Egypt and also includes a comprehensive bibliography relevant to this essay.

Much appreciation is extended to the inspectorates (regional/governorate SCA offices) in Aswan, Abu Simbel and Faiyum for help and guidance in the field, as well as to the Egyptian Antiquities Information System (EAIS) for cooperation. Sincere thanks are especially due to fellow quarry researchers Adel Kelany (senior inspector at SCA Aswan and head of the Department for conservation of ancient quarries and mines), Elizabeth Bloxam (Egyptian archaeologist, University College London), Tom Heldal (geologist, Geological Survey of Norway) and James A. Harrell (geologist, University of Toledo, USA); the latter also commented on the manuscript. Much of the fieldwork was funded by EU's 6th Framework programme through the QuarryScapes project (contract no. EU FP6, INCO/MED 015416, see www.quarryscapes.no). The views expressed in this essay are the sole responsibility of the author.

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Constructing a quarry landscape from empirical data. General perspectives and a case study at the Aswan West Bank, Egypt

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Ancient quarry landscapes are neglected, but important pieces of our common heritage, giving us insight into aspects of daily life throughout human history. As archaeological sites, quarry landscapes may, at first sight, appear insignificant, and contain layer upon layer of quarrying and other activities that can be difficult to interpret in a way that can help build a case for conservation. The present paper builds on the empirical data collected in the QuarryScapes project, and suggests a method for grouping such data into five main elements: the stone resource, secondary resources, material remains from production, logistics and evidence of social infrastructure. Moreover, how these elements can be analysed and provide a basis for revealing and visualising different quarrying activities and layers, as a tool for getting closer to assess the significance of a quarry landscape. The Aswan West Bank, Egypt, is used as a case study for illustrating the methodology. This particular quarry landscape contains multiple layers of quarrying, from the Lower Palaeolithic to at least into the Roman Period, displaying different uses of the same resource through millennia. When analysing the empirical data, collected through several years of surveying, a pattern of several short- or long-lived quarrying activities (or quarry complexes) comes to the surface. These can be viewed individually, each containing particular historical values, or collectively, as a rare landscape shaped by human engagement with a specific resource through several hundred thousand years.

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Introduction

Stone[1] quarries are found more or less everywhere where there has been human activity, from the earliest hominids into the present day. Hence, quarries can give us insights into important aspects of the daily life of our ancestors in terms of how they exploited and used natural resources. Quarries may provide important 'pools of knowledge' of ancient technology, social organisation, trade and communications. Since many quarry landscapes were exploited over thousands of years, quarries can also be 'indicators' of important events or changes in society. Quarrying techniques and stone working have for a long time fascinated researchers and the lay audience, particularly in connection to the great monuments of Antiquity. In Egyptian archaeology, this fascination resulted in the important works by Petrie (1883) on the pyramid sites, Clarke and Engelbach's interpretation of the Unfinished Obelisk quarry in Aswan and other work on Egyptian masonry (Engelbach 1922, 1923, Clarke and Engelbach 1930), the discovery and description of Chephren's quarry (Engelbach 1933, 1938), the quarries in the Faiyum depression (Caton-Thompson and Gardener 1934) and, although much later, Röder (1965) on the quarrying of the Aswan granite. In the Graeco–Roman world, Ward-Perkins gained interest in marble quarrying quite early, summarised in Ward-Perkins (1971).

Ancient quarries have rightfully gained more attention of researchers during the last 25 years, lifting this subject significantly. The formation of ASMOSIA (Association for the Studies of Marble and other Stones used in Antiquity) was an important factor. The proceedings from these biannual conferences (Herz and Waelkens 1988, Waelkens et al. 1992, Maniatis et al. 1995, Schvoerer 1999, Herrmann et al. 2002, Lazzarini 2002) have made significant contributions to the understanding of ancient quarrying and in developing methods for linking quarries to their places of use. The excavations of two Roman quarry sites in the Western Desert of Egypt run by the University of Southampton (Peacock and Maxfield 1997, Maxfield and Peacock 2001) definitely demonstrated that quarry sites can contain a rich archaeological record, as did also several seasons of surveys and excavation at Chephren's quarry in southern Egypt (Harrell and Brown 1994, Shaw and Bloxam 1999, Bloxam 2000, 2003, 2005, Storemyr et al. 2002, Shaw and Heldal 2003). Surveys of several quarries in the Faiyum area (Harrell and Bown 1995, Bloxam and Storemyr 2002, Heldal et al. 2009) continued the work initiated by Caton-Thompson and Gardener (1934). Survey work carried out by Harrell et al. (1996), Harrell (2002)[2], Harrell and Storemyr (2009) and Klemm and Klemm (1993, 2008) of quarries in Egypt through many years have added significant knowledge to understanding stone procurement in ancient Egypt, and also cleared numerous misinterpretations on stone sources and use. Furthermore, their work and active cooperation from Harrell made it possible for the Egyptian heritage authorities to make a comprehensive national inventory of ancient quarries, through the QuarryScapes project (Harrell and Storemyr 2009, Shawarby et al. 2009). Significant contributions to the understanding of 'soft-stone' quarrying in Antiquity, including experimental archaeology, has been made by Bessac (i.e., Bessac 1996).

Research of Neolithic and Palaeolithic quarrying has naturally been 'nearer to the surface' due to the focus on origin, manufacturing and typologies of stone implements. Due to the development of more sophisticated geological methods of fingerprinting rocks, there has been an increasing focus on sourcing quarries and investigating artefact distribution patterns and trade (i.e., Bruen Olsen and Alsaker 1984, Bradley and Edmonds 1993). Some of the more recent works take a holistic view of quarries and landscapes (Cooney 1998, 1999, Bradley 2000, Edmonds 1999), viewing quarries as important places in 'social landscapes'.

Another 'sector' of quarry research is related to millstones. Some of the largest industrial landscapes in Europe are made from millstone quarrying, and in recent years there has been an increasing cooperation among geologists, historians and archaeologists regarding millstone quarries (i.e., Vretto-Souli 2002, Anderson et al. 2003, Belmont 2006,; Belmont and Mangartz 2006, Grenne et al. 2008). An important meeting point is a biannual conference and a European millstone database on the web[3].

However, in spite of the positive contributions of the last few decades, research of quarry or production sites still remains compartmentalised into studies of either single periods (i.e., Neolithic, Classical Antiquity, Pharaonic Egypt, Medieval), commodity (i.e., millstones) and/or geographical region (i.e., Egypt). With ancient quarries disappearing at a high rate due to modern development and the lack of registration of such sites as cultural heritage (Storemyr 2009, Storemyr et al. 2007) the need for quarry researchers to come together and find ways of raising awareness of these important places has never been more pressing. The first step is to find ways where we can analyse the diversity of quarrying remains, across many time periods, and thus find a common ground between all aspects of production-site research. The basis for QuarryScapes was to thus design tools for better characterisation and valorisation of quarry sites as cultural heritage in terms of not only bringing researchers and professionals together, but as a crucial step in forwarding their significance to heritage authorities (see also Bloxam 2009).

The objectives of this paper are to look at quarries and quarry landscapes from a *micro-level* perspective in terms of their characterisation and interpretation from the geological resource, to mate-

[1]In this context, 'stone' is used as a collective term covering rocks that are used as more or less shaped and dressed blocks.
[2]See also Harrell's web site http://www.eeescience.utoledo.edu/Faculty/Harrell/Egypt/AGRG_Home.html
[3]http://meuliere.ish-lyon.cnrs.fr/en/welcome.htm.

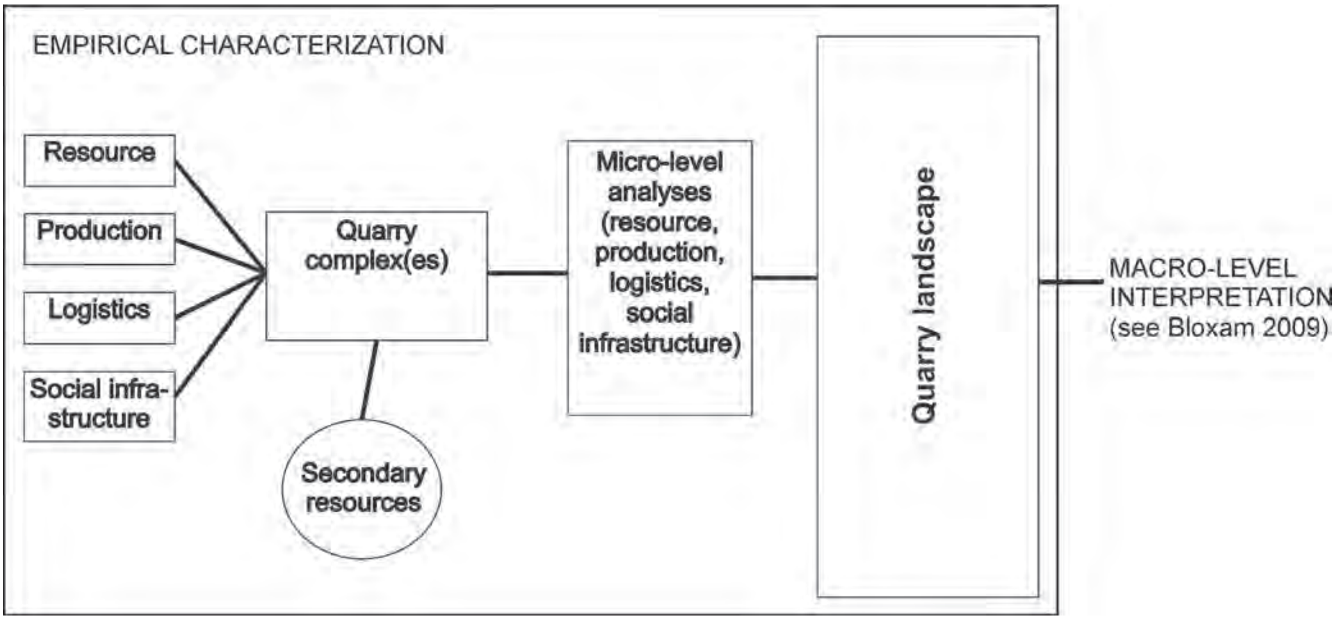

Figure 1. Proposed procedure for empirical characterisation of ancient stone quarries; from identification of features and elements to interpreting complexes.

rial remains from quarrying, to the 'construction' of quarry landscapes by sets of similar quarrying activities. Such analyses may be a useful way of structuring empirical data enabling interpretation of the bigger picture (*macro level*) (Figure 1). The present paper builds on a methodology presented in a QuarryScapes report (Bloxam and Heldal 2008), from which also several of the figures have been taken.

A general approach to quarry landscapes

All quarry landscapes, whether these are Neolithic chert quarries, Roman marble quarries or paving stone quarries from the Industrial Period, have aspects and features in common that can be examined and analysed in a systematic way, establishing a base of empirical characterisation for the assessment of their historical significance (Figure 1). A quarry site may be visualised from *the material remains* of the various processes involved in the exploitation of its resources, over one or several periods. These remains might include traces of the extraction of rocks (tool marks), deposition of excess rock (spoil), tools, semifinished and discarded products, work areas, ceramics, shelters etc. Collectively, they tell us something about the processes involved in the selection of stone to be quarried, the production of it, the logistics related to its transportation and the social context and organisation related to sustaining the people involved in the quarrying. The remains from quarrying may be characterised from a purely physical and descriptive perspective. However, when characterising quarries at a micro level, this analytical phase has to achieve a basic overview of the quarrying process in order to identify different quarrying activities within a quarry landscape, and as a tool for comparing one quarry landscape with another. A key problem is to address multiperiod and multifunctional quarrying, as seen in many quarry landscapes. This requires 'deconstruction' of quarry landscapes into connected activities, but without loosing the holistic perspective of the dynamics through time.

Stone resources—reading behind the quarries

One of the important aspects of resource characterisation is to find the link between the quarry and distribution of its products (provenance). Most of the studies involving ancient quarries have in fact investigated such aspects, as published in the ASMOSIA proceedings (op. cit.). But there are also other important aspects of the stone resources, less addressed, that can shed light on quarrying activities and stone procurement. These may be illustrated as a process. The selection of stone type to be quarried (commodity and quality in use), the physical landscape in which the stone resources occur (morphology and geometry of deposit) and the condition of the deposit (production quality) all count when choosing the place for quarrying (Figure 2).

One key aspect is the question of commodity. Why were the rocks desirable? At present time, as in the past, the exploitation of stone resources can originate from different needs, such as building material, valuable stone for decoration, and for high-quality rocks suitable

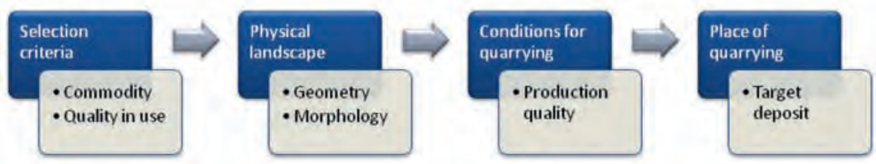

Figure 2. View of a stone resource—from selection to choice of place for quarrying.

for specialised tools. With these key aspects in mind, one may view stone resources from three extreme perspectives: building stone, ornamental stone and utilitarian stone (Table 1). From these perspectives we can then get closer to the reasons for quarrying; was the quarrying due to technical quality of the stone, its rareness or just that it was an available raw material? Visual appearance and even remoteness have been important in many cases of stone quarrying (i.e., Peacock 1992, Lazzarini 2004), in contrast to obtaining the 'everyday' building stone for a city, which often was extracted in the most available deposits of sufficient quality (Degryse 2007, Degryse et al. 2008, 2009, Abu-Jaber et al. 2009), or the high weight put on quality when applied to utilitarian stones. However, the city builders may have decided to go further away to obtain building stone of a particular quality and aesthetic appearance for prestige buildings, or for economic reasons they may have chosen to use the local, low-quality stone also for ornamentation. Thus, although the three perspectives are helpful, it is important to acknowledge that the divisions between them are not—and should not be—rigid.

The overall conditions for quarrying are decided by the exposure of stone resources in the landscape, as a result of multiple geological processes; from the formation of the rocks, through transformations of them to weathering and erosion. The geometry and outcropping pattern of the resource establishes the 'geometrical condition' of quarrying, to which quarrying methods to a large extent must be adapted. Consequently, it also represents the condition of how the morphology resulting from the transformation of the natural landscape by quarrying visually appears. Thus, it is valuable to reconstruct the situation before quarrying in order to interpret the size and spatial evolution of a quarry landscape. A simple division of stone resource geometries, as they appear in the bedrock, is given in Figure 3.

Production quality may be viewed as a result of the resources' (rocks') physical properties—their workability. Such issues can be viewed on different scales. On a *micro scale*, the mineral composition, texture and structure commonly decide the hardness, brittleness and preferred direction of splitting in rocks, properties that highly influence the quarrying techniques. On a *meso scale*, a key issue is the distribution and density of naturally occurring fractures, determining the obtainable sizes and shapes of stone blocks. Unsystematic and scattered spatial distribution of quarries can often reflect the movement of exploitation between places of favourable fracturing (see example in Kelany et al. 2009).

In many cases, quarrying requires input of other natural resources used in the production process. Defining the quarried resource as 'primary', we can collectively name the use of these other natural resources as 'secondary' resources (see Figure 1)[4]. These may be stone resources for use as tools, wood for smithies, stone for other constructions such as settlements, wells and roads, or grinding stones for food production. Secondary resources may be directly applied in the production process, or indirectly for sustaining the people doing it, such as housing for the workers and various utensils. Moreover, secondary resources may be imported or obtained locally.

Production evidence

Understanding the production process is a key aspect when it comes to characterising quarry landscapes. The stone resource, secondary resources and human resources are the 'inputs' to the production, the resulting products, finished objects or rough-outs, are the 'outputs'. The production process can be read from the marks on the quarry faces and blocks (tool marks), the composition and distribution of spoil rock, broken or half-finished products, remains from tools and the existence or not of designated work areas for different stages in the production. When compiling the empirical data from QuarryScapes, we found that a simple division of a production process in a quarry into four steps was useful, both for illuminating similarities and differences between these different activities (Figure 4). These are: 1) extraction from bedrock, 2) block reduction to 'cores', 3) semifinishing of cores to rough-outs or blanks, and 4) finishing to the final product.

The techniques involved in the extraction of blocks from the bedrock can be described as three fundamental principles—or combinations of them: levering, splitting and channelling. Le-

Table 1. Stone commodities, use and important quality aspects.

	Commodity	Uses	Common rocks	Important aspects
Stone resources	Building stone (masonry stone)	Rubble walls Ashlar walls Architectural elements Roof Floor Paving	Sandstone Limestone Granite Gneiss Marble Schist Slate	Availability Workability
	Ornamental stone (decorative stone)	Sculpture Cladding Floor Columns Funerary	Marble Granite Misc. igneous rocks Porphyry Gneiss Quartzite	Aesthetic appearance Symbolic value Rarity Carving properties
	Utilitarian stone	Tools Weapons Grinding stone Millstone Whetstone Cooking vessels	Chert Volcanic rocks Quartzite Sandstone Schist Soapstone	Physical properties

[4] Here, we will specifically address the secondary stone resources, not organic resources, water etc.

vering, being the simplest, involves the extraction of blocks bordered by natural cracks that are widened with the help of levers or inserted stones. Splitting involves the creation of cracks by percussion (stroke), inserting wedges of some kind in prefabricated holes or by heat. In a modern context, splitting is mainly done by detonating explosives in drill holes. Channelling is the third fundamental principle. Channels in the rock are made by removing the rock mass by chiselling, picking, sawing or heating. In most soft-stone quarries from the Bronze Age onwards, channelling is the most important extraction method. In most cases, channelling is combined with splitting (i.e., along bedding planes in limestone). Blade sawing of rocks, even basalt and granite, were applied since the Old Kingdom (Petrie 1883, Moores 1991). As a method in channelling, however, it may not have been applied until modern times, although sawn blocks are observed in Roman quarries (Harrell and Brown 2002).

When a stone block is obtained by extraction from bedrock, or collected from natural boulders or scree blocks, it is either reduced in size producing a core, or directly dressed to a rough-out or blank. Reduction of blocks may be described basically in the same way as extraction; e.g., splitting with percussion, splitting with wedges, splitting with heat (fire setting), sawing or carving/hewing. Dressing of semifinished products is essentially carried out by hewing and trimming, whilst finishing also can involve grinding and honing.

When analysing a quarrying process, it is important to address the start and end of the process, the number of steps involved and the techniques applied, based on the material remains. Did the process involve bedrock extraction, or just a collection of naturally occurring blocks? Did it involve few or several types of skilled labour? How far towards final finishing did it go? As will be shown in the case study, the presence (or absence) of these steps in a quarry site may reveal important information about the organisation of quarrying, which can be

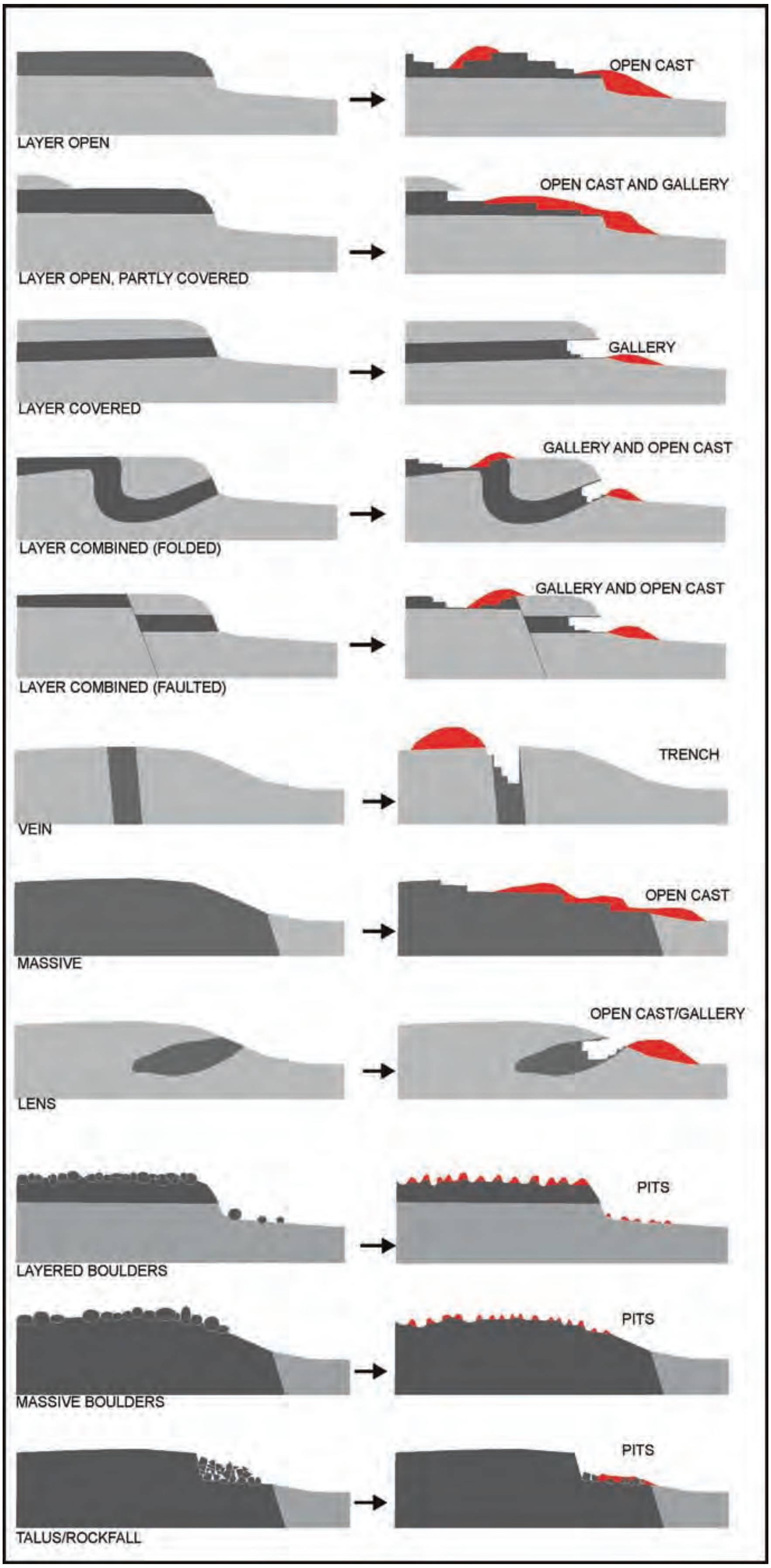

Figure 3. Various geological and morphological situations of stone resources and the resulting quarry landscapes. Stone resource=dark grey colour; spoil heaps=red colour.

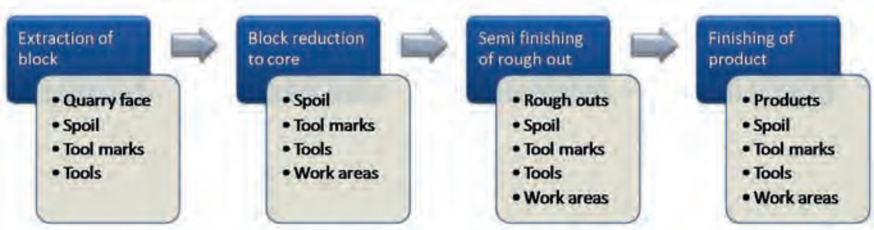

Figure 4. Production process in stone quarries and features defining each step.

valuable for assessing the broader social context of these operations.

Transporting the stone

The transport of stone blocks and products is an important element of all quarrying activities. Clearly, the production of small objects that can be carried by a man or a donkey requires less constructed infrastructure than huge obelisks. However, whatever the output of the quarrying was, the remains of features related to transport are important to characterise. Such remains may be constructed features such as ramps, roads and harbours, less visible features such as cairns (site lines) and worn paths, or other features such as fixingholes for ropes and postholes for fixing lifting devices. Also, stocked or lost stone products on the transport route are found in many cases, providing further evidence of the logistics.

Such remains can collectively give sufficient empirical information about the logistical process, the internal logistics (between the steps in the production process) and the transport of stone to other places for further processing and/or use, as illustrated in Figure 5. They may also provide evidence of how the transport was carried out. For example, the nature of the quarry roads may uncover the type of transport vehicle applied.

The logistics not only concern the transport of products out from the quarry, but also transport of people and resources into the quarry area. Examples are given in Maxfield and Peacock (2001, p. 96).

Social infrastructure

Written sources such as epigraphic data associated with quarrying, as well as historical texts that can relate to practice, are one key data source for extrapolating the social context through which ancient quarrying was expedited. Other sources are the built structures linked to dwellings for the work force, ceramics and other associated artefacts that comprise the social infrastructure of quarrying. Elements of this infrastructure that might be found across an ancient quarry landscape, vary from built features to epigraphic data, from which an assessment of the social context can be made.

The problem in visual terms is that easily recognisable large purpose-built settlements associated with ancient quarries, are the exception rather than the rule. The large purpose-built quarry settlements of Mons Claudianus and Mons Porphyrities in the Eastern Desert of Egypt are such an exception (Peacock and Maxfield 1997, Maxfield and Peacock 2001). Hence, in the search for dwellings for quarry labour forces, much emphasis has been placed on the ubiquitous 'stone circles' or 'stone enclosures' that occur in a number of ancient quarries in Egypt, as being places of habitation (see Shaw 1994, Harrell and Bown 1995). Such subtle remains are extremely difficult to interpret (see Heldal et al. 2009); for instance to separate temporary dwellings from storage, lookouts or later features not connected to quarrying at all. Thus, such remains must be combined with other evidence in order to make any inference on labour force and organisation (see Bloxam 2003).

Pottery is key in terms of indirectly determining periods when quarrying occurred, and when found associated with stone-built features in secure contexts, is important for dating such structures. Typologies of ceramics can indicate not only chronology, but can aid in characterising subsistence patterns of a labour force, particularly when associated with organic remains and/or other domestic artefacts. Epigraphic data—and of course written sources—may be key for understanding quarrying activities, where present. These can include inscriptions (i.e.,

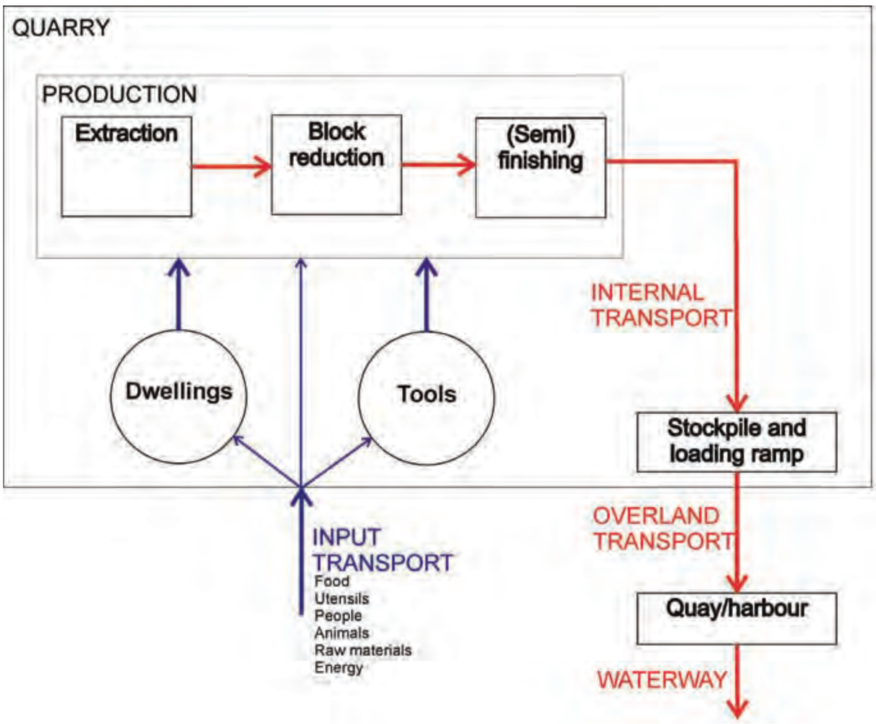

Figure 5. Schematic view of the logistical system in a stone quarry.

dedications), graffiti and rock art. Many of the large Roman and Dynastic Egyptian quarry sites are rich in epigraphic data, but in many other contexts such evidence is lacking or rare.

When analysing the empirical data in terms of making inferences into the social context of ancient quarrying, there are key questions that we need to ask of these data. For instance, the size of labour forces (did they reside permanently at the quarry?), levels of social organisation and the extent to which such activities may have been controlled by the 'state' or other type of centralised bureaucracy. We also need to contextualise these data historically, and compare with other ancient quarries. Moreover is the need to develop conceptual models through which we can gain fresh insights into the social context of quarrying, this being relevant where there are data gaps and an absence of written sources.

Quarry landscapes as constructions: evolution through time and space

Quarry landscapes are often composed of multiple layers of activities from more or less continuous activities through time. The different time layers do not form well-stratified layers, but rather a complex system of use, reuse and frequent relocation of material culture. Individual quarry sites were commonly revisited during several periods, spoil material was moved to make space for new quarrying, roads/other infrastructure may have been moved or reused. In addition, many quarry landscapes, particularly those that did not have permanent settlements for the work force, tend to have little dateable material culture. However, finding the time depth of a quarry landscape is one of the most crucial research questions when it comes to evaluating its significance. Naturally, the earliest phases of quarrying are less visible (and more difficult to identify) than the younger, but not less significant. Given such limitations, finding time depth in quarries can be achieved by several methods:

- Through *direct dating*: charcoal and other organic remains can be found in settlement areas and trapped in spoil heaps. Cosmogenic nuclides (particularly $^{10}Be/^{26}Al$) may prove useful in particular cases for dating of the time rocks have been exposed near or at the surface.
- Through *indirect dating*: ceramics, inscriptions and other epigraphic data.
- Through *consumption*: one of the most valuable methods of dating quarrying activities is through consumption of the rocks, being buildings in a city or other well-dated objects.
- Through *technology*: the interpretation of tool marks may reveal the use of specific tools and tool materials (stone, iron) that can be dated.
- Through *relative dating of events*: such as overlapping layers of quarrying activities, weathering of rocks.

Concerning direct dating by cosmogenic nuclides, the method seems to work best when rocks have become exposed at the surface by sudden events (such as quarrying). Obviously, this is particularly valid in bedrock quarries, where large volumes of stone have been removed (Wagner 1998). There may be more problems related to quarrying of small, scattered surface blocks, given that such blocks already have been exposed for a long time before they were worked. In spite of that, there is hope that the method may prove to work well on particular types of quarries. There have been some studies of rock artefacts from quarries with a certain success, such as dating of Lower Palaeolithic chert flakes in Egypt (Ivy-Ochs et al. 2001) and a study using ^{10}Be for separating Neolithic chert (brought from deep mines) from Palaeolithic (exploitation of surface blocks) (Verri et al. 2005).

Time depth alone does not get us much closer to understanding the evolution of quarrying at a given place. The micro-level data, as addressed above, must be drawn together and understood, allowing us to build a composite picture of the ancient quarrying process and its social context. From the case studies in QuarryScapes, it became useful to identify quarrying activities (or elements) that were connected to each other in time, space and/or function. Such a definition of *quarry complexes*, more than being a division into rigid classes, can aid in visualising similarities and differences in a quarry landscape. In a general view, a quarry complex may be visualised as in Figure 6, as a system of interconnected quarries sharing social infrastructure and logistics, input of labour force

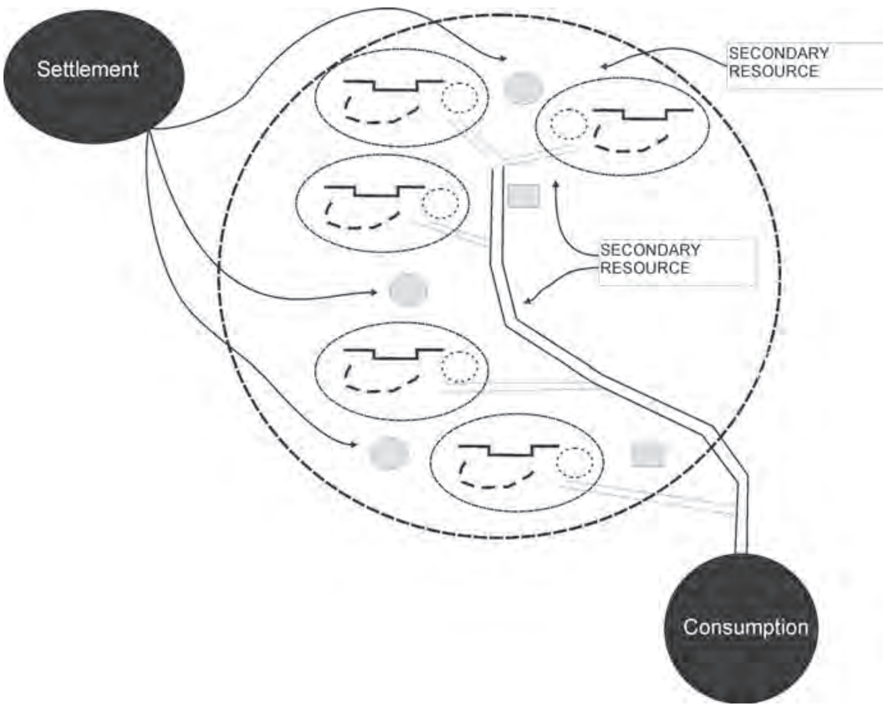

Figure 6. A quarry complex—as defined by a group of interconnected quarries sharing logistics, social infrastructure and secondary resources.

and secondary resources and output of products. Criteria used for identifying quarry complexes may be by time period ('historical complex'). But it may also be linked to the resource (as the 'arena' of exploitation), production/technology, consumption (i.e., parts of a city, or even a historical complex in a city) and function (which largely relates to commodity). The main reason for keeping an open view on the definition of complexes is that it is important to view quarry landscapes in perspectives other than the strictly historical. Although it is interesting to place quarry landscapes into historical 'slices' (and indeed in some cases this will be the most valuable perspective), one often faces problems in doing so, due to the above-mentioned lack of material culture. Moreover, in many cases the longevity of quarry activities is itself a major point to visualise and characterise. In the physical meaning of the term, a quarry landscape may thus be simply defined as the sum of its complexes.

The empirical data of the Aswan West Bank quarry landscape

The West Bank quarries

The ancient quarries at the West Bank of the Nile, at Aswan, cover an area of some 50 km² between the Old Aswan Dam in the south and Wadi Kubbaniya in the north (Figure 7). Some of the quarries, notably Gebel Tingar and Gebel Gulab (Figure 7), are known to be a major source of prestigious objects of silicified (hard, 'quartzitic') sandstone in ancient Egypt, together with deposits on the East Bank (Wadi Abu Agag, Harrell and Madbouly 2006) and Gebel el-Ahmar in Cairo (Klemm et al. 1984, Klemm and Klemm 1993, 2008). Such use of silicified sandstone is known from the 1st Dynasty to the Graeco–Roman Period, but peaked in the New Kingdom. See Bloxam (2007) for an overview of the use of silicified sandstone. Of particular interest in the West Bank quarries is the production of obelisks during the reign of Sety I (1294–1279 BC), which left an inscribed tip of an obelisk in the quarries (Habachi 1960, Brand 1997, 2000). Moreover, Klemm and Klemm (1993) suggested major exploitation of statue blocks (including the Colossi of Memnon) during Amenhotep III, and recognised Roman ornamental stone quarries. They also recognised and described several building stone quarries in the area in poorly silicified sandstone ranging from the Old Kingdom to the Coptic Period.

In Wadi Kubbaniya in the far north of the quarry landscape, Roubet (1989) discovered a quarry of grinding stones for food processing (hand querns), which she linked to a nearby Upper Palaeolithic (18,000 BP) settlement (Wendorf and Schild 1989), being so far evidence of the oldest production and use of such implements, certainly in Egypt and perhaps in the world. More recently, QuarryScapes surveys have revealed that such production of grinding stones in the Upper Palaeolithic and at least into the Roman Period, is the most extensive quarrying activity across the landscape (Heldal et al. 2005, Bloxam and Storemyr 2005, Bloxam et al. 2007). Furthermore, these surveys uncovered Palaeolithic production of tools in silicified sandstone, representing the earliest layer of quarrying in the landscape (Bloxam et al. 2007, Bloxam and Moloney 2009). Hence, the Aswan West Bank comes forward as a quarry landscape with high complexity, displaying many types and layers of quarrying operations through a vast period of time. In order to get closer to an assessment of historical significance, it is crucial to look closer at the empirical data and how these can contribute in deconstructing the quarry landscape into different elements.

Geology and stone resources at the West Bank

The sedimentary rock succession on the West Bank is part of the 'Nubian Sandstone' (Rüssegger 1847), which is a term used for the Upper Cretaceous in Sudan and Egypt (Zittel 1883). The term 'Nubian Series' (Sandford 1935) has also been in common use; however in more recent times the term 'Nubian Group', as introduced by Whiteman (1970), has been accepted by several authors (Klitzsch et al. 1979). The Nubian Group on the Aswan West Bank displays layers of claystones, mudstones and sandstones of Upper Cretaceous age (Turonian–Campanian, Klitzsch 1990). The lower part rests directly on top of Precambrian granitoid rocks ('Aswan Granite', see e.g., Ball 1907, Kelany et al. 2009), where the contact represents an irregular topographic surface formed by erosion of the Precambrian rocks prior to deposition of the sedimentary rocks.

The succession is divided into three formations as defined by Zaghloul (1970), and also used in some of the most recent papers, e.g., Klitzsch (1990) and Endrisewitz (1988), namely (from bottom to top): the Abu Agag Formation, the Timsah Formation and the Um Barmil Formation. In the present paper, some modification of the formation boundaries have been made, based on work by Bhattacharyya and Lorenz (1983) and van Houten et al. (1984). Most of the stratigraphic section is well displayed on the eastern slope of Gebel Gubbet el-Hawa (Figure 7, Heldal et al. 2007b), where the Tombs of the Nobles are situated. A log of the section is given in Figure 8, and a geological map showing the distribution of the three formations at the West Bank is shown in Figure 9.

The Abu Agag Formation displays a lower unit of cross-bedded sandstones and conglomeratic sandstones, resting directly on the Precambrian rocks. This unit is overlain by a unit of mudstones intercalated with thin sandstone and siltstone beds. In the upper part there is a several-metres thick point-bar deposit, which probably represents a meandering river channel (Heldal et al. 2007b). The uppermost few metres of the formation consist of shallow-marine sandstone beds locally containing oolitic hematite-goethite iron beds, subject to intensive ancient iron mining south of Gebel Gubbet el-Hawa. Most of the rock-cut tombs on the West Bank are found in the rocks of the Abu Agag Formation, and also several building stone quarries.

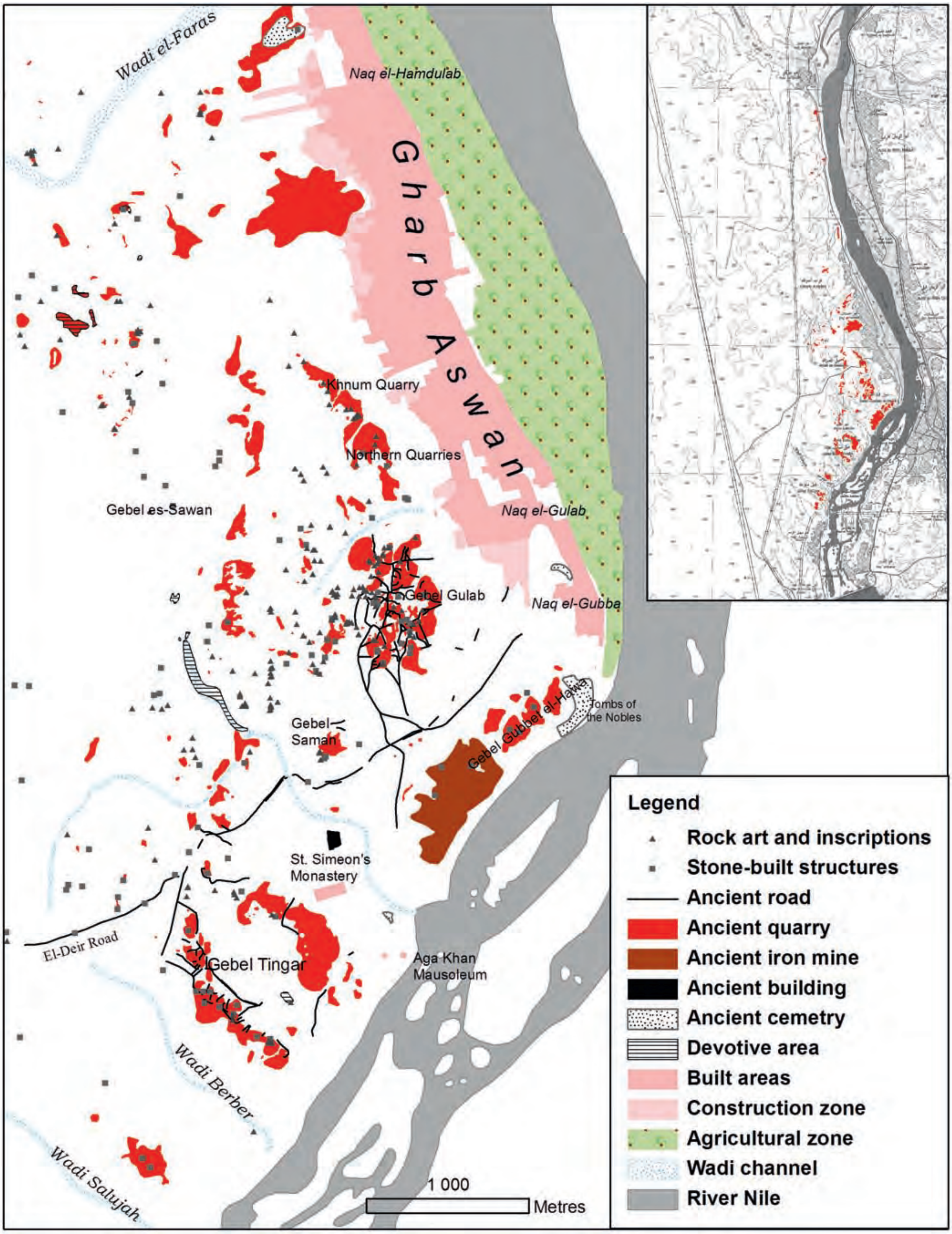

Figure 7. The central part of the Aswan West Bank quarry landscape and the main archaeological elements in the landscape.

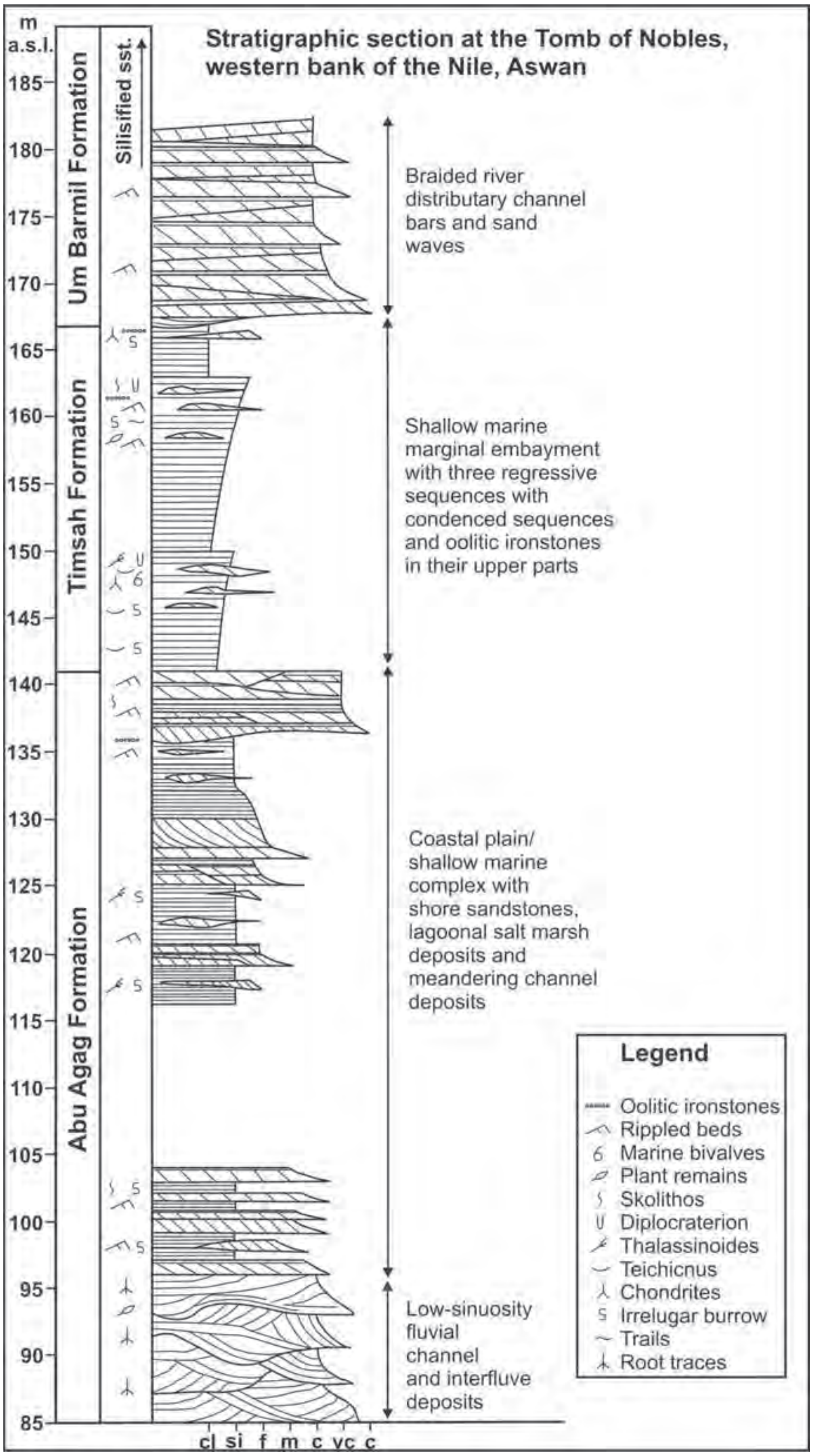

Figure 8. Stratigraphic section through the Nubian Group at the Tomb of Nobles, Aswan West Bank. From Heldal et al. (2007b). Drawing by Reidulv Bøe.

The Timsah Formation represents three shoaling-upwards sequences, each containing mudstones grading upwards to cross- and ripple-laminated sandstone beds. The Timsah Formation contains several thin layers of oolitic iron stone, predominantly occurring on top of the sandstone beds.

The Um Barmil Formation occupies the uppermost part of the topography within the concession area. It lies unconformably on top of the Timsah Formation, and locally, ferruginous conglomerate is developed along its base. It consists of two units of tabular cross-bedded sandstones and conglomerates interpreted as braided-river deposits. A 10 m-thick unit of mudstone, siltstone and rippled sandstone occurs between the two sandstone/conglomerate units. Parts of the fluvial sandstone beds have undergone extreme silica cementation so that they appear much harder than the bulk of the sandstones, and are thus termed silicified sandstone (or 'quartzite'). The first appearance of silicified sandstone is approximately 4–8 m above the base of the formation.

The degree of silicification varies considerably (Figure 10), from porous, poorly-cemented sandstone (target for building stone), to highly silicified sandstone, in which the spaces between the detrital quartz grains are almost completely filled with quartz cement (Figure 11). These variations can be observed both laterally and vertically, and even within single outcrops (Figure 10a). Silicification influences the hardness and the durability of the sandstones; the more silicified ones being extremely dense and durable, and displaying clear and bright colours. The colour is of particular importance when it comes to use of silicified sandstone for ornamental purposes, as will be described below.

The layered succession of mudstones, siltstones and sandstones defines the morphology of the area, with the more resistant, silicified sandstone beds capping hills and terraces, and escarpments formed where erosion has cut through sandstone beds and into underlying mudstones. The silicified sandstone is the most important target for stone extraction in the area, due to its mechanical quality (hardness) and/or aesthetic appearance. The hardness and low porosity has caused the silicified sandstone to be much more resistant to weathering than the other rocks, it thus occurs not only in layers capping the hilltops, but also as 'blocky remains' of the layers scattered across the area (Figure 12). In such

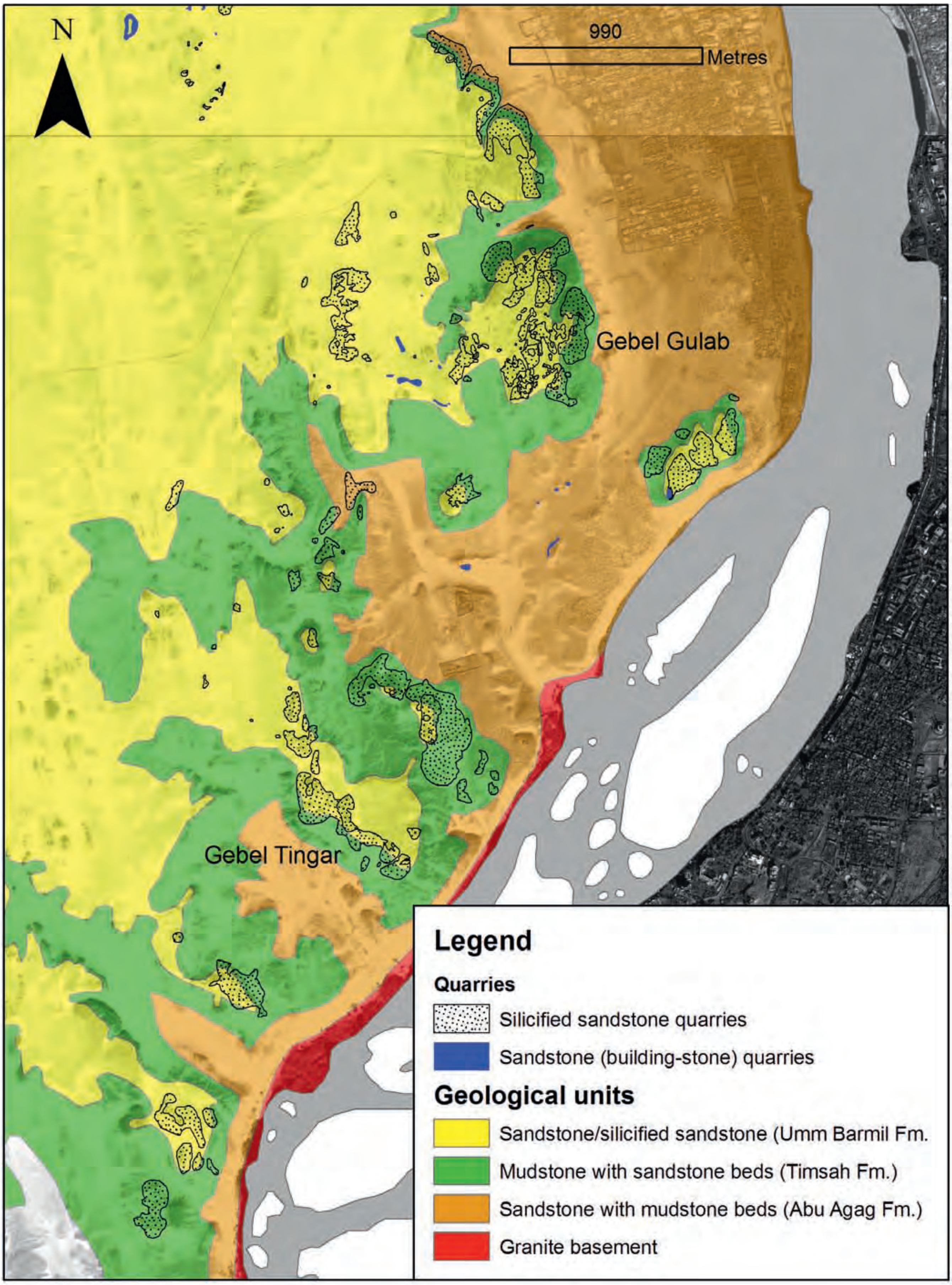

Figure 9. Geological map of the south-central part of the Aswan West Bank and location of main quarries.

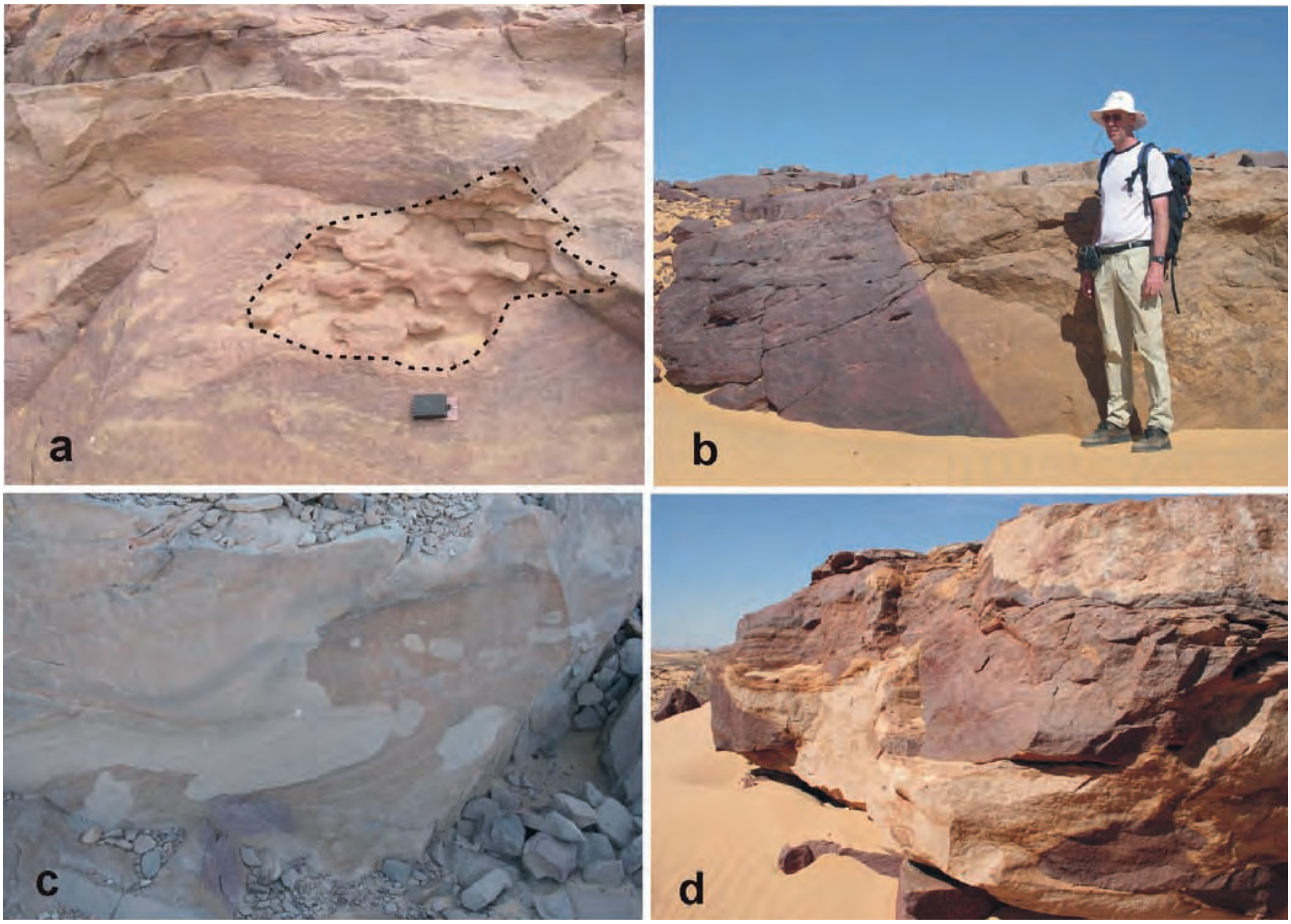

Figure 10. Aspects of silicification on a mesoscopic scale. (a) non-silicified spot in silicified sandstone, (b) border between purple and yellow silicified sandstone, (c) silicified sandstone (darker) in poorly silicified sandstone, (d) lenticular 'flame-structured' zones of purple silicified sandstone in yellow sandstone.

areas, silicified sandstones occur as collapsed, discontinuous block layers more or less in situ in the landscape. However, the farther away from their initial stratigraphic position the blocks are found, the smaller in size and more rounded they are. This aspect is important for interpretation of quarrying methods and chronology; it seems clear that the 'earliest' quarrying for tools and grinding stones targeted clusters of small, rounded blocks, whilst later mass production of grinding stones and ornamental stone quarrying focussed on the large blocks and the solid bedrock. Also 'softer' sandstone varieties have been exploited in the area, but to a smaller extent and mainly in the north, between Gebel el-Qurna and Wadi Kubbaniya. Oolitic iron stone and ferruginous sandstone layers occur in the sedimentary rock succession, and in the central part of the area these have been important sources of hematite and goethite; thus exploited at an early stage for ochre pigment and later for iron ore.

Hence, it is possible to 'deconstruct' the deposits in the area into qualities that fit the different commodities quarried; physical properties as important in the case of the utilitarian production (tools and grinding stone), workability in the case of the building stone quarries and 'rareness'/colour as key value regarding the ornamental stone production (Figure 13).

Finding production evidence

As key for understanding the layers of quarrying activity, the remains from the various steps in the quarrying process needed to be characterised. These include quarry faces/work areas, spoil heaps, tools and artefacts (rough-outs and discarded products). In the silicified sandstone, extraction and block-reduction techniques can be read from the tool marks on the quarry faces (for more detailed descriptions, see Heldal and Storemyr 2007). Simple techniques include levering by widening natural fractures and splitting with stone tools, which are particularly applied in grinding stone quarrying (Figure 14). Splitting with heating, leaving flaked quarry faces combined with large amounts of charcoal in the spoil heaps, are found both related to grinding stone quarrying and quarrying of large objects, such as statues (Figure 15). Channelling with stone tools, similar to the technique used in the Unfinished Obelisk quarry, Aswan (Röder 1965), is seen particularly connected to the obelisk quarrying at and near Gebel Gulab (Figure 16). Dressing of blocks with stone tools is commonly seen where there is evidence for quarrying large objects (Figure 15). Splitting with wedges, as typical for Roman granite quarrying, is found at Gebel Gulab and Gebel Tingar (Figure

17), overprinting previous quarries. In 'softer' sandstone varieties, extraction techniques (predominantly for ashlars) mostly involved channelling with chisels and wedging along the sedimentary layering, similar to methods described from various periods at Gebel el Silsila (Klemm and Klemm 1993) (Figure 18).

The discarded material from quarrying (spoil) can contribute much to the interpretation. The distribution of spoil heaps define the focal point of quarrying (such as concentric ones around extracted boulders), and their stratigraphy the number of quarrying cycles at one defined spot. The size distribution of spoil rock indicates the size of the products made; production of small objects leaves a uniform distribution of small-sized pieces, as in the case of the grinding stone quarries (Figure 19), whilst a variegated composition is found were large objects were targeted. Chips from trimming or dressing may be concentrated at specific spots (designated work areas) or more evenly distributed in-between larger fragments. The shape of the chips themselves gives inferences of whether the production involved trimming of small object blanks (such as grinding stones), dressing of surfaces (as statues and obelisks) or producing flakes (Palaeolithic tool production, Figure 20). At Gebel Gulab, there is also evidence of grinding of stone surfaces, leaving heaps of stratified sand mixed with tool fragments (Figure 17d).

Stone tools or fragments of such are found all over the area. They can basically be divided in three groups: quartz pebbles from ancient river beds in the

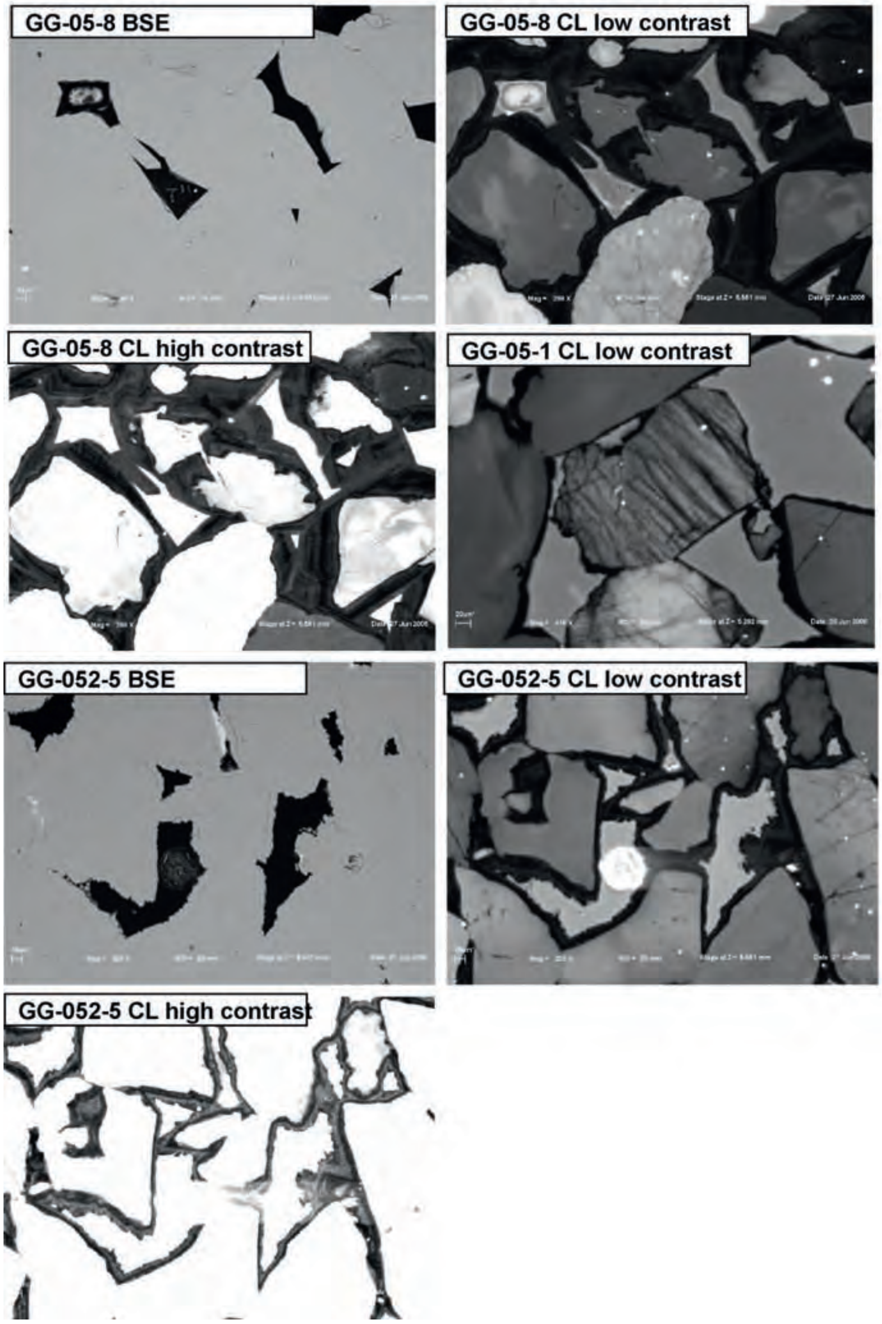

Figure 11. Silicification on a microscopic scale and diagenetic overgrowth patterns. Thick overgrowth (~40 µm) with internal planar zoning (GG–05–8), thin overgrowth (5–10 µm) without internal zoning (GG–05–1) and moderately thick overgrowth (~20 µm) with internal collomorph zoning (GG–052–5).

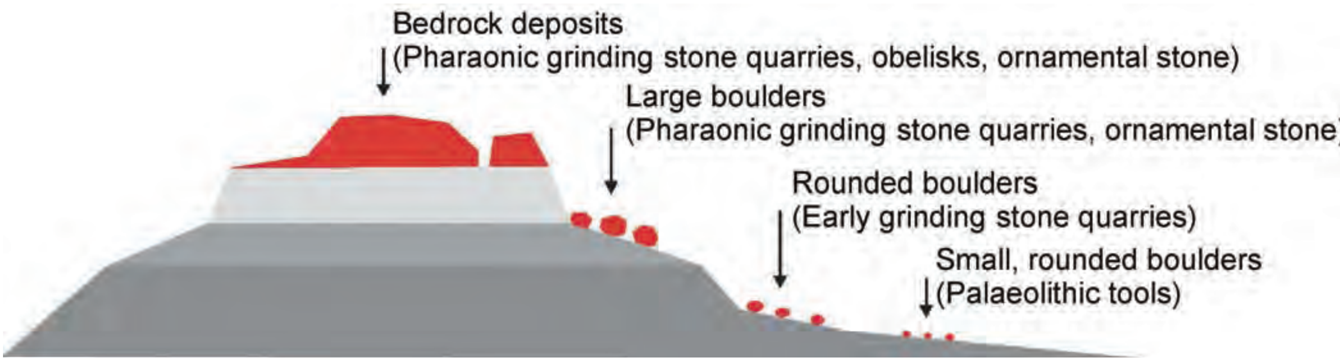

Figure 12. Simplified sketch of the morphology of the Aswan West Bank and occurrences of silicified sandstone deposits.

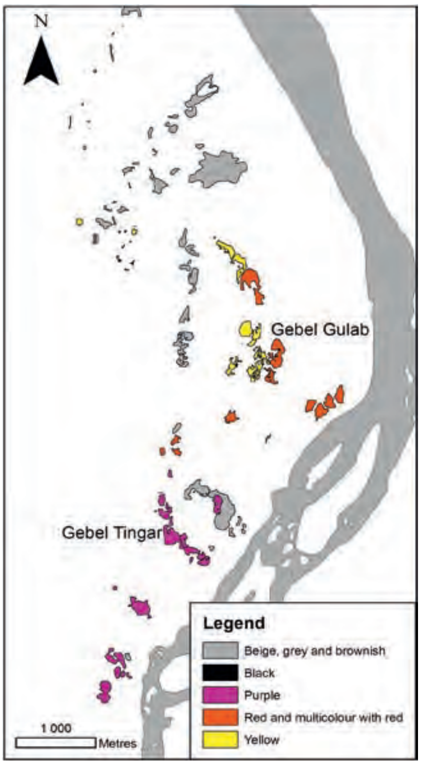

Figure 13. Distribution of colour in the silicified sandstone deposits.

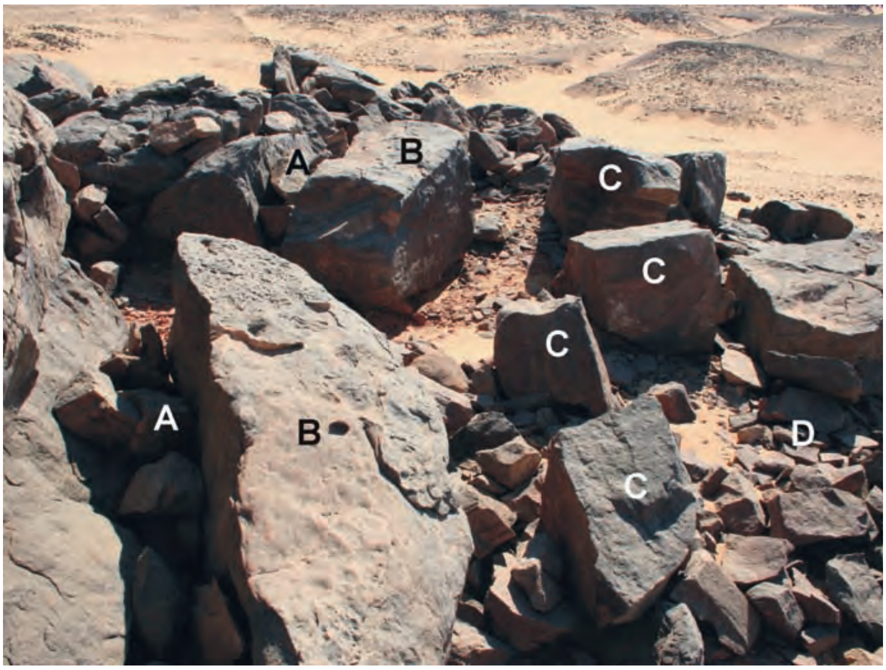

Figure 14. Grinding stone quarry showing different steps of block extraction and reduction. A: primary wedging with stones to open cracks. B: primary blocks. C: secondary split blocks. D: debitage from trimming of grinding stone blanks.

Figure 15. Pharaonic ornamental stone quarrying. (a–b) Area for extraction of large blocks, all removed from the quarry site. (c) Stages of producing statues or obelisks from large blocks. Right: splitting of surface-parallel flakes (by heating?). Left: dressing of surface by stone hammers. (d) Statuette blank made by trimming by stone hammers, similar method as production of grinding stones.

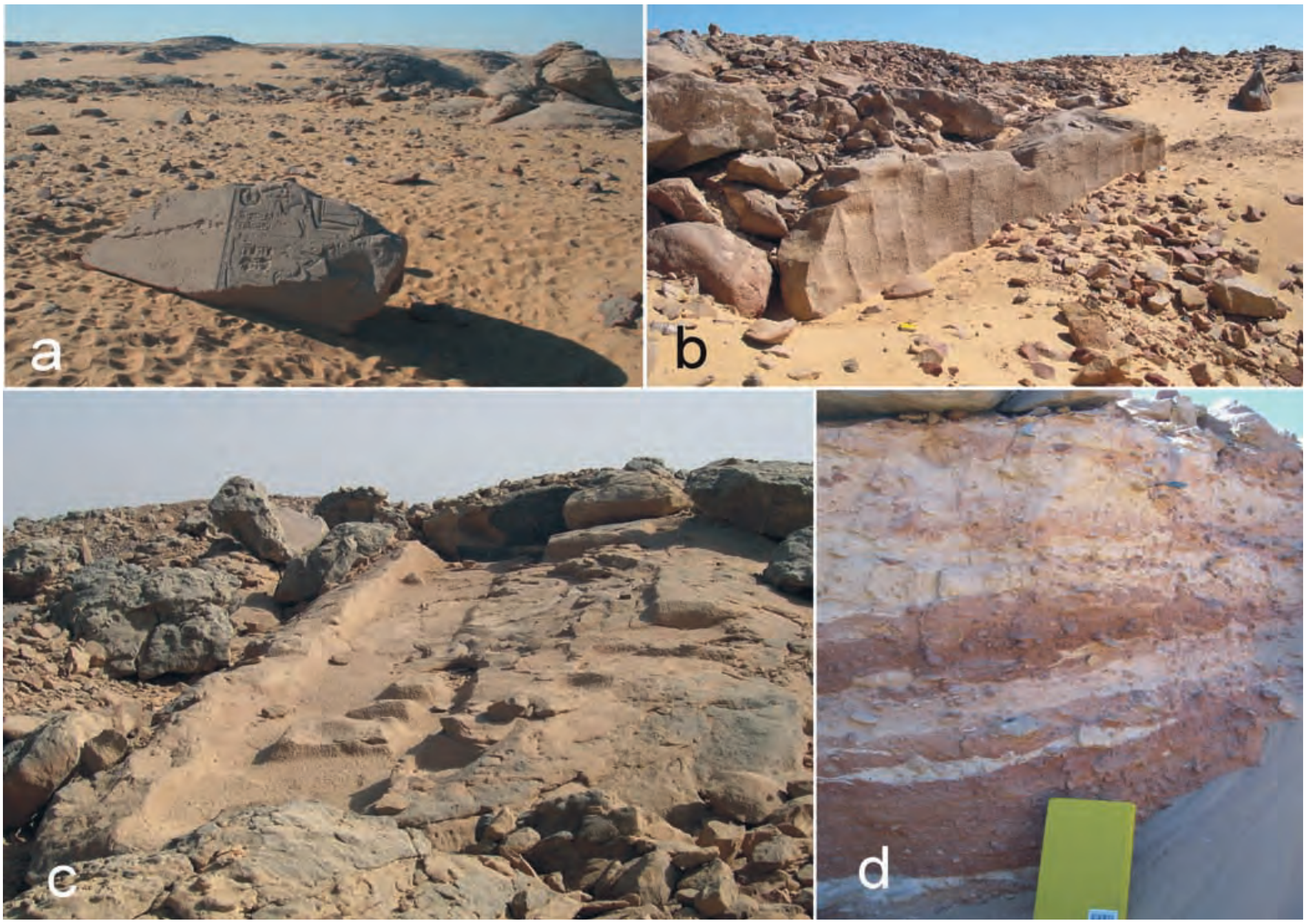

Figure 16. Obelisk quarries. (a) Sety I obelisk tip, (b) quarry face from extraction of obelisk block displaying tool marks from stone tools, (c) initiation of an obelisk quarry displaying initial levelling of the top of the obelisk surface, (d) stratigraphy of sand from grinding/polishing the surface of the obelisk mixed with tool fragments.

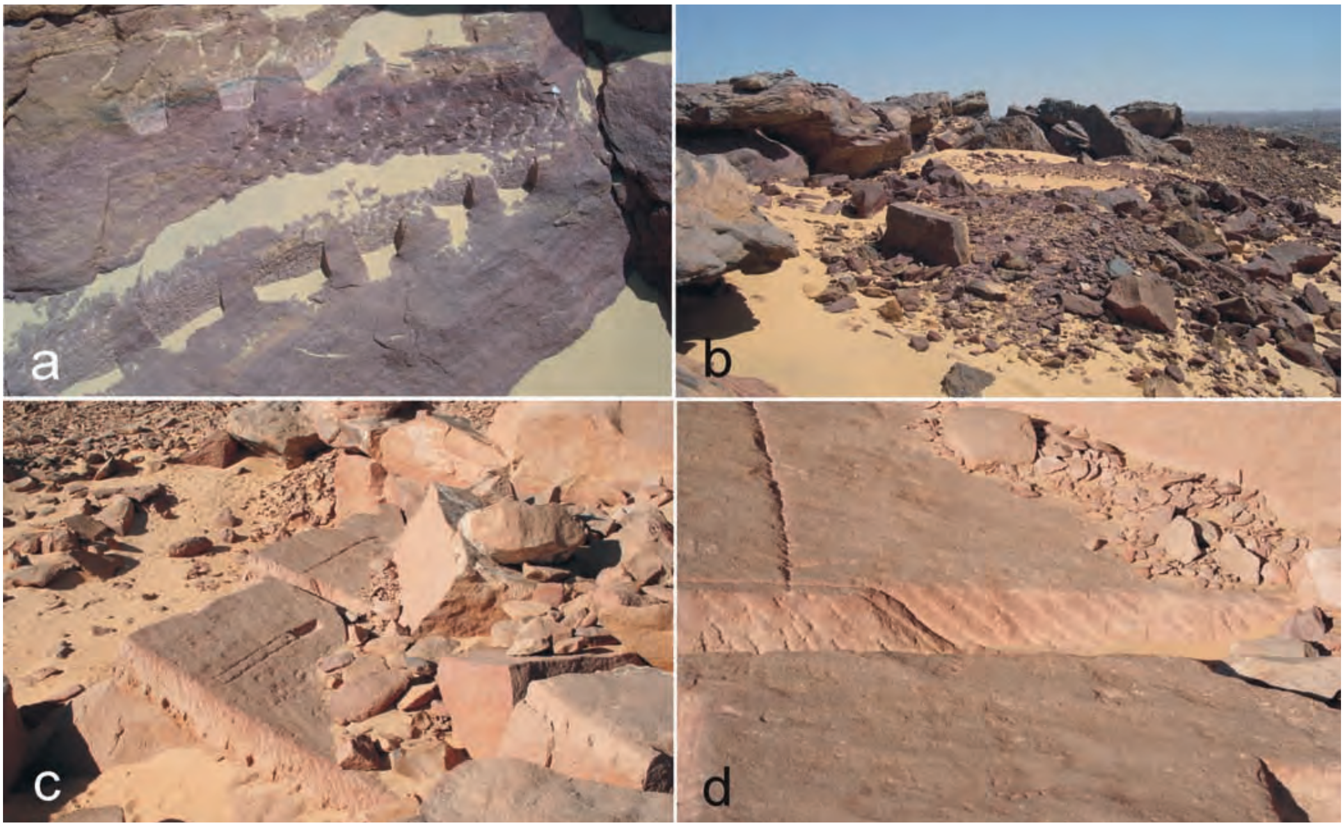

Figure 17. Traces of Roman Period quarrying of silicified sandstone. (a) Wedge marks, (b) work area, (c–d) wedges in shallow channels for extracting ashlar blocks.

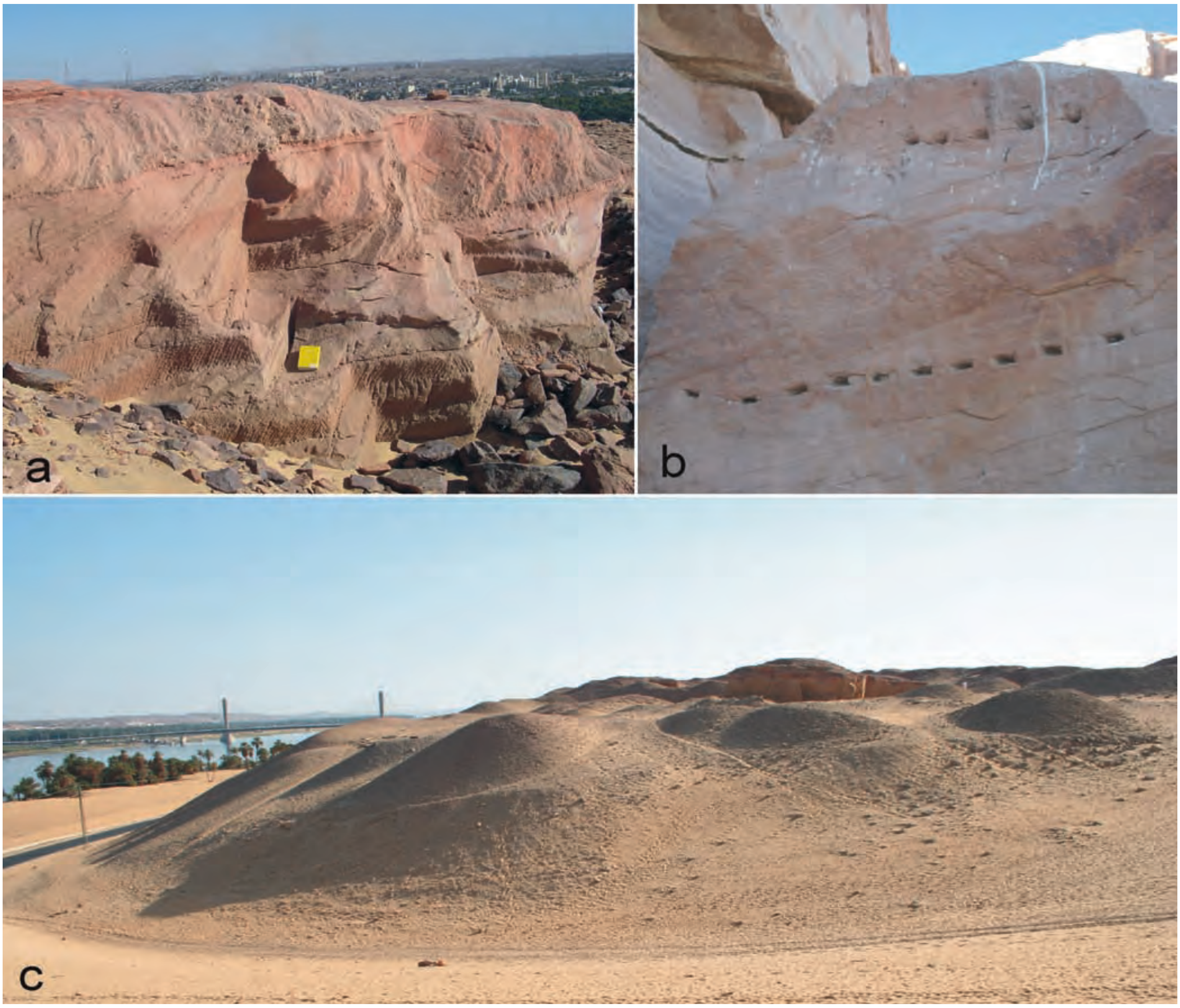

Figure 18. Building stone quarries in 'soft' sandstone. (a) Extraction of ashlar blocks by chiseling channels, (b) wedge marks along sandstone layering, (c) large building stone quarry (Naq el-Fugani quarry, Bloxam et al. 2007) and spoil heaps from production.

Figure 19. Grinding stone quarries. (a) Small and low-scale extraction site of grinding stone blocks, probably dating from the Upper Palaeolithic, (b) circular spoil heaps from quarrying of grinding stones from large boulders of silicified sandstone, (c) Middle Kingdom grinding stone quarry in bedrock, displaying evidence of the use of fire in the extraction, (d) typical grinding stone blanks.

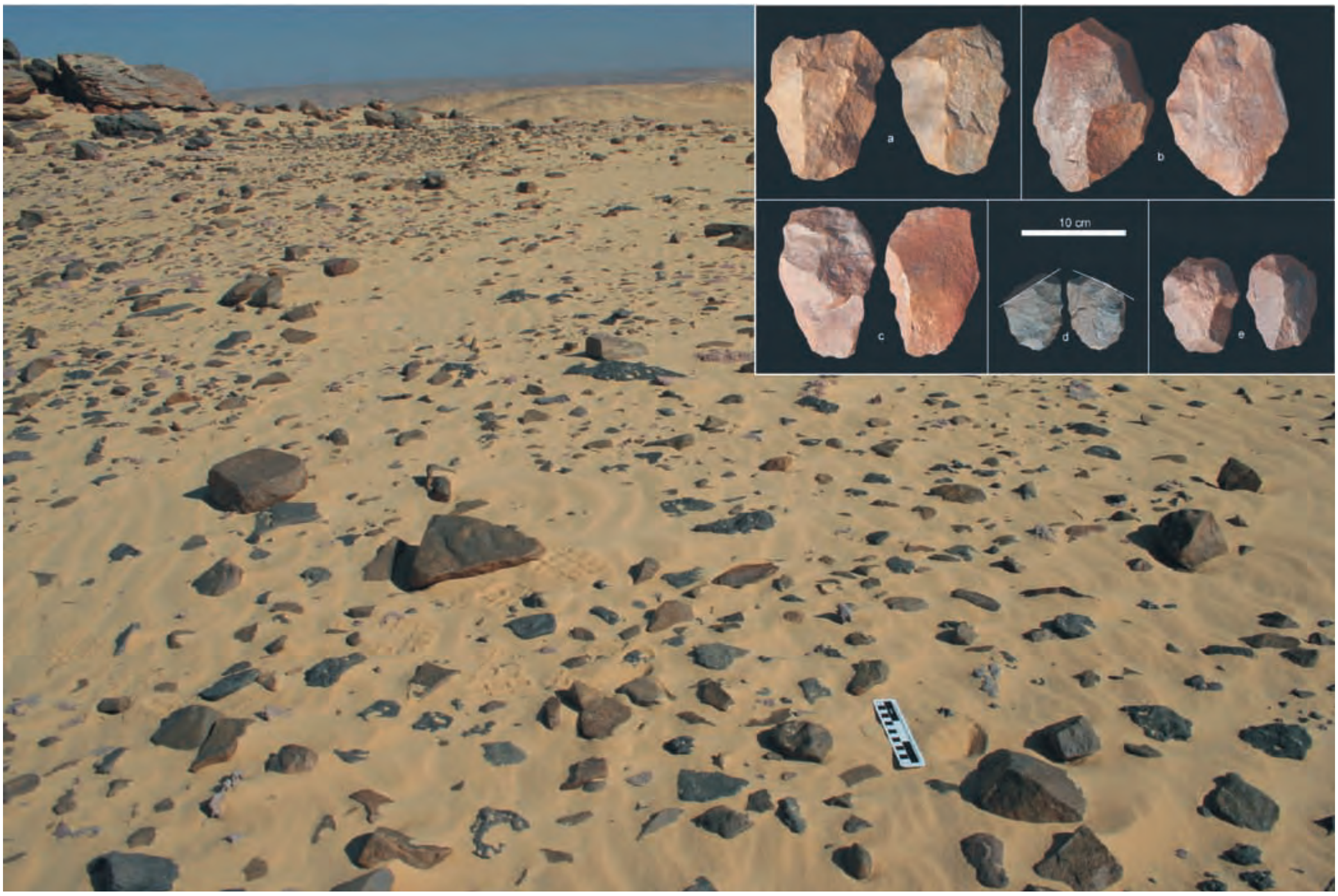

Figure 20. Debitage from production of tools from silicified sandstone cobbles, assumed Lower and Middle Palaeolithic.

Figure 21. Cobble of microgranite from the river bed used as a hammer stone (pounder) in the quarrying of silicified sandstone.

area (only in Palaeolithic tool quarries), cobbles of igneous rocks or silicified sandstone predominantly from the banks of the Nile, and pre-fabricated dolerite pounders, most likely originating from the East Bank (only in and near the obelisk quarries) (Figure 21). No metal tools have been found, although there are traces of slag from smithies connected with the Roman quarrying.

Finally, numerous semifinished or even finished products are recorded, providing evidence of what was produced in the quarries and how far the production went towards finishing. They include Palaeolithic tool rough-outs, oval to rounded grinding stone blanks, semifinished statues and obelisk bases, columns and capitals (from the Graeco–Roman Period), stelae or lintel blocks and ashlars. The well-known Sety I obelisk tip (Figure 17a) is so far the only evidence of finishing in the quarries, down to its inscriptions.

Collectively, the remains from production made it possible to interpret different production processes (Table 2). When such interpretations are combined with the spatial distribution of quarries, we get a picture of the size and distribution of different types of quarrying. For example, we see that the grinding stone quarrying in volume largely overshadows the other quarrying activities (85% of the quarrying area). Even in areas where there has been significant production of statue blocks, it turned out that most of the spoil was produced in the making of grinding stones.

As shown in Table 2, the remains from production can also aid in identifying evolutionary patterns. The earliest grinding stone quarrying involved just a few steps in the production process, exploiting clusters of naturally occurring blocks of silicified sandstone—up to one metre in size. At later stages, larger blocks and even bedrock were targeted and so production involved more steps of extraction and block reduction, but the semifinishing remained the same through thousands of years.

Quarry logistics

As the grinding stone production did not need any elaborate infrastructure, most of the remains of quarry roads are related to the movement of large objects from the quarries. Hence, the existence of road construction also provides evidence of where blocks actually were brought out of the quarries. Quarry roads are predominantly found in the Gebel Gulab (Figure 22) and Gebel Tingar areas. They include slipways and built-up ramps (for moving blocks from one level to another), causeways (built-up structures for evening out topographic features), paved roads, stone-

Table 2. Interpretation of the production processes for different quarry activities at the Aswan West Bank.

Activity	Extraction	Block reduction	Semifinishing	Finishing
Palaeolithic tools		Splitting of small boulders to cores, using quartz pebbles from riverbeds	Producing flakes (Acheulean, levallois) from cores with quartz pebbles	
Upper Palaeolithic grinding stone		Splitting scattered blocks with pounders into few cores	Trimming of cores to roughly shaped grinding stone bases with light pounders	
Predynastic(?) grinding stone	Extracting blocks by levering along natural fractures	Splitting blocks with heavy pounders to cores	Trimming of cores to roughly shaped grinding stone bases with light pounders	
Middle/New Kingdom grinding stone	Producing cracks on bedrock surface or large boulders by heating with fire and using heavy pounders, resulting in large flakes		Trimming of flakes to roughly shaped grinding stone bases with light pounders	
Pharaonic ornamental stone quarrying		Removing weathered surface of boulders and rough shaping of their perimeter by heating and trimming with pounders	Dressing with pounders	
Sety I Obelisk quarrying	Channelling in the bedrock by dolerite pounders, possible combined with heating		Dressing of surface with pounders	Honing of surface with grinding stones and inscribing
Roman ornamental stone quarrying	Splitting of blocks from bedrock by wedging (Roman style)	Splitting of blocks with wedges	Dressing of surface with mallet and chisel, producing roughly shaped columns and other objects	
Graeco–Roman building stone quarrying	Channelling by mallet and chisel, splitting loose blocks along sedimentary layering with wedges		Dressing of ashlar blocks with mallet and chisel	

aligned roads, cleared tracks and regular dirt roads. More detailed descriptions may be found in Heldal et al. (2007a).

By characterising the roads themselves and combining with production evidence, two recognisable logistical systems emerge (Figure 23): one from the Pharaonic Period (mainly New Kingdom) and one from the Roman. The Pharaonic system includes the wide causeway in front of the Sety I obelisk tip (Figure 24), slipways, ramps and paved or stone-aligned roads, most of them approximately two metres wide. The roads are similar to the 11 km-long, Old Kingdom quarry road from the Widan el-Faras basalt quarries (Caton-Thompson and Gardener 1934) and assumed New Kingdom quarry roads at the Aswan East Bank (Kelany et al. 2009), and were probably designed for supporting sledges

Figure 22. Pharaonic quarry roads, Gebel Gulab.

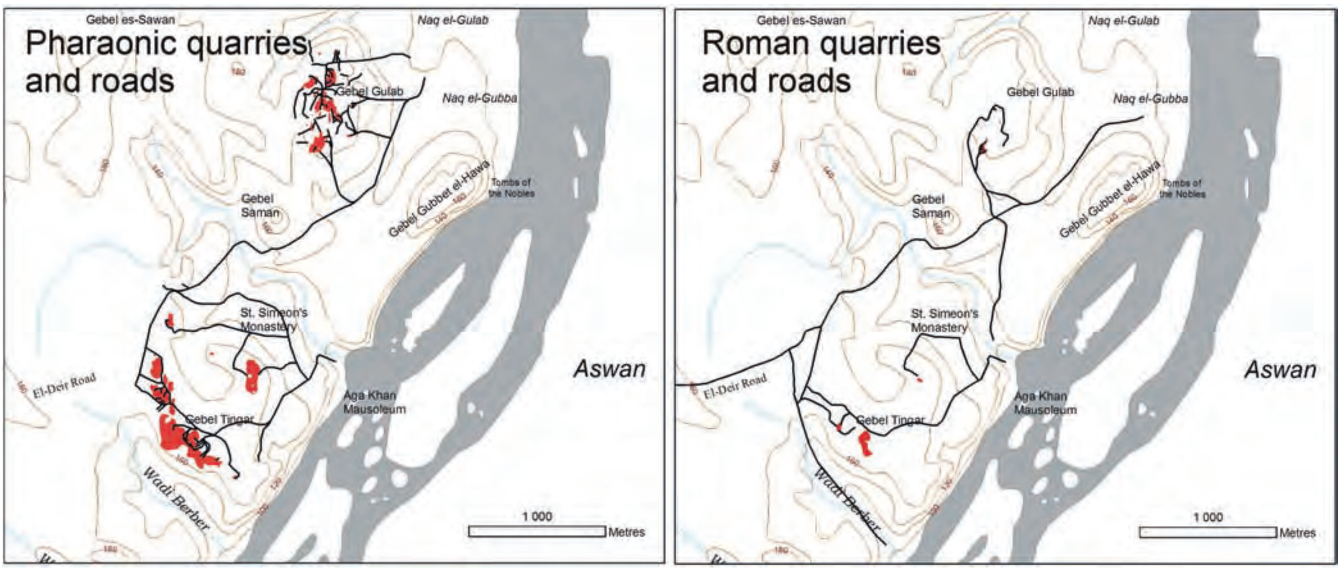

Figure 23. Interpretation of the quarry road systems at the Aswan West Bank linked to ornamental stone quarries. Quarries in red, associated roads shown as black lines.

running on top of a layer of logs. In the Roman Period, some of the routes were reused, but now in the shape of wider, cleared tracks and dirt roads, probably made for wagons. The Roman roads tend to climb downwards along the perimeter of the steeper hills, in order to minimise the inclination. In the Roman Period, a wide, cleared track went through the area. This was by Klemm et al. (1984) interpreted as a quarry road, but the track leads evidently westward into the desert (el Deir Road, see Storemyr 2007). However, the lower part of the road may have been used also as a quarry road.

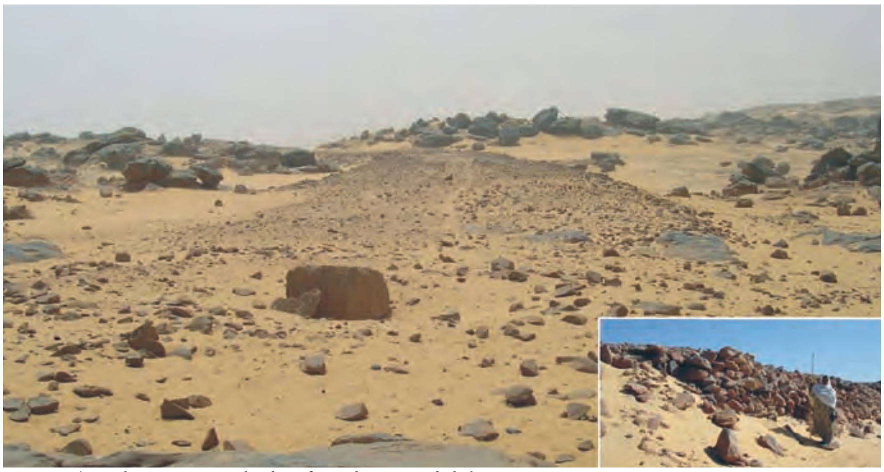

Figure 24. Built-up causeway leading from the Sety I obelisk.

People in the quarries and in the landscape

The Aswan West Bank is a rich cultural landscape used for thousands of years, not only for quarrying. One of the key problems is therefore to distinguish between features related to quarrying and those linked to other use of the landscape (see descriptions and discussion in Bloxam and Kelany 2007).

Numerous stone-walled structures have been recorded (Figure 25). Most of these are ephemeral, reminiscent of simple shelters from the sun and wind (Figure 26). Some of them have a close, spatial connection to quarries, others to the road system (lookouts) but many may be related to other activities, such as hunting, the Coptic monastery, travelling along the desert routes and even modern contexts.

Similar ambiguity exists regarding the ceramic evidence. Are the ceramic remains found in the quarry areas actually related to such? In some cases, it is likely to assume a connection, due to the close spatial relationship between ceramics, shelters (connected to quarries) and production remains (ceramics found in work areas). Furthermore, the ceramic evidence tends to cluster in the main quarrying areas—Gebel Tingar and Gebel Gulab. Given such limitations, there are two main groups of ceramics—the New Kingdom and the Roman Period. In addition, there are more scattered findings of Predynastic, Old Kingdom and Middle Kingdom pottery.

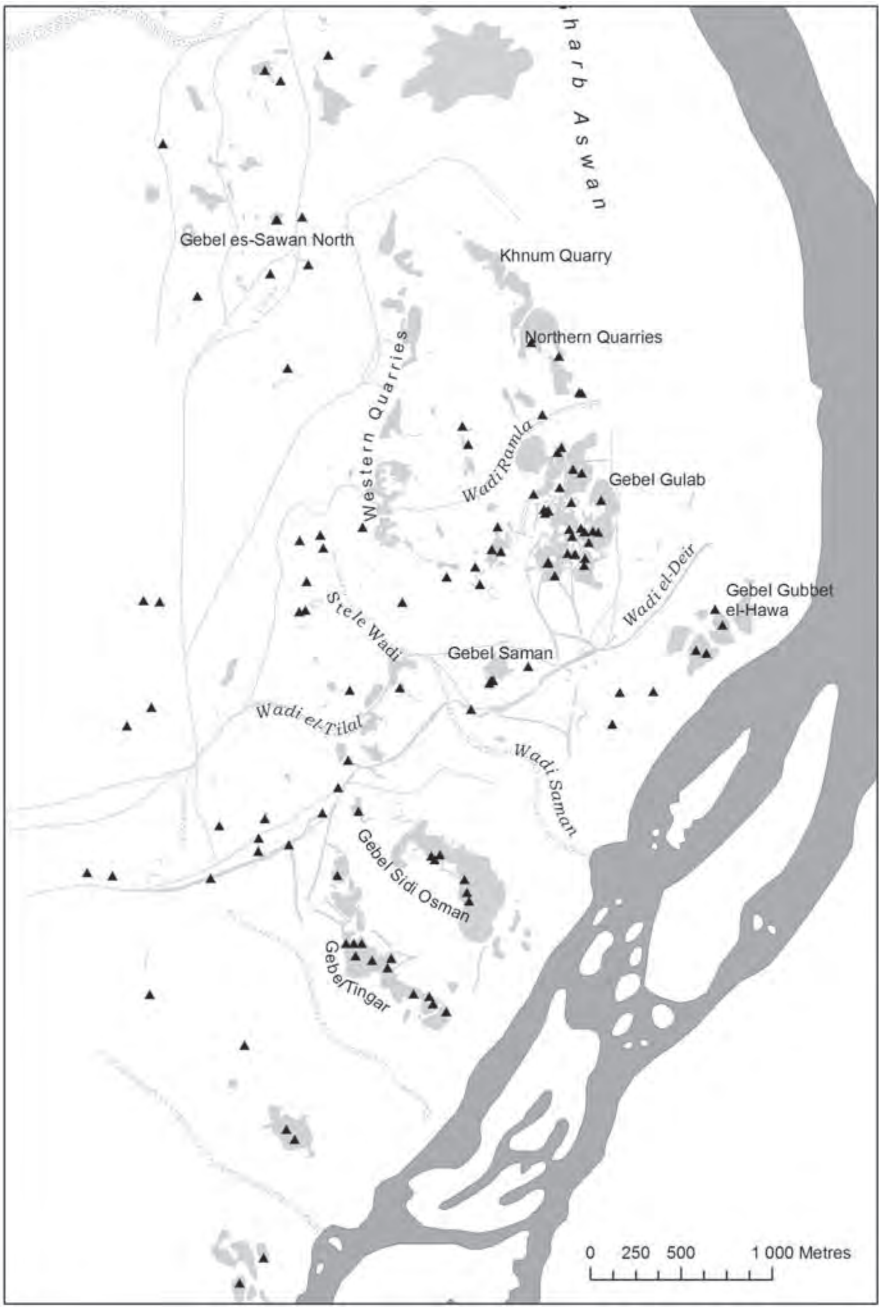

Figure 25. Distribution of stone-walled structures (triangles) and quarries (grey areas) at the Aswan West Bank.

Figure 26. A simple, stone-walled structure around natural outcrops by one of the obelisk quarries, probably a shelter for the quarrymen.

The area is rich in epigraphic data. Rock art from several periods are found all over the area (Storemyr 2007), but with few exceptions, the connection to quarrying remains unclear. Hieroglyphic inscriptions and graffiti are more evidently in context with quarrying, and in particular the 18th Dynasty of the New Kingdom (Bloxam and Kelany 2007). These include the hieroglyphic symbols for *mr-Ra* ('beloved of Ra') found on rock surfaces within the assumed Sety I obelisk extraction sites (Figure 27), in one case also directly associated to a cartouche of Sety I. An iconographic depiction of a Pharaonic Period boat, measuring 1.5 m long by 1 m high (Figure 28), was an important addition to the corpus of rock engravings that date specifically to the 18th–19th Dynasties of the New Kingdom. In the Khnum Quarries, north of Gebel Gulab, is a shelter/overhang between two large stones, on the internal faces there are many inscriptions in different types and size, with some graffiti of boats, ships, fish and images of men and women. Another *mr-Ra* sign was found beside the shelter area and also a rare incidence of the name of a person who could be the 'overseer' of the quarrying:

"Overseer of the Building Jw-Khnumw, true of voice."

Although there are more names that are still in the process of translation, these names give an indication about the

Figure 27. 'Beloved of Ra', one of the mr-ra *signs found near an obelisk quarry.*

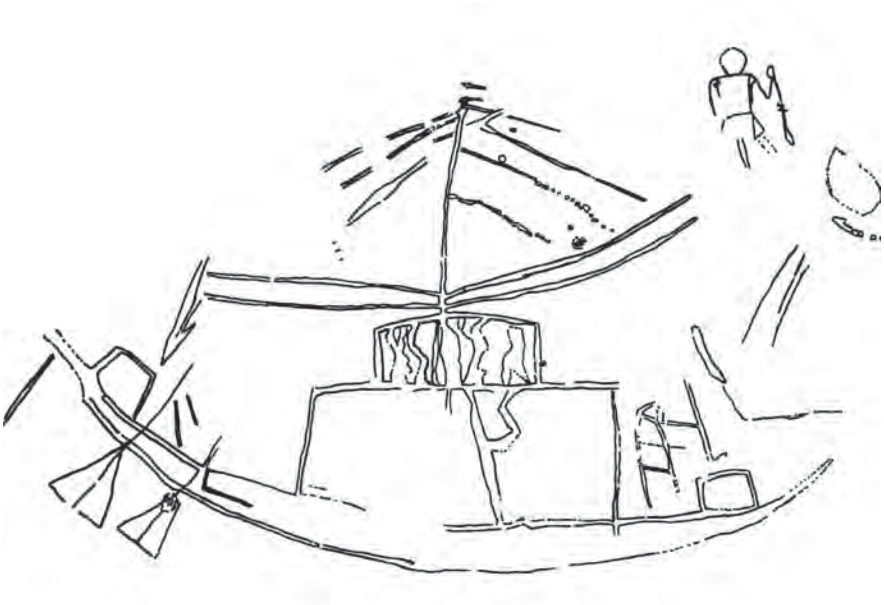

Figure 28. Depiction of a New Kingdom vessel found near an obelisk quarry, Gebel Gulab. Drawing by Adel Kelany.

titles and names of people working in the quarry in Dynastic times.

Several inscriptions have been recorded by other authors from the Graeco–Roman Period. Although many of these graffiti probably refer to the names of quarry workers, one is particularly interesting as it refers to an architect with the name 'Prepalaos son of Orestês forgeron of Memnon'. Fournet (1996, p. 144–146) suggests that Prepalaos may have been sent to the West Bank to quarry for silicified sandstone restoration blocks, on the orders of Roman Emperor Septimie Sévère, to repair the Colossi of Memnon between the end of 2nd century to early 3rd century AD.

Other man-made structures found at the Aswan West Bank include a large system of stone alignments (game drives, Storemyr 2007) and burials from different periods, often reusing quarries (Bloxam and Kelany 2007).

The Aswan West Bank quarry landscape in time and space

The Aswan West Bank comes forward as a quarry landscape of high complexity, with great time depth and exploitation of several stone commodities (utilitarian, building stone and ornamental stone), creating many layers of connected and less connected quarrying activities. Analyses of the material remains from the quarrying and the resource itself made it possible to identify and map such layers, thus separating grinding stone quarrying from ornamental, Roman quarrying from Dynastic times, etc. Consequently, the quarry landscape was 'deconstructed' into a number of complexes, each being a unique type of quarrying activity, targeting different parts of the resource, using different quarrying technology and producing different types of product (Figure 29). Some of them also have a recognisable logistical system (see Bloxam et al. 2007, Bloxam and Heldal 2008).

The oldest defined complex is the Palaeolithic tool quarries. Only small patches remains, others are either removed by erosion or overprinted by later quarrying. The oldest assemblages are Achuelean from the Lower Palaeolithic (between 150 and 700 ky) (Bloxam and Moloney 2009). Such production sites are rare, and definitely add to the overall importance of this quarry landscape. In addition, there are several Middle Palaeolithic tool quarries (op. cit.), frequently found in the same spots. In the Upper Palaeolithic, the use of silicified sandstone for sharp tools decreased, substituted by chert from slightly more distal sources and 'Egyptian Flint'. One exception is Sebilian assemblages (10,000–12,000 BP) in which particularly ferruginous sandstone is more common (Wendorf and Schild 1989).

The grinding stone complex is by area and volume the largest (approximately 85% of the quarrying area). Its time depth spans from the Upper Palaeolithic to at least the Roman Period. The earliest grinding stone quarrying, first described by Roubet (1989), involved quarrying of roughly shaped querns (lower grinding stones) for grinding roots. Although the evidence of the evolution of grinding stone production in the area yet remains fragmentary, clearly in Pharaonic times it involved mass production of ovalshaped lower grinding stones and 'loaf'-shaped upper ones for grinding cereals. The earliest quarrying involved few steps (Table 2), exploiting clusters of naturally occurring blocks of silicified sandstone, up to one metre in size. Block reduction involved splitting by percussion with stone tools. Thereafter, the resulting cores were trimmed by removing small scales from its surface until a more or less regular shape was produced. Finally, the perimeter of the grinding surface was 'retouched' with finer tools producing a grinding stone blank.

The semifinishing step of grinding stone production basically remained the same all the way up to the Roman Period. The blanks were never completely finished in the quarries, final fitting, and possibly smoothing the grinding surface, was carried out elsewhere. The first production steps, however, vary, most likely chronologically. It seems that in the Predynastic and Early Dynastic Periods, larger blocks were extracted from their in situ position in the silicified sandstone layers by levering, followed by at least two steps of block reduction (Figure 14). In the Middle and New Kingdom, some quarries display extraction of small blocks directly from the bedrock by heating (fire setting), each of these being worked to one grinding stone blank (Table 2). These are just some examples, but they illustrate the differences between the grinding stone quarries (more sophisticated extraction) and (not least!) the similarities—how the methods of

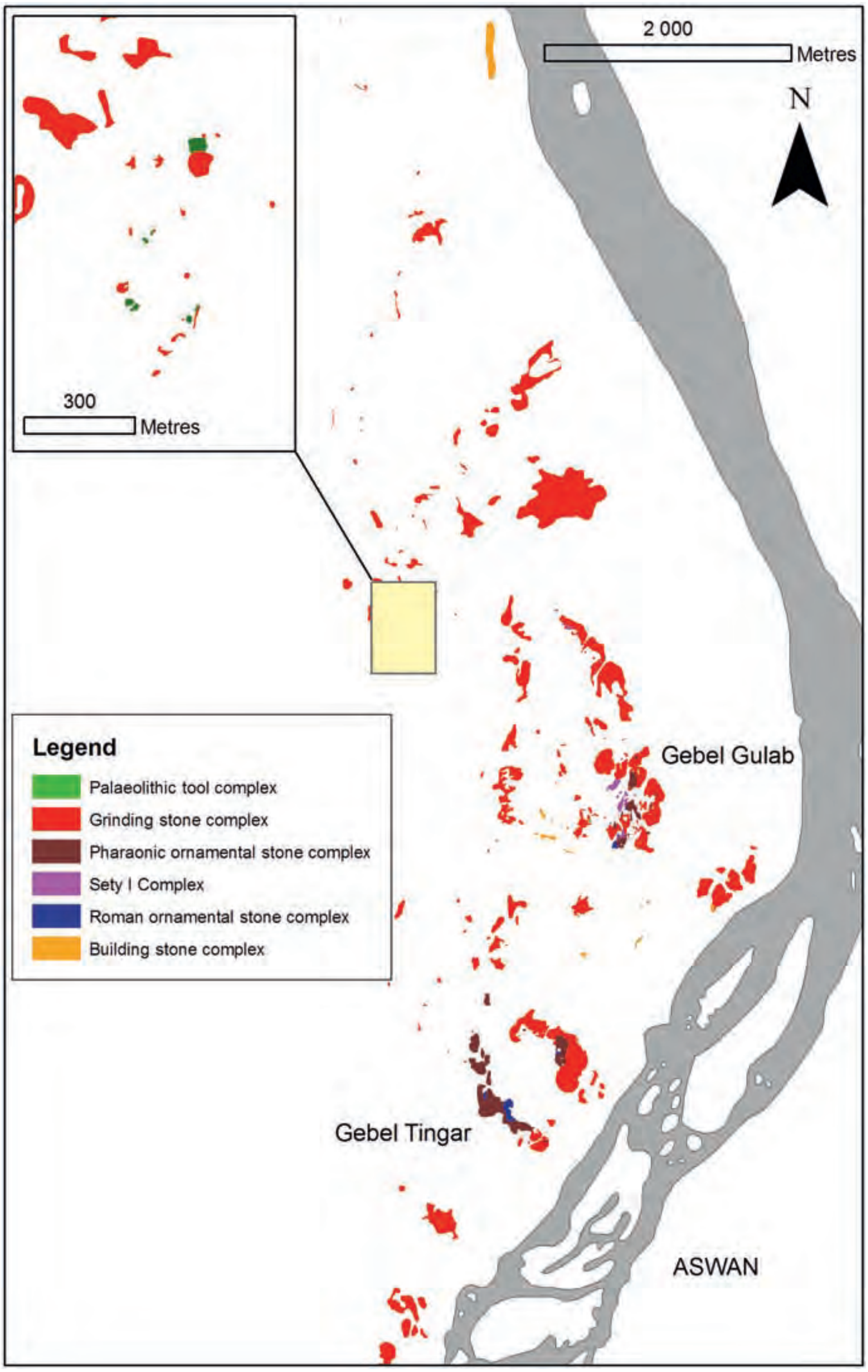

Figure 29. Spatial distribution of quarry complexes at the Aswan West Bank.

producing the blanks remain the same for thousands of years.

For ornamental purposes, silicified sandstone came into use during the 4th and 5th Dynasties of the Old Kingdom. During the Middle Kingdom use of the stone for monumental purposes, such as stelae, statuary, wall linings and lintels was maintained (Aston et al. 2000). However, it was during the New Kingdom that the use of silicified sandstone in monumental architecture, colossal and life-sized statuary, obelisks, lintels, stelae and small statuettes, reached its highest level. Historical sources suggest that this overwhelming use of silicified sandstone in the New Kingdom, particularly in the 18th Dynasty (1390–1352 BC) reign of Amenhotep III, was associated with a refocussing of religious ideas to solarise the major cults of Egypt in which the colours of the silicified sandstone played an important symbolic role (Bloxam 2007, p. 42–43, and references therein). By the following Amarna Period (1352–1336 BC), solarising of the royal cults reached its zenith. Hence silicified sandstone remained one of the principal hard stones used for royal statuary; in particular there seems to be a marked increase in the use of the purple variety. Moreover, it seems that there was a transformation from the monumental-scale use of the stone during the reign of Amenhotep III to generally smaller, highly crafted statuettes of the Amarna Period (op. cit.).

After a hiatus of approximately 80 years, the consumption record sees a short revival in the use of silicified sandstone for royal ornamental and monumental purposes during the reign of Sety I in the early 19th Dynasty (1294–1279 BC). Having modelled himself on Amenhotep III, the use of silicified sandstone for obelisks (including a truncated obelisk form that rests on a wider base) and colossi was again sought after (Brand 2000, p. 128, 360). It is important to note that a number of large building programmes, particularly in the Luxor Temple at Thebes (modern Luxor), were not completed due to Sety's early death (Brand 2000, p. 365, 384).

Seen from the quarries, Pharaonic ornamental stone production seems to have involved several activities. Firstly, in the areas where there are grinding stone quarries situated in the attractive red and purple varieties of the silicified sandstone (mostly the southern part of the area), there is evidence of production of small statuettes and possibly bowls and plates. From the consumption evidence, it is tempting to suggest that at least some of this activity is from the Amarna Period. Interestingly, this activity seems to have gone hand in hand with grinding stone production, displaying evidence of the use of the same tools and techniques for making the blanks (Figure 15d). Thus, blurring the 'boundary' between utilitarian and ornamental stone production.

A group of quarries situated in red, multicolour and purple varieties has collectively been defined as a Pharaonic ornamental stone complex. This quarrying involved production of large blocks, from in situ block layers or loose boulders. A few remaining blocks in different stages of production indicate that the first production step involved removal of the weathered surface by the use of heat and pounders. Next, the blocks were dressed with pounders before they were removed along the constructed ramps and roads. Klemm and Klemm (1984) suggest that much of this activity may be assigned to Amenhotep III.

One activity of Pharaonic ornamental stone production has been identified as a particular complex: the Sety I Complex, based on the famous obelisk tip. The targeted resource was yellow, moderately silicified sandstone, occurring only at Gebel Gulab and along an escarpment further to the north (Khnum quarries). The quarrying seems to mainly have involved production of obelisks, obelisk bases and possibly also truncated obelisks. Predominantly, the quarrying focussed on massive layers of sandstone, in which it was possible to obtain the large sizes needed for the obelisks. The technology involved was exactly the same as in the case of the Unfinished Obelisk quarry in Aswan: levelling of surfaces by shallow channels around 'pillows' of remaining rock, which then were split, probably aided by fire, and making wide channels around the attempted blocks leaving the same tool marks as in the granite quarries. Even the tools (pounders) were made of the same dolerite type found in the granite quarries, and seem to have been brought to the West Bank from the same source. Also, the Sety I Complex is the only one in the area displaying evidence of complete finishing in the quarries, down to honing of the obelisks and inscribing them. In contrast to the other Pharaonic ornamental stone quarries, there seem to be few objects that actually were brought away from the Sety I quarries, due to the many half-finished objects, quarries just in their initial phase and the lack of logistical infrastructure associated with some of them (particularly the Khnum quarries). In fact, it seems that work going on in many quarries simultaneously suddenly stopped. It is tempting to suggest that such a sudden halt in production was related to the death of Sety I.

The Roman ornamental-quarry complex in silicified sandstone involved the production of squared blocks for unknown purpose, columns and probably a range of medium-sized products. The quarrying technique is similar to other Roman Period hard-stone quarrying, in which splitting by wedges is primary. Designated work areas where the extracted blocks were brought for reduction and semifinishing are common. However, the Roman activity was rather small scale, and involved 'revisits' to previous quarry areas, particularly at Gebel Gulab and Gebel Tingar. As shown above, it also involved building of new roads and reworking of older ones more suitable for the period's means of transport.

The remains of building stone quarries (building stone complex) are found in the softer sandstone varieties all over the area, but particularly in the north. Most of them seem to belong to the Graeco–Roman Period, involving extraction of ashlar blocks (for yet unknown buildings/purposes) by chiselling channels around them and splitting along the base by wedging. But some of them may date back to the Old Kingdom (Klemm and Klemm 1993) and others as late as the Coptic Period (i.e., quarrying for the St. Simeon Monastery).

Back together: new perspectives of the Aswan West Bank

After such an exercise of deconstructing the Aswan West Bank quarry landscape into several complexes by interpreting their characteristic elements from the empirical data, the complexity of it becomes easier to understand. The different quarrying activities originating from different needs for raw materials through many periods resulted in layer upon layer of quarries. This can be visualised by defining such main activities as complexes, which can be seen as projections of different quarrying activities, needing different ways of evaluation when it comes to conservation. The Pharaonic ornamental stone quarrying may, for instance, be important projections of solar symbolism in the New Kingdom (Heldal et al. 2005), and of New Kingdom quarry logistics.

Even more important is that the analyses have changed the overall perception of the quarry landscape, in its totality, significantly. The 'old view' of the quarry landscape as being almost solely created by massive Pharaonic ornamental stone quarrying for the elite (as expressed by Klemm and Klemm 1993 and shared by ourselves in the beginning of the field work) has been replaced by the view of a huge landscape made by utilitarian stone production over tens of thousands of years, where the ornamental stone quarrying represents a relatively minor activity in time and space, superimposed on the utilitarian quarry landscape. Clearly, such a view must have impact on how we regard this particular quarry landscape. Although the ornamental stone quarrying, with its logistics, is an important feature of the landscape, its greatest significance may be found in its longevity—perhaps the most long-lasting quarry landscape in the world displaying human engagement with a specific resource throughout human history (Figure 30). In such a context, the importance of the more 'invisible' and less spectacular remains becomes more obvious. Furthermore, even though it can be argued that there may be better examples elsewhere of all of the individual complexes (i.e., the Unfinished Obelisk quarry in Aswan is 'better' than the ones at the West Bank), the fact that so many different periods and purposes of quarrying are found in one area, should in itself be considered as a major aspect of significance.

Conclusion

Features related to ancient quarrying may be described and characterised in a systematic way by dividing them into four main elements: the resource, the production, the logistics and the social infrastructure. This provides a useful method of connecting physical remains in quarries to processes, technology and organisation, by micro-level analy-

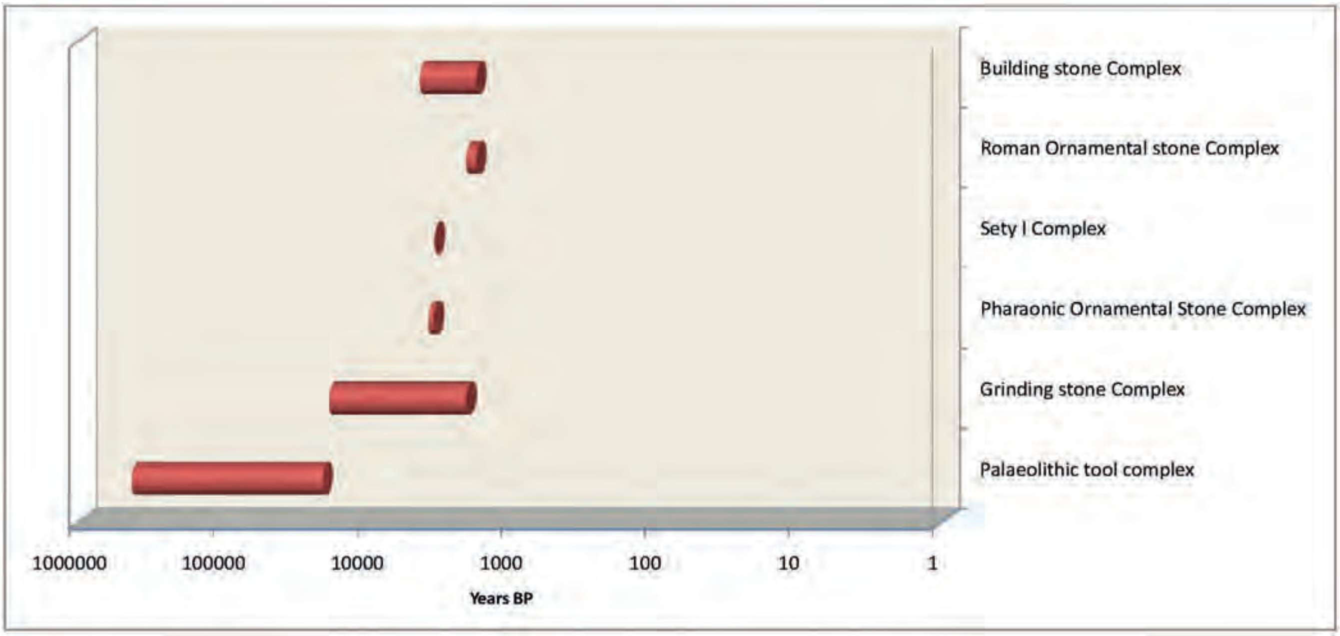

Figure 30. Time depth of quarry complexes at the Aswan West Bank. X-axis shows years, logarithmic scale.

sis. Finally, the term 'quarry complex' is introduced as a necessary tool of interpretation, in-between a quarry and a quarry landscape. We believe that defining such complexes helps in visualising complexities in quarry landscapes, and extracting individual characteristics that can aid the articulation of significance. The complexity of the Aswan West Bank quarry landscape was in itself one of the main reasons to develop a methodology that could separate one quarrying activity from another.

By using a characterisation method that on the one side is standardised enough to allow comparison between different places and different periods and 'open' enough to take heights of the individual characteristics, the evaluation of such landscapes can be made easier and more targeted—when the aim is to build a strategy for conservation and management. This method embraced new approaches in heritage management which have stressed the appropriateness of holistic landscape perspectives, and adopting 'characterisation' as a means to document and understand the distinctive characteristics (material remains) of a place (see discussion in Schofield 2008, p. 19, Fairclough 2008).

In the case of the Aswan West Bank, the characterisation of the resources and the material remains together with interpretation of production techniques and logistics lead to the identification of connected activities and finally to the reinterpretation of the quarry landscape. This also had an impact on how we evaluate the significance of such landscapes from a purely elite stone procurement, towards a composite system of quarrying through deep time. When deconstructing the quarry landscape into its complexes, it is also easier to point at particularly important places for future conservation that are good informational projections of the different activities.

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National inventory and database of ancient stone quarry landscapes in Egypt

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The Egyptian Antiquities Information System (EAIS) started as an Egyptian–Finnish project and finally developed to be a fully functioning GIS Centre of Excellence within the Supreme Council of Antiquities (SCA). Over the course of seven years it succeeded in analysing, identifying and offering solutions, which supports the digital documentation of various Egyptian heritages. Throughout the QuarryScapes project it was generally concluded that of all the Egyptian heritages the quarry landscapes are among the least recognised and appreciated. The present paper will briefly highlight some of the problems identified during our research activities, in addition to our modest efforts for the digital documentation of the Egyptian quarry landscapes. Our activities concluded with a belief that we have succeeded in drawing the attention of the Egyptian administration to such an important element of the Egyptian heritage. However, extreme efforts need to be exerted to initiate a concrete protection and preservation strategy, plans and practices. Efforts should primarily focus on changing how the quarries are being regarded through conducting awareness-raising campaigns that target concerned institutions (SCA, Governorates and quarrying authorities), specialists in the field of archaeology, as well as inhabitants living adjacent to the sites. The Egyptian administration, will face extreme challenges attempting to resolve the current problem. Consequently, setting and conducting national and international projects similar to the QuarryScapes project and encouraging research in the field of ancient quarrying, should be encouraged as part of the long-term sustainable strategy.

Shawarby, A., Fathy, E., Sadek, M., Amin, N., Yousri, R. and Kayser, S. (2009) National inventory and database of ancient stone quarry landscapes in Egypt. *In* Abu-Jaber, N., Bloxam, E.G., Degryse, P. and Heldal, T. (eds.) *QuarryScapes: ancient stone quarry landscapes in the Eastern Mediterranean*, Geological Survey of Norway Special Publication,**12**, pp. 155–163.

Introduction

Throughout Egyptian history, stone has been a key element in the monumental heritage, from the Predynastic Period to the Islamic. The exploitation of such resources has created quarry landscapes all over the country in a variety of rock types. In order to best manage and protect these areas, it is vital first to get an overview of where they are located, and then identify when they were quarried, in what condition they are today and what legal measures can be taken to protect them. In this sense, a vital part of the QuarryScapes project was to design and produce a comprehensive map and database of ancient Egyptian quarry landscapes to facilitate general land-use management and awareness raising. The aim of the present paper is to present the results of the activities undertaken over the course of our involvement in the QuarryScapes project.

Several regional surveys of ancient quarries have been conducted in Egypt, and of these the work by Professor James A. Harrell is so far the most comprehensive. The database developed during the QuarryScapes project largely builds on Harrell's work (Harrell and Storemyr 2009), but with contributions also from other researchers (particularly Klemm and Klemm 1993, 2008) and from several case studies in the QuarryScapes project. In particular, the risk assessment of ancient Egyptian quarries as presented by Storemyr et al. (2007) and Storemyr (2009) has been important for evaluating the conservation status and threats to the quarry landscapes. The technical and practical aspects of constructing a spatial database that can contribute in implementing measures on a national scale for future conservation of the sites will be discussed in the following sections. An overview of the rock types and quarries is given in Harrell and Storemyr (2009).

Egyptian quarries and the use of GIS

A Geographical Information System (GIS) is a system of computer software, hardware, data and personnel to help manipulate, analyse and present information that is tied to spatial location. With a GIS, information (attributes) can be linked to location data, such as people to addresses, buildings to parcels, or streets within a network. The information can then be layered to give a better understanding of how it all works together. The combination of layers will vary based on the questions that need to be answered.

Though the emergence of the GIS technology worldwide can be traced back to 1960s, its practical implementation in Egypt has been significant only over the last two decades. Nevertheless, lack of data, data inconsistency and the unwillingness to share information are still common limitations to a wider distribution of this technology in the country.

GIS can help planners and analysts 'visualise' data to better understand patterns and spatial phenomena. In addition, layers of information can be displayed through the use of GIS software, which eventually helps in establishing a spatial relation among various sets of data. Each set of data can be displayed in the form of points, lines or areas. Points, which are used in the inventory of Egypt's National Quarries, are used to represent phenomena that have a specific location, such as mines, trees and houses. The most important concept involved in the use of GIS is associating, or 'attaching', attribute data to a specially referenced base map. The organisation of the attribute data is a very crucial stage towards conducting advanced analysis.

The availability of a solid information base is not only essential for data analysis. The challenges arising from climatic changes, global warming and all other environmental hazards, and the fragile state of the archaeological heritage, require an immediate development of 'Crisis Management Plans (CMP)'. The preparation of accurate CMPs will mainly rely on the presence of updated information, e.g., precise location, current status, state of preservation (to set priorities for intervention). In the above context, the output of this activity, the *National Digital Map of Ancient Stone Quarry Landscapes in Egypt*, was designed to specifically address similar problems.

However, the *National Digital Map* layer cannot alone be used for analysis. Other layers, relevant to the case analysed, need to be available to be able to conduct the analysis procedure. As an example, if a question arises on the possibility of using some of the ancient quarries for modern quarrying activities not only the current status of each of the ancient quarries is enough, other basic information (layers) must also be available; such as roads, railways and urban agglomerations.

Data capture

Through his painstaking research and field work, Professor James A. Harrell has located nearly 200 ancient quarries in Egypt and Sudan, and the result of his work was selected as the base for the creation of the *National Quarry Map*. The information was categorised in the form of 3 tables, covering the main groups of rocks (Hardstones, Softstones and Gemstones) and including the location of the quarries in degrees (d) and minutes (m) for north latitude and east longitude. In addition, quarry age, sometimes tentative, was also included in the tables (see Figure 1).

The tables were subsequently extracted into Excel sheets and imported inside ESRI ArcView, and the coordinates were used to create the *point shapefile (version #1)*. The ID_EAIS, added to the attribute table of the *point shapefile (version #1)*, was created by overlaying the Egyptian administrative division shapefile, and based on the geographical location of the quarry site.

ID_EAIS consists of three sections: q (for quarry), xx (two digits of the governorate code) and the last section is zzzz (four-digit serial number) i.e., qxxzzzz (see Figure 2).

Based on the *version #1* shapefile, the

[1]Egypt risk and monitoring.

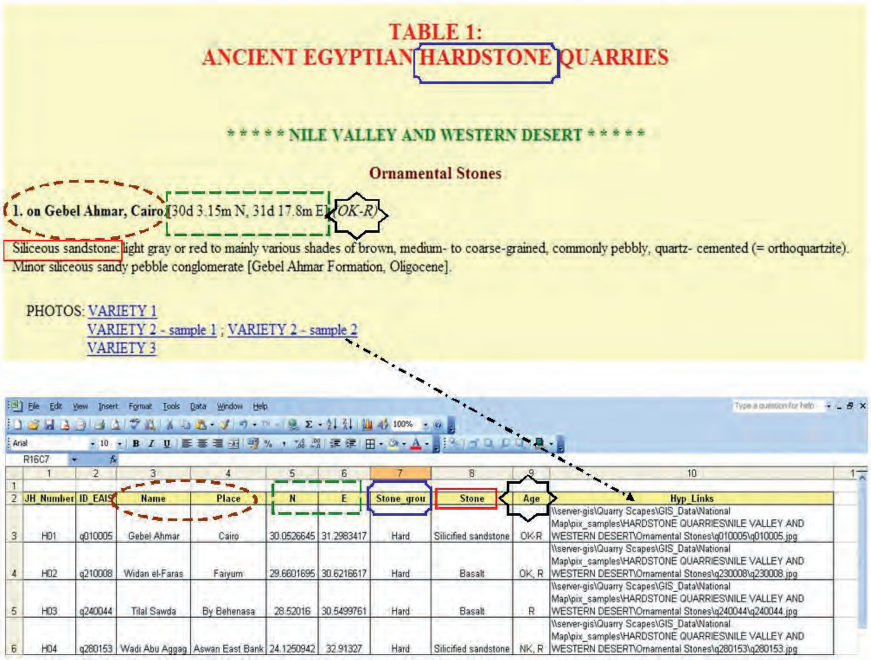


Figure1. Illustration of the categorisation methodology used to convert Harrell's tables into excel sheets.

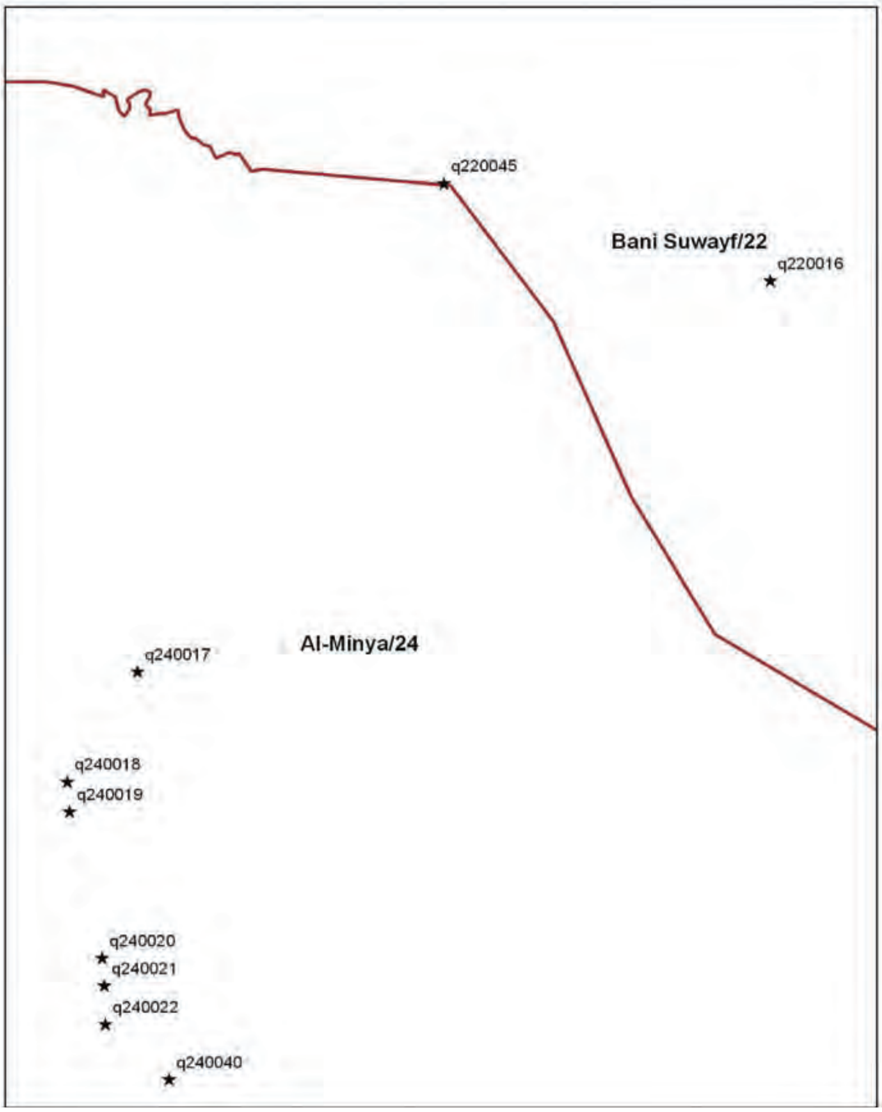


Figure 2. Sample of the National Quarry Map shapefile where the ID_EAIS is used for labels.

activities of Work Package 5 in the QuarryScapes project[1] developed the *'Extended Database; Egypt quarries WGS84 Database Application'* which brings together the information in the shapefile along with the data attained from other sources and through QuarryScapes research. The database was extracted into an excel sheet and converted into a shapefile *(Version #2)*; which included the addition of several new quarries, as well as updated data for the existing quarries. In some cases, photos of samples of the rocks for stone types were available for the quarries, and were linked to the database.

The next stage included performing all necessary research (archaeological, historical and legal) crucial to determine the actual condition of these quarries. Knowing that the quarries' legal status (i.e., how the SCA regards the quarries) is a vital element for their protection, the available SCA records were examined and the local inspectorates were contacted (see below). The outcome of the legal research was summarised in a separate field named (Ident_Taft), which would make it possible to visualise quarries in terms of their legal status.

Archaeological and historical data

The GIS shapefile was also combined, based on a common ID, with an archaeological database (see section 3: Database Enhancement), which contains entries describing the archaeological features of the quarries, the history of their use as well as an analysis of the environmental and human risks threatening their preservation. It indicates where features have been lost, or are in danger of becoming so, and complements the spatial data in the GIS. This information was retrieved from available reports and articles, as well as from field research, and was integrated into the site datasheets where it was reviewed before it was entered into the database.

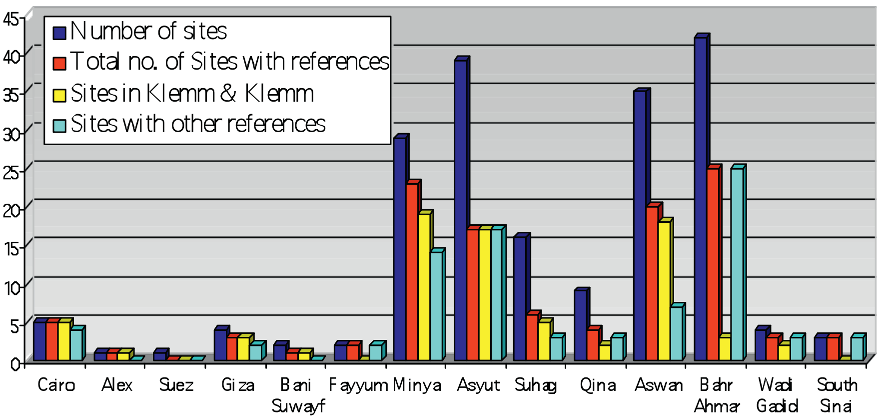
As mentioned above, the most extensive list of known quarries in Egypt (and Nubia) currently available is the result of the survey carried out by James Harrell over the past two decades. As with the quarry map, his list has been the starting point for the literature review, and data for the ca. 200 quarries on this list have been collected from a range of sources, including scientific publications in English, French, German and Arabic, and unpublished reports from the archives of the Supreme Council of Antiquities (Table 1).

The results of these activities have shown that in general terms there is an alarming lack of specialised information about ancient quarries in Egypt[2]. Nevertheless, a small number of scholars have made extensive contributions to the knowledge of ancient quarrying and have surveyed a larger number of sites. It is unfortunate, however, that the interest among the great majority of scholars seems to remain low.

The sources reviewed in this study can be roughly divided into six types:

1. Notes on ancient quarries found in excavation reports/or publications, which mainly deal with archaeological features other than quarries; e.g., Giza plateau.
2. Comprehensive surveys of ancient quarries all over Egypt or in selected areas.
3. Publications dealing entirely with results of work on selected quarry/mine sites.
4. Survey/excavation results provided directly by the QuarryScapes team.
5. Reports from SCA.
6. Quarry excavation reports.

Table 1. Graph which summarises the outcome of the archaeological and historical literature review.



Extensive research from the first source (notes on ancient quarries) has on the whole produced limited information about the quarries. Quite often the notes consist of brief passages stating that there are quarries in the vicinity of the archaeological site and occasionally a brief mention of when and for what they were used. This translates into relatively sparse data related to a limited number of sites in the database. On rare occasions, however, there are sections in the archaeological reports dedicated entirely to surveys of nearby quarries. Examples are Akoris and al-Bersheh (Willems 1989). Also, references to quarries are found in several classical works, including Petrie (1894), Legrain (1900), Weigall (1923) and Baedeker (1929).

More important are the quarry surveys (including Harrell's own, see Harrell and Storemyr (2009) and references therein) and, in particular, *Steine und Steinbrüche in Alten Ägypt* (Klemm and Klemm 1993), which is the main reference work for the archaeology of quarry sites. It covers the majority of the sites on James Harrell's list. In addition, the chapter on stone in *Ancient Egyptian Materials and Technology* (Aston et al. 2000), co-authored by James Harrell, and Harrell (2001) has provided good archaeological details for a number of the sites.

There are also a number of similar surveys exclusively covering quarries, but with a focus only on the inscriptions that are a common feature of these sites. Although useful in the sense that they can provide information on the periods of use and the intended employment of the extracted stone, the results of these epigraphic surveys rarely provide any details on the archaeological features of the quarries or associated infrastructure (Cruz-Uribe 2004).

The third source (publications dealing with results of work on selected quarry/mine sites) focusses on work conducted on individual quarries and mines, such as those of Mons Claudianus (Peacock and Maxfield 1997) and Mons Porphyrites (Maxfield and Peacock 2001) in the Red Sea region, Hatnub (Shaw 1986, 1987, 1999), Widan al-Faras in Giza (Bloxam and Storemyr 2002) and Khafre's quarries in the Western Desert (Storemyr et al. 2002, Shaw and Heldal 2003, Bloxam 2005).

The results from recent targeted surveys provided directly by the QuarryScapes team are the most valuable sources of information as they provide the most updated and comprehensive data. The project has so far provided in-depth data on quarries in Aswan (Bloxam et al. 2007), Al-Faiyum (Heldal et al. 2009) and the Tushka region in the Western Desert, as well as additional data filling in gaps in the national database (Storemyr et al. 2007).

As for the fifth source of information (reports from SCA), this has so far yielded the smallest amount of information. This is mostly due to the fact that ancient quarries have not yet been widely recognised as significant archaeological sites.

Considering this overseeing of quarry sites, an important task of Work Package 7 in the QuarryScapes project[3] has been, together with the newly established Quarry Department in the SCA, to inform and raise the awareness of the inspectorates about the importance of quarries and to encourage them to docu-

[2]Note that the sources available in Cairo, where the work has been conducted, are somewhat limited. However, it can be considered to have included enough sources to allow for an initial discussion of them here.
[3]Quarry Landscape GIS.

ment those known within their respective districts. Requests to produce reports about the quarries have been addressed to SCA/EAIS, but have so far provided little additional information about the quarries' location, typology or estimated period of use. It is hoped that the reports that are to be delivered in the future will produce additional data.

Legal aspects in the protection of ancient quarry landscapes

In order to have a better understanding of what the current constraints and regulations are that affect the Egyptian archaeological and historical heritage, the identity and role of the SCA and other organisations need some explanation.

The Supreme Council of Antiquities was established as an official agency, based on Presidential Decree No. 82/1994, as a reshape of the Egyptian Antiquities Organization (EAO). Though chaired by the Minister of Culture, the SCA strategy, orientations and administration are largely led by the Secretary General of SCA jointly with its Permanent Committee and Board of Directors.

According to the Antiquities Protection law No. 117/1983, the SCA is the official agency responsible for registration, documentation, protection and management of the country's historical and archaeological heritage sites and monuments in a way that is compatible with their security, sustainable exploitation and conservation. The SCA administration consists of five sectors, next to the central General Secretary and Central Management departments. Each sector is divided into geographical regions, which in turn are divided into directorates. These are finally divided into affiliated inspectorates, which are SCA local management offices.

Antiquities Protection law No. 117/1983 states that an archaeological site must have a precise boundary and area, in addition to a buffer zone that could be 3 km for inhabited areas. The SCA should ensure the availability of all information of archaeological and heritage sites to related organisations, which in turn should consider the sites in their general planning.

The SCA currently identifies archaeological sites as either ancient Egyptian (Prehistoric–Roman Periods) or Islamic and Coptic, and their legal activities as either a complete ownership of the area identified or a direct supervision of the activities performed (residential, vegetation, etc.). It is common for ancient Egyptian and Islamic and Coptic sites to be located either in rural or inhabited areas, which in turn seriously affects the implementation of a buffer zone. Fortunately, the quarry landscapes tend to be more commonly located in rural areas. Thus a better opportunity exists for the identification of a buffer zone.

As part of our research activity, it was important to determine the perspective at which the SCA reviews the quarry landscapes. Our investigation concluded that:

1. Quarries are sometimes identified and registered by the SCA as *Ancient Egyptian* sites.
2. Generally, if known, all ancient quarries are supervised by SCA under the Antiquities Protection Law No. 117/1983, specifically article No. 20 which powerfully regulates the establishment of new activities (construction, vegetation, etc.) or the modifications of current activities on any land that shows probability of having antiquities (or features) present. This also applies to desert lands and lands assigned for stone quarrying.
3. Local Inspectorate offices (Tafteesh) usually only identify a quarry if it is found in association with other archaeological remains, such as tombs or dwellings. As a consequence, quarries might be ignored if their significance is considered trivial vs. other archaeological remains. Consequently, quarries which are not associated with other archaeological remains are often overlooked.
4. Considering the above, the research conducted to determine the legal classification of each quarry, distinguished only two cases, known (quarries are identified by local inspectorates but usually are not registered by the SCA) and unknown (neither the records nor the local inspectorates have recognised the quarry).

Though law No. 117/1983, article No. 20 permits the SCA to impose a dominant role for the protection of archaeological heritage, our assessment revealed the presence of a serious malfunction in the whole system as related to registering quarries. The SCA local inspectorates identify 53% of the Egyptian quarries recognised during our literature research (193 quarries). However, only 20% of the identified quarries are either officially registered by the SCA or automatically protected as they are located within the extent of another registered archaeological area. For the remaining identified quarries, the SCA local inspectorates have only basic information about them; commonly the name of the quarry and a general idea of its location. Moreover, few quarries are property of the SCA and although some are currently under the process of being registered, the bureaucracy of many governmental organisations might hinder the registration process, which eventually may be halted and lost through the system.

A more accurate legal status will involve extensive research, which will require visiting most of the quarries that are classified in our lists; this activity must be conducted with the involvement of local inspectorates. The aim of these visits would be to collect updated information and to coordinate the registration process of the quarries which proved to be worthy of protection with the local inspectorates.

The new Quarry Department of the SCA is expected to perform a major role in the identification and protection of quarry landscapes in the future. The official decree that creates the department, states that it is entitled to:

- Conduct all necessary actions for the registration of ancient quarries and mines. The department is to initiate its activities in the Aswan governorate by delineating the borders of ancient quarries and mines on maps. The activities should subsequently cover the rest of the Egyptian governorates.

- Provide development and planning organisations with the necessary information about ancient archaeological quarries and mines to have them considered in their future plans.
- Establish collaboration channels with the Egyptian Geological Authority.
- Prepare selected ancient quarries and mines to be opened for public visits.
- Provide inspectorate offices with periodic memos to inform and raise their awareness about ancient quarries and mines in other areas.
- Collaborate with foreign missions working on sites with ancient quarries and mines.
- Raise the capacity of archaeologists and local inspectorates in identifying and recording local, ancient quarries and mines.

In this sense, the department has successfully conducted a training course for local inspectorates (the first course was given to Upper Egypt Inspectorates), which introduced them to the basis of identifying and documenting quarries using up-to-date technologies. The impact of the training was evident as more than 10 quarries (not mentioned in J. Harrell's research) were identified in the Upper Egyptian governorates and are currently being studied. Other training courses will be successively conducted. It is expected that the activities of this department will be very helpful in the future for matters related to quarry landscapes.

Visits to ancient quarry sites

Though archaeological and legal research was mainly based on literature and in-house research, it was important to conduct a few field visits to compare the outcome of the research with the current conditions and actual status. Over the course of 28+ months, 11 quarries were visited in different areas (Table 2). Moreover, steps to identify quarries located near existing sites were conducted alongside regular SCA/EAIS site visits. The aim of the field visits was to identify location, acquire updated information and investigate legal status with local inspectorates. Field visits were not limited to identified or pre-identified sites, but included visits to a larger number of sites to verify if they included quarries or could be classified as quarries. The following points summarise the quarries identified during these visits:

- In some cases, the quarry's location is known to the local inspectorates but the lack of facilities (appropriate vehicles, surveying tools, etc.), in combination with the unawareness of their archaeological value, results in a general ignorance of quarries.
- In other cases, the local inspectorates' knowledge of the quarries comes only from what other inspectors or former missions have told them, with no attempts to actually verify their existence.
- Many of the quarry sites are located deep in the desert, which makes it very difficult to reach them.
- As previously mentioned, there is no separate legal identity for the registration of a quarry site. Hence, their importance is not evident and appreciated by local inspectorates.
- The quarries located within the borders of another registered archaeological area are automatically protected. Though usually their identity and importance are considered less significant than the registered archaeological area.
- The most common factor threatening the existence of an ancient quarry is modern quarrying activities where the archaeological inscriptions and remains are usually damaged or stolen.

Table 2. Detailed information on quarries visited.

Quarry	No.	Status
Baharia Oasis	1	Unknown/Unregistered
Helwan	1	Known/Unregistered
Fayyoum	2	Known/Unregistered
Giza	1	Known/Unregistered
South Sinai	3	Registered
Suez	1	Registered
Abu Rawash	1	Registered
Qina	1	Registered
Total	**11**	

Database enhancement, adaptation and integration

The SCA/EAIS database—which was mainly designed to accommodate data of ancient Egyptian, Islamic and Coptic archaeological sites—had to be (1) adapted to contain the quarry data, then (2) a connection had to be established between the quarry database and the *Extended Database*, updated with information on legal status, condition, threats and other issues.

Initially, and based on sample data provided by the Aswan West Bank Survey database (Storemyr et al. 2007), *general point module*, information useful for creating site management plans for quarry landscapes was added to the SCA/EAIS database in order for it to be able to adapt quarry data.

The coding system was changed from a system that accepts ancient Egyptian and Islamic/Coptic sites only i.e., Exxyyzzzz/Ixxyyzzzz to a system that can include quarry sites i.e., qxxyyzzzz (Figure 3). For cases where an archaeo-

Figure 3. The system was modified to accept a quarry ID code i.e., qxxyyzzzz, an entry was created to show both IDs for sites already existing in the EAIS system and also identified as a quarry landscape.

logical site already exists in the SCA/EAIS system and is also identified as a quarry landscape, an entry was created that shows both IDs and links the two sites together. All changes in the coding system and predefined lists mentioned above are mainly made through changes in the database structure.

Changes in the interface were needed to allow (1) the implementation of the changes in the coding system, predefined list(s), (see Figure 4), and (2) the integration between SCA/EAIS database and the *Extended Database*.

The main purpose of the adaptation is to allow the user, while navigating through the quarry sites in the SCA/EAIS database, to open the equivalent *Extended Database; Egypt Quarries WGS84 Database Application (.mdb).* The integration of the two databases would serve the needs of users with different specialisations, as a wide range of detailed information about the quarry sites is presented: archaeological data, threat data, conservation data, legal data and geological information, taking into consideration the quality of this information as it is collected and researched by specialists.

Finally, a data form was created in SCA/EAIS database for displaying the *Extended Database* (see Figure 5). The ID code, which is a common field present in both the SCA/EAIS database and the *Extended Database*, was used to establish the link.

Future challenges

Research is not sufficient to save the sites for the future. Ultimately, the process of identifying, locating and finally registering new quarry sites should be followed by measures to control the threats that may affect them.

The database is designed to facilitate such operational action considering that *the design and construction of a national map of ancient stone quarry landscapes in Egypt* would not ONLY imply creating digital layers, but would deeply investigate the actual status of these quar-

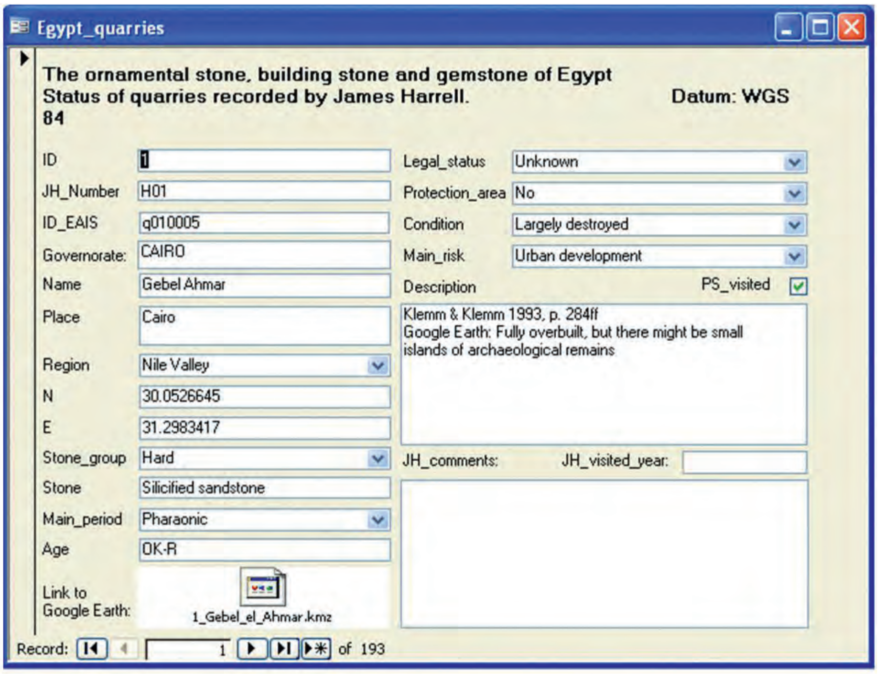


Figure 4. Original Egypt Quarries WGS84 Database (.mdb).

ries inside the Egyptian governmental administration. Hence, discovering the malfunction in the current documentation system and consequently recommend possible protective measures.

The primary output of the national database is the creation of a shapefile, which includes 193 records. Each record represents a single, ancient quarry landscape and is composed of several fields covering most of the essential information needed to recognise an ancient quarry (see Table 3). The practical aim is that the output will be used as an efficient tool in the physical protection of the sites and coherent management by inspectors who are well aware of their significance.

Although SCA has yet to classify ancient quarry landscapes as a separate legal entity, which are registered as archaeological sites and are differentiated based on their dating as either ancient Egyptian or Islamic and Coptic sites, it has recently recognised a separate archaeological identity for the ancient quarry landscapes by establishing a new department within the SCA to be specifically responsible for the identification and protection of these ancient quarry landscapes and mines.

An important challenge to be met is appropriate education of the inspectorates, for increasing their knowledge about quarry sites, how to characterise them and assess their significance. Another challenge is the inspectorates' lack of physical resources for actually visiting quarry sites. Many of them are located in remote desert areas, and field visits require appropriate vehicles and surveying tools.

Concluding remarks

Our activities, which extended over almost 28 months, have led to the general conclusion that the value of the Egyptian quarry landscape is underestimated. Extreme efforts need to be exerted to initiate a concrete protection and preservation strategy, plans and practices.

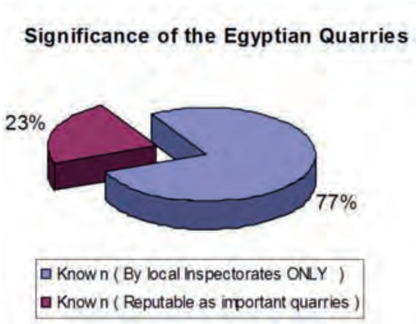


Figure 5. The significance of the Egyptian Quarries among inspectorates.

Efforts should primarily focus on changing how the quarries are being regarded through conducting awareness-raising campaigns that target concerned institutions (SCA, governorates and quarrying authorities), inhabitants living adjacent to the sites, as well as specialists in the field of archaeology. Setting and conducting national and international projects similar to the QuarryScapes project and encouraging research in the field of ancient quarrying, should be encouraged as part of the long-term sustainable strategy.

By the end of the project's 28+ months time span, we conclude that the project activities, while being essential for the long-term safeguard of the quarry heritage, are only a starting point for continuous actions. The activities of this project only permitted conducting general research activities for each of the quarries identified. Additionaly, more focussed, long-term activities need to be designed and implemented to specifically identify and establish the status, conditions and intervention measures of each classified quarry landscape. Consequently, designing and applying a systematic methodology to classify and list other quarry sites will be an important step.

Fortunately the Egyptian administration has already taken first measures towards the reconsideration of the value and significance of quarry landscapes through the establishment of the Quarry Department within SCA. The role of this administration is to prescribe and undertake result-oriented measures that will, when implemented, provide protection for and enhance the value of Egypt's quarry landscapes. However, based on

Table 3. An explanation of the fields used in the Egypt National Map shapefile.

Field name	**Sample data**	**Description**	**Field originator**
ID			
JH_Number	H03	A serial no. based on the categorisation in J.Harrell's tables	WP5
ID_EAIS	q240044	ID code created based on the geographical location of the quarry site and its relation with the enclosing governorate	WP7
Governorat	Al-Minya	Enclosing governorate	WP5
Name	Tilal Sawda	The quarry name as described in J. Harrell's tables	WP5
Place	By Behenasa	A description for the quarry's location as described in J. Harrell's tables	WP5
Region	Western Desert	The general region where the quarry is located	WP5
N	28.52016	North latitude	WP7
E	30.5499761	East longitude	WP7
Stone_grou	Hard	The group to which the quarry stone belongs	WP7
Stone	Basalt	Stone type	WP7
Main_perio	Greco-Roman	The main period to which the quarry dates	WP7
Age	R	Other period(s) to which the quarry dates	WP5
Legal_stat	Unregistered	How the SCA regards the quarry	WP5
Protection	No	Whether the quarry undergoes and type of protection (e.g., World Heritage Site)	WP5
Condition	Partially destroyed	Current condition	WP5
Main_threa	Mining and quarrying	Main threats endangering the quarry	WP5
Descript	No Google Earth high resolution coverage Eastern part of the site completely destroyed	Any additional relevant information	WP5
PS_visited	1	Whether the quarry was visited by Per Storemyr (1 = Yes, 0=No)	WP5
JH_visited	0	Whether the quarry was visited by J. Harrell (0=No, a year is specified in case the quarry as visited)	WP5
JH_comment		Other comments by J. Harrell	WP5
Hyp_Links	\\server-gis\Quarry Scapes\GIS_Data\ National Map\ pix_samples\ HARDSTONE QUAR RIES\NILE VALLEY AND WESTERN DESERT\Ornamental Stones\q240044\ q240044.jpg	A field essential to create the link to the sample photo (if it exists)	WP7
Ident_Taft	unknown	Whether the quarry is identified by local inspectorates	WP7

previous experience and flexible resources, the involvement of international expertise remains crucial for creating a long-term system for the protection of ancient quarry landscapes.

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New directions in identifying the significance of ancient quarry landscapes: four concepts of landscape

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As a largely forgotten cultural heritage, articulating the significance of ancient quarry landscapes to a wider public is key if such are to be conserved and protected. Given the mundane aspect of the material remains that make up these sites this can be particularly difficult to do. Significance may only be fully understood by decision makers, heritage authorities, stakeholders as well as the broader public if we can find ways to connect ancient quarry landscapes with other places and/or events of more widely known historical importance. When concepts of landscape are deployed as a method of macro-level interpretation into ancient quarry landscapes across the QuarryScapes project study region, we have been able to identify significance in several different ways. For instance, quarry landscapes such as that at Sagalassos in Turkey that are largely invisible, can be holistically significant when they are viewed as telling the greater story of how these resources were utilised in the construction of a major city of antiquity. The extensive and complex quarry landscape of the Aswan West Bank in Egypt can be considered as holistically significant, when viewed as telling the story of human engagement with a specific resource over exceptionally deep time. Explosions in quarrying for specific products may also be of greater significance and research value when viewed as an indicator of profound political and ideological change in history and prehistory. In addition, when extensive quarry landscapes are under pressure from modern development, we can also 'best project' where these events can be visualised and authenticated by material remains at specific places in the landscape. The need to separate the scientific values of ancient quarry landscapes that are of interest to experts, from the bigger story that they collectively convey, can be the way forward if we are to build a case for conservation in a more accessible way.

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Introduction

Conservation of any cultural resource needs to address a fundamental question: why should a particular place, landscape or monument be conserved over other types of cultural resource? Finding ways to convey the significance of a cultural resource is thus a key component in approaching this question, which is largely drawn from an assessment of heritage values gathered across a range of perspectives. In the conservation process, these values are put into a 'statement of significance', which heritage authorities, stakeholders and other relevant parties use in the evaluation of a cultural resource. One of the key objectives of 'QuarryScapes' has been to put ancient quarry landscapes on the conservation agenda and it has been important to find ways to articulate the significance of this forgotten heritage in such a way to relevant authorities. Developing a methodology to put across the significance of ancient quarry landscapes in more broadly based terms is thus essential in building a case for their conservation.

As with any cultural resource, ancient quarry landscapes vary greatly in terms of preservation of their material remains. For instance, some ancient quarry landscapes may present all elements related to the stone extraction process such as roads, extraction sites, inscriptions, settlement and other material remains, whereas others may only consist of a few remaining rock outcrops and the odd spoil heap. In addition, their character is essentially mundane when compared with other cultural landscapes, particularly those that comprise monumental structures. It may be said that outside of professional interest, the significance of ancient quarry landscapes as a 'cultural heritage' in themselves is often difficult for non-professionals and heritage authorities to grasp. So, how do we find a way to forward the significance of these 'difficult' landscapes in a meaningful way to others outside of academic disciplines?

This paper presents a summary of how a methodology was developed as a means to transmit the significance of ancient quarry landscapes in an accessible way to a wider public. It discusses the background to developing 'four concepts of landscape' and their practical application to the extreme diversity of ancient quarry landscapes, as seen through several case studies from across the QuarryScapes project region.

Background

Given their extreme variability in terms of preservation and visibility, ancient quarry landscapes can present us with particular problems when it comes to articulating their significance and value. For instance, we may be presented with quite highly visible landscapes with good preservation of key elements, such as the Aswan West Bank (Figure 1), or those that have become enveloped in modern cities such as Ankara (Figure 2). An ancient quarry landscape may completely loose its identity by being eclipsed by more spectacularly built remains in antiquity, such as ancient cities like Jerash and Petra in Jordan (Abu-Jaber and Al Saad 2007, Abu-Jaber et al. 2007a, b, Al Saad et al. 2007), or Sagalassos in Turkey, where the quarries have largely disappeared by being integrated into the ancient city (Figure 3) (Degryse et al. 2008). Man-made transformation processes such as multiple quarrying over time, as well as proximity to developing cities and unchecked tourism, can obliterate earlier phases of quarrying. In addition, natural transformation processes such as weathering, can make the visualisation of early tool-making quarries of distant periods such as the Palaeolithic hard to distinguish.

Any conservation strategy has to be realistic and balance protection of key cultural resources with local and national development needs. This is particularly relevant to ancient quarry landscapes when it comes to assessing 'what can be saved' given they can often cover areas upwards of 100 km^2. As Fairclough (2008, p. 412, 421) points out, conservation approaches should be made from the premise that *"…protection of cultural landscapes is not first and foremost about preventing change but managing it…[in] …sustainable historically sensitive directions"*.

Within this range of parameters, the task of developing a method to identify the significance and value of ancient quarry landscapes needs to be flexible and transferable. Moreover, the mundane nature of the material requires a method to make these inaccessible places

Figure 1. Quarry roads of the New Kingdom and Roman Period on the Aswan West Bank, Egypt.

Figure 2. The cityscape of modern Ankara (Turkey), the arrangement of houses following the contours of quarries used in the building of the city.

Figure 3. Remains of a large house/villa built of rubble situated inside a disused limestone quarry at Sagalassos, Turkey.

accessible and relevant to those outside of professional disciplines such as archaeology and geology. The 'statement of significance' is a key document on which hinges future strategies in terms of protection, conservation, and even as the first step to World Heritage nomination, of a cultural resource. This document, aimed at decision makers in cultural heritage, stakeholders and heritage managers, is thus the formal medium through which heritage significance and values are drawn. In essence, as Aplin (2002, p. 18) points out, the 'statement of significance' has to provide the justification, from an expert perspective, as to why a cultural resource should be conserved over other forms of land use or development.

There are several key steps involved in drawing up a 'statement of significance' that are common to all types of cultural resources, and which constitute the basis of an expert value assessment. Drawing from the works of scholars such as Lipe (1984), Sullivan (1997), Aplin (2002), Mason (2008) and Fairclough (2008) these steps can be summarised as follows:

1. Identifying heritage values.
2. Assigning heritage values to cultural remains at a micro level (the empirical data).
3. Developing a theoretical screen to articulate significance at a macro level and to a scale of heritage values.
4. Creating a 'statement of significance'.

In developing a strategy and method to draw up a 'statement of significance' applicable for ancient quarry landscapes, we have modified these basic steps to make them more relevant to the specific problems presented by the material remains found in ancient quarries . These are summarised below.

Identifying heritage values

Lipe (1984) developed what are still key heritage value terms that can be related to any cultural remains of the past. Yet, certain heritage values may only be applicable within certain domains of interest. For instance, economic, social and aesthetic values are usually assessed at local and national levels and involve stakeholders, managers and other decision makers—such values being integrated into the final 'statement of significance'. From our expert perspective (geological and archaeological), the key values that we use to assess a cultural resource are *historical* and *informational* value. These are defined by Lipe (1984, p. 2–8) to give meaning and importance to cultural remains in this way:

Associative/symbolic value (historical value) — the essence of physical cultural remains and their authenticity, even if reused, that can transmit cultural information about the past. These are powerful symbols of the past that can also be bound up in 'Communal value' in terms of collective memory for those who relate to it by proximity, but also in terms of society's needs for continuity through time.

Informational value — emerges from formal 'expert' research, in particular from multidisciplinary approaches and having to make 'best projections' of what kind of resources/elements will be most useful for future study.

Although these definitions are largely in the domain of Western value systems, there is arguably a universal aspect to them in the expert domain. Noting that even within Western perspectives of value, statements of significance may often be contradictory, given that 'heritage' is multivalent and corresponds to different stakeholders and contexts that are not fixed (Lipe 1984, p. 2, Sullivan 1997, p. 19, Mason 2008, p. 100). As Mason (2008, p. 114, 119) points out, rather than collapsing all values to form a whole, the statement of significance should rather identify the main themes of significance in the experts' field and isolate these judgments from others outside the field.

Assigning heritage values to cultural remains at a micro level (the empirical data)

The physical remains of ancient quarrying, or the empirical data that is left across a landscape related to quarrying of a stone resource, can include roads, settlements, harbours, inscriptions and production remains such as spoil heaps and tools. As discussed above, all these elements can range enormously in terms of their visibility and preservation. In addition, ancient quarry landscapes are the product of resource exploitation that may have occurred over great time depths and so leave multiple traces over time. Hence, we have to finds ways to disentangle, identify and characterise these layers and different types of material remains as a baseline to assigning values. Given that all ancient quarry landscapes to a greater or lesser extent comprise one or all of these key elements, to do this, four main categories of characterisation were designed that are summarised below: (i) the *Resource* or actual stone deposit; (ii) *Production remains* such as quarries, tools and discarded products; (iii) *Logistics* or infrastructure laid down to remove the stone products from the quarry; (iv) the *Social infrastructure*, or the remains left by the people who worked in the quarry, such as settlements, inscriptions and ceramics (Bloxam and Heldal 2008, p. 21, table 3, and Heldal 2009).

Although historical and informational value may be assigned to one or more of these key elements, cultural landscapes by their very nature are dynamic and so represent layering of ranges of material culture, sometimes not directly associated with quarrying, across time and space. As Mason (2008, p. 120) points out, the historical value of a building is not necessarily the sum of the building itself, but its relationship with other material remains and other landscape elements. Moreover, delineating values to 'complexes' of material remains or 'sites' within a landscape allows for all the elements that make up a particular 'historical complex' to be taken into account (in the planning process), no matter what their particular nature, visibility or preservation. Hence, identifying and assigning values is linked to how they are embodied in particular 'complexes' of material remains.

Deploying such a method to ancient quarry landscapes led to the development of the notion of the 'quarry complex'

(Bloxam and Heldal 2008, p. 118–133, also see Heldal 2009 for more detailed overview) as a way of identifying collections of quarry elements that may be related to each other in time, space or function. So, rather than viewing a quarry landscape as collections of four quarry elements (resource, production, logistics and social infrastructure) the 'quarry complex' gives us the opportunity to group these elements in many different ways and so allowing for historical and informational value to be assigned in a much more flexible way. In addition, to the non-expert, a delineation of values can be seen to be embodied in two ways: first, onto individual material remains, and second, in a collective way as material complexes. Hence, this can aid significantly in identifying where complexes of materials or 'sites' that hold key values are located. This is particularly important when pressure from modern development requires 'best projections' to be made, in terms of which sites or complexes of material remains in a landscape should be conserved over others.

Developing a theoretical screen to articulate significance at a macro level and to a scale of heritage values

Assigning informational and historical values to micro-level material remains and quarry complexes rests greatly in the domain of expert assessment, and aspects of technology, logistics and the social organisation of quarrying hold key values from this perspective. However, to the non-expert and broader audience, who may often have no interest in the technologies of ancient quarrying, significance and value needs to be transmitted in a far more wide-reaching way. In addition, people need to know at what comparative scale the site's significance and value is comparable with others, i.e., at a local, national or international level. To identify these broader aspects of significance, as Aplin (2002, p. 18–20) proposes, a theoretical screen or conceptual framework has to be developed to view the material remains in terms of assessing a scale of values.

In essence, the methods of value assessment described up to this point have been concerned with assigning historical and informational value at a micro level, and so now we need to turn our attention to the macro level in terms of the broader historical significance of cultural resources. Developing theoretical screens that enable us to get at the broader significance and value of quarry landscapes that are diverse in terms of the visibility, preservation and multilayering of remains over large areas, is particularly challenging. We also have to remember that a quarry complex may only consist of a few traces of the resource and production evidence may only be represented by a few tool marks, with no evidence of the social infrastructure. At the other end of the scale, an ancient quarry landscape may comprise several quarry complexes with rich and diverse material remains of multiple periods. So, does this mean that the quarry complex with fewer traces is less significant than the one with numerous traces?

To grapple with such questions it is necessary to construct analytical approaches that identify a range of 'value contexts' in the light of such diversity. Accordingly 'four concepts of landscape' were designed as a baseline theoretical screen through which we can articulate macro-level value contexts of ancient quarry landscapes. In essence, the idea is to find ways of articulating the significance and value of a site within its broader geographical and historical context, however diverse its material remains, or in other words, the degree to which it has connections to other places and/or historical events.

Four concepts of landscape

1. *Socially constructed landscapes*: this concept can be used to isolate values of multiperiod quarry landscapes in terms of the time depth of the quarrying as well as the use and reuse of the landscape for other activities. Authenticity of cultural remains are key to assessing historical values, although often ancient quarry landscapes can lose the 'authentic' remains of earlier quarrying as a result of later quarrying and reuse. To identify the significance of these multiple traces of quarrying over time, and its connection to other activities occurring across the landscape, the concept of a *'socially constructed landscape'* allows for the historical context to be assessed holistically. Stone-working traditions, aspects of ancestry and connection to a landscape, are key concepts to identify. Contributions from landscape archaeology, anthropology, ethnography and social archaeology (Ingold 1993, Barrett 1999, Cooney 1999, Knapp 1999, Ucko and Layton 1999, Bradley 2000, Thomas 2001, Grzymski 2004) are key theoretical sources that can aid in reconstructing the social landscape and from which historical values might be linked to specific material resources.
2. *Contact landscapes* (consumption): ancient quarry landscapes do not exist in a vacuum but have connections with other places, often thousands of kilometres away, through consumption of their products. In some instances these contacts may be extremely close to a quarry landscape and may be related to providing stone for a major city or monument of enormous historical importance. Part of the historical significance of the ancient quarry, although this may be hard to visualise and attach to actual physical remains, comes from its connection to another more highly visible and significant place. Consumption of stone from a particular resource over a wide geographical range can also be historically significant, in terms of identifying ancient trade patterns and values placed on particularly sought-after resources over time. These contacts may also be significant in terms of identifying cross-cultural social relations between people, centred on the trade and consumption of a stone resource, that places the ancient quarry landscape at the epicentre of these connections.
3. *Associated historical landscapes*: at a macro level, some ancient quarry landscapes may be implicated in and provide additional evidence about sig-

nificant events and transformations in history and prehistory. For instance, political and ideological change at key periods in history may provoke intensive production of a specific resource due to its symbolic association with an emerging religious cult. Quarries can also be key places to identify changing social relations in the transformation of early states, particularly where monumentality and large-scale raw material procurement were key indicators of an emerging political elite. Dramatic intensification in quarrying for utilitarian objects from a specific resource, such as grinding stones, may tell us about major changes in diet and methods of food processing at key transformative stages in prehistory. Important insights into past environment may also be directly and indirectly evident at ancient quarries. For instance, methods of stone transport and types of infrastructure may provide evidence of once easy accessibility to water in now hyper-arid environments. Technological changes in society over time can also be reflected in quarries, for instance, the introduction of iron technology into quarrying.

4. *Dynamic landscapes*: quarry landscapes, as with any type of landscape, are dynamic places that are not static in time. Although the concept of a *'socially constructed landscape'* allows us to view multiperiod transformations as adding new layers of historical significance, directly or indirectly related to quarrying; how do we articulate values of quarry landscapes where reuse for other activities may have completely or partially destroyed them? The aim is to view the landscape holistically from a perspective of how human agency into the present may have totally changed an earlier landscape and what threads of these past elements have been inherited and still survive. Aspects of this approach have been incorporated into methods relating to Historic Landscape Characterisation (Fairclough 2008, p. 414) and form the basis of this macro-level concept. This is a particularly useful concept to use when a quarry landscape has been totally integrated into a modern city and where we need to assess historical and informational values through human agency as characterising the *present-day* landscape, rather than its past.

The idea is not to analyse an ancient quarry landscape through just one of these concepts, as more often than not the diversity of material remains and their status of preservation may mean that significance has to be articulated in several ways. These concepts have been developed more as a way to remind us of the flexibility that there can be in identifying significance and most importantly, that significance is culturally and socially specific and therefore variable from country to country.

Values in terms of scale

The final step in the assessment of historical and informational values, at both micro- and macro level, is to inform decision makers and heritage authorities as to the scale to which these values can be assigned to an ancient quarry landscape and its material remains. The key terms of reference for assigning scale to a cultural resource, as forwarded by Aplin (2002, p. 20) have three dimensions:

1. *Scale*: something may be important to a local community, region, state, nation or globally.
2. *Importance*: how important is it at the appropriate scale and why.
3. *Either uniqueness or representativeness*: this can be a unique case such as the last remaining, or a representative example of a type.

At a macro level, deploying the four landscape concepts allows for historical and informational value to be assessed by analysing the quarry landscape holistically, rather than as individual areas, sites, or complexes of material remains. The assessment of scale comes by comparative analysis of the quarry landscape against others at local, regional, national and international levels. At the top end of the scale, the historical and informational value of an ancient quarry landscape may rest in the totality of its material remains as laid down over time as representing a narrative of human exploitation of a resource that is of global significance. To this end, a statement of significance may urge decision makers and heritage authorities to consider World Heritage nomination of the cultural landscape. At the lower end of the scale, a site's significance may only be important, as a representative example of a type at a local level.

Yet, quarry landscapes can also present complexes of material remains within them that may vary greatly in terms of their historical and informational value in terms of scale. Moreover, we can never present to decision makers conservation planning options that only adhere to the view that 'all must be saved'. Conservation has to be balanced with modern development needs, and the expectation that 'whole' landscapes, sometimes covering upwards of 100 km^2, should be saved has to be based on strong arguments based on global significance. Consequently we need to provide decision makers with two views of heritage values: first, as a total 'landscape' entity and second, to 'best project' where particular material remains or 'quarry complexes' might, in terms of scale, have more historical and/or informational value than others. In other words, we have to look at a relative scale of these values at a micro as well as a macro level. For instance, a particular 'quarry complex' of material remains may represent the best preserved example of one of the world's oldest quarry roads and so its historical and informational value may be assessed as significant at a global scale. Whereas other parts of the same quarry landscape may be assessed as having historical and informational value only at a national level.

'Outstanding universal value': global significance, authenticity and UNESCO criteria for establishing World Heritage Status

'Outstanding universal value' of a cultural resource, be that a single monument or entire landscape, is the highest level of scale that can be attained. The four concepts of landscape described above can be a useful method to gauge if an ancient quarry landscape, or elements within it, may fit into such criteria. Nomination documents for World Heritage status are, similarly, primarily based on the articulation of significance at the broadest level and where identifying a scale of values is key. Criteria for assessing values for World Heritage nomination are thus useful additional concepts to apply, particularly when assessing landscapes holistically (UNESCO 2008). Importantly, it grapples with the question of authenticity of cultural remains and the difficulties inherent in defining this as a criteria for assessment when cultural landscapes are, by their very definition, dynamic and comprise material culture that can represent several historical periods (von Droste 1995, p. 22–23, Cleere 1996, p. 228–229, Titchen 1996, p. 236–237). After the Nara Conference on authenticity (UNESCO 1994) a more open and flexible approach to the concept of authenticity and cultural landscapes as representing 'the combined works of nature and man' allowed for the distinctive character and components of a landscape across multiple periods to be recognised (Mitchell 1995, p. 245, von Droste 1995, p. 22–23, McBryde 1997a, Jones 2003, p. 40, Fowler 2004, p. 5). Such modification of this key criteria has allowed for the inclusion of 'industrial landscapes', that may have evolved over several millennia, to be considered as World Heritage Sites. Out of the current sixteen 'industrial landscapes' listed as World Heritage Sites (Jokilehto 2005, p. 78) none are related specifically to stone quarries in their own right. The need to redress this imbalance means that we should be thinking more seriously, when making a value assessment of an ancient quarry landscape, about whether 'outstanding universal value' can be applied in certain cases.

The concept of 'outstanding universal value' has recently been used in the assessment of significance of two ancient quarry landscapes in terms of World Heritage status: the Northern Faiyum (Bloxam and Heldal 2007) and the Aswan West Bank (Bloxam 2007a). Key to this methodology was how we conceptualise the significance of the transformed landscape across time and its social construction, in essence as a *'socially constructed landscape'* that incorporated theoretical approaches from social archaeology and landscape archaeology (Ingold 1993, Ashmore and Knapp 1999, Barrett 1999, Ucko and Layton 1999, Thomas 2001). Deployment of these concepts allowed us to get at aspects of the 'human experience' of quarrying in the past and its significance in terms of time depth.

Creating a 'statement of significance'

The 'statement of significance' is where we formalise the results of the historical and informational value assessment, from an expert perspective, of an ancient quarry landscape. This document has to be accessible and meaningful across a range of interests from those of decision makers in heritage authorities to local stakeholders and is where macro-level interpretation and the articulation of significance in broad historical terms is key. Moreover, it is where guidance is given, in terms of micro-level material remains, as to which sites, or (quarry) complexes of material remains in a quarry landscape provide 'best projects' historical and informational values at a relative scale.

Into this document, other values such as the aesthetic, economic and social are added, the assessment of which lies in the domain of identified local stakeholders and other interest groups. Moreover, such assessments would be made with regard to national legislation and other legal frameworks at local and national levels. Accordingly, as several commentators have remarked, there is the expectation that statements of significance will often be contradictory, for instance, historical value may be in conflict with aesthetic value and so there is clearly no imperative for reflecting a universal view (Sullivan 1997, p. 19, Mason 2008, p. 119).

Towards a statement of significance: applying the notion of 'four concepts of landscape' to ancient quarry landscapes—case studies from across the QuarryScapes project region

The methodology described above and key definitions relating to the idea of four concepts of landscape have both been summarised in Figures 4 and 5, respectively. But how, in practice, do

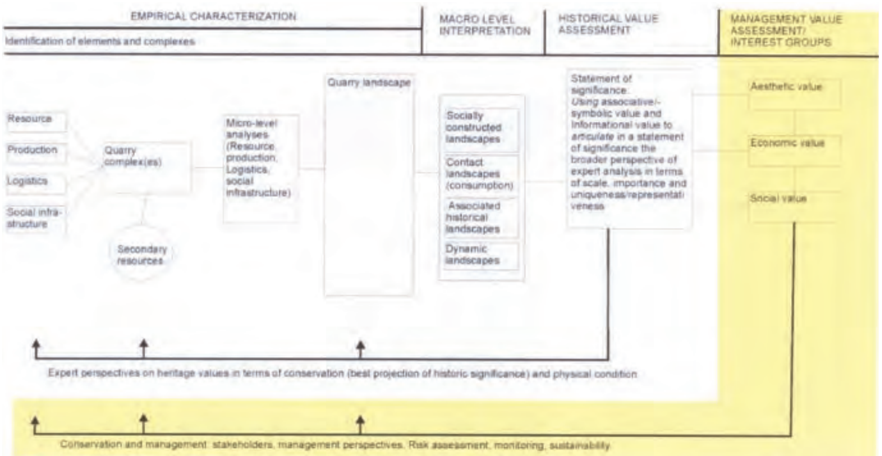

Figure 4. Steps in the process of making a 'statement of significance' from an expert perspective specific to ancient quarry landscapes (white area). Value assessments (yellow) are those identified by stakeholders, managers and other decision makers involved in the conservation planning process.

Socially constructed	Traditions, other use of landscape, ancestry, re-use
Contact	Consumption, trade, exchange
Associated historical	Connections to political, ideological and technological changes and evolutions
Dynamic	Transformations of landscape, re-use, present day situation

Figure 5. Four concepts of landscape: a summary of their key attributes.

we apply this method to ancient quarry landscapes? To test this method, specific ancient quarry landscapes have been selected from across the Eastern Mediterranean QuarryScapes project region as case studies that represent the diversity of material remains that can be encountered. This diversity is represented in terms of preservation, authenticity, time depth and geographical location in relation to other monuments, or ancient cities which consumed their products.

Socially constructed landscapes

The Aswan West Bank in Upper Egypt presents us with a key example of how an ancient quarry landscape can comprise material remains of extreme complexity, spread over an area of 60 km^2 (Figure 6). QuarryScapes geological and archaeological surveys of the landscape revealed a hitherto unknown deep history to silicified sandstone quarrying here, from the early toolmakers of the Lower–Middle Palaeolithic into the Roman Period (Bloxam et al. 2007). Consequently, the landscape has been transformed by the exploitation of a single resource that may have commenced up to one million years ago. Apart from the range of silicified sandstone quarries that cover such a large time depth and their associated infrastructure, there are additional material remains from other activities that occurred across the landscape at different times. These activities, such as hunting via game drives, development of desert transport routes and burials of the elite in the Dynastic Period, may have occurred in conjunction with quarrying. In addition, significant material remains were also laid down *after* quarrying ceased to be a core activity, for example, the building of monasteries and use of areas for burial (Bloxam et al. 2007, p. 201–202, Storemyr 2007, p. 163–181). In other words, there were periods when the landscape was socially reconfigured for other activities.

In terms of the ancient quarry landscape as a whole, the material remains present great complexity associated with many time periods, often overlying each other and spread over a large area (60 km^2). Consequently, even from preliminary analysis it is possible to see that the historical and informational values of the landscape rest largely in its totality as a cultural landscape. Yet, how do we make this accessible to heritage authorities and make a case for conservation in such terms? In particular, assigning secure chronological sequences to all these phases of quarrying and other activities when we often encounter poor visibility of material remains as well as data gaps. However, the concept of *'socially constructed landscape'* that can be applied to the total landscape allows us to grasp significance as not being attached to specific 'sites' or to sets of material remains, but identifies historical values through ancestry, longevity and connections to the landscape that include all activities that occurred across it. Thus, it provides a medium with which to view the narrative of a landscape as represented in its totality.

First we needed to deconstruct the landscape into the four elements of ma-

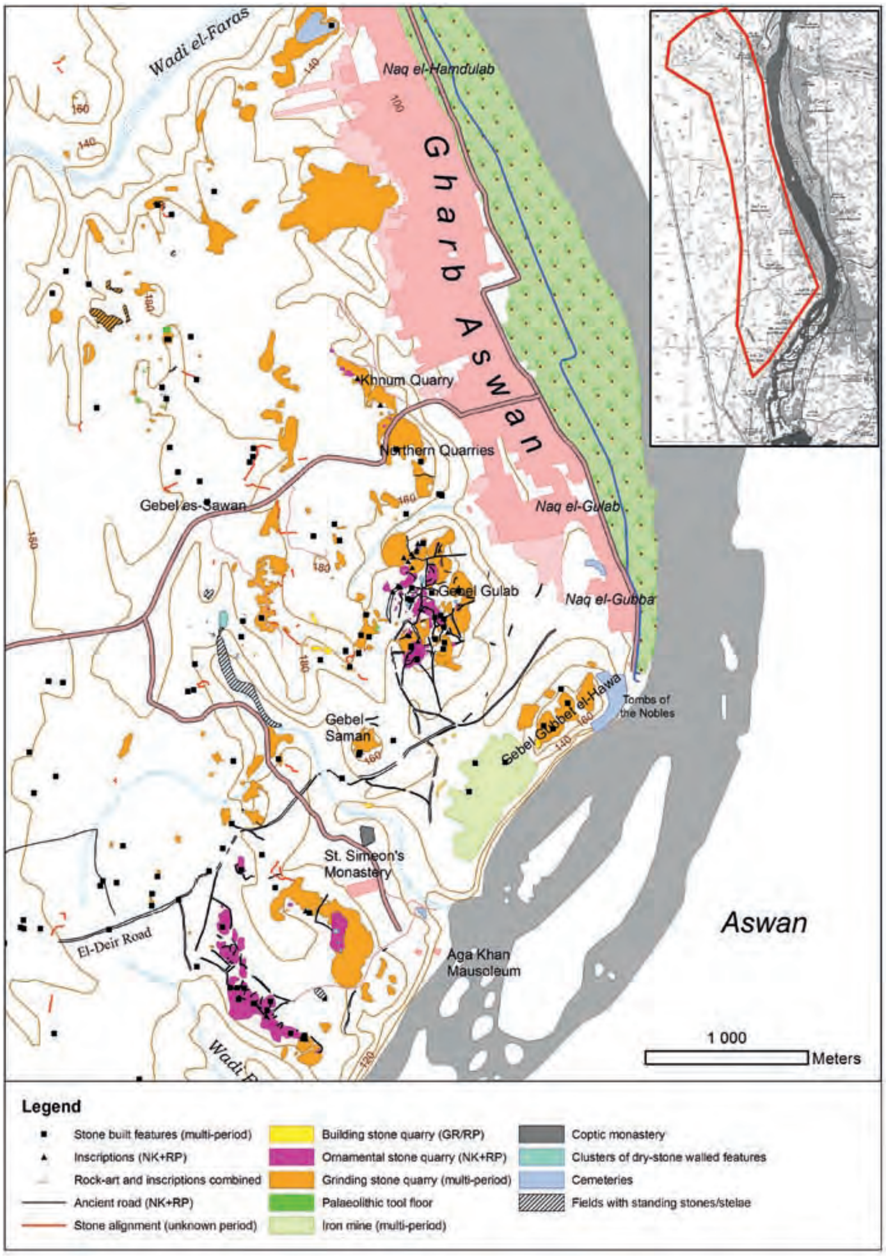

Figure 6. Map of the Aswan West Bank quarry landscape. Detail map shows key areas of archaeological remains and quarries mapped during the QuarryScapes survey. Insert map (top right hand corner) shows the overall extent of the quarry landscape (map produced by Tom Heldal and Per Storemyr).

terial characterisation as described above: resource, production, logistics and social infrastructure. Then, reconstruct it by grouping material remains into 'complexes' that are related to the quarrying of specific products. Five quarry complexes were identified (Bloxam and Heldal 2008, p. 127–129, also see Heldal 2009) as follows: a Palaeolithic tool complex; a grinding stone complex; a Dynastic ornamental stone complex; a Roman ornamental stone complex; and a building-stone complex. These complexes represent the whole of human engagement with this landscape in terms of quarrying its resources, particularly of silicified sandstone, over a period of up to one million years.

Of all these complexes, it is the grinding stone complex that is the largest and which had most impact on transforming the landscape over a period of 16,000 years (Heldal and Storemyr 2007) (Figure 7). Hence, applying the concept of *'socially constructed landscape'* to this complex, particularly as it cuts across most of the other quarrying complexes in time, was key. Yet, these quarries are some of the most mundane and difficult to visualise, particularly those of the prehistoric period (Figure 8). However, they have associated with them other material remains, in particular rock art and inscriptions (Figure 9) that have been important to understanding the loci of human activity as being linked to specific places across the landscape (Bloxam 2007a, p. 7–11, Storemyr 2007, p. 165–166, Storemyr 2008). These places may be directly linked to quarrying or other activities that occurred, but in essence, the inscribing of the landscape gives us the impression of the continuity of human presence over time. Hence, in terms of assigning values to the rare narrative of this landscape we can make connections between people and places over deep time, not only that associated with quarrying but also of other activities.

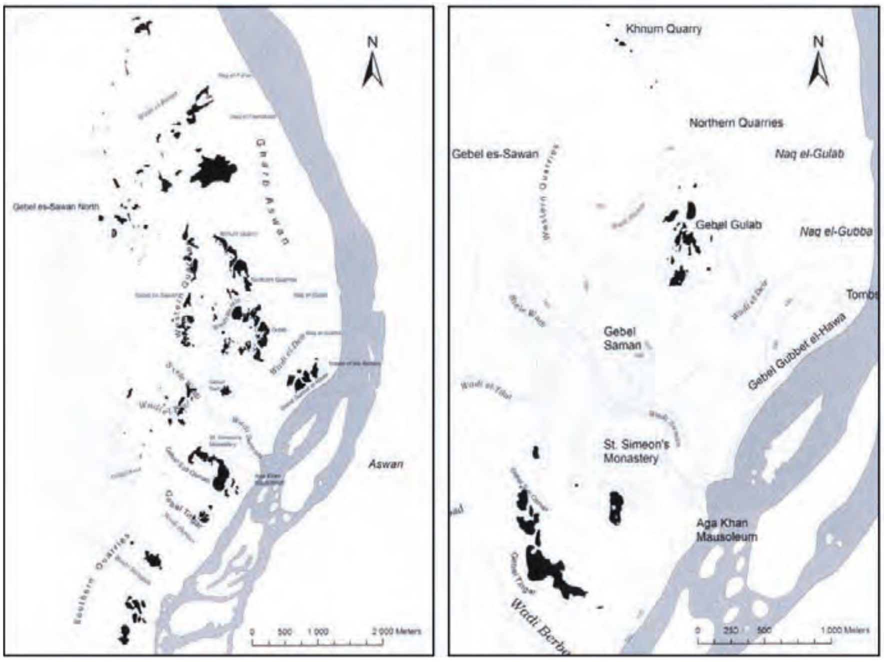

Figure 7. Map (left) shows the extent of keys areas of grinding stone quarrying (in black) along the Aswan West Bank; map (right) indicates (in black) key areas of ornamental stone quarrying (prepared by Tom Heldal).

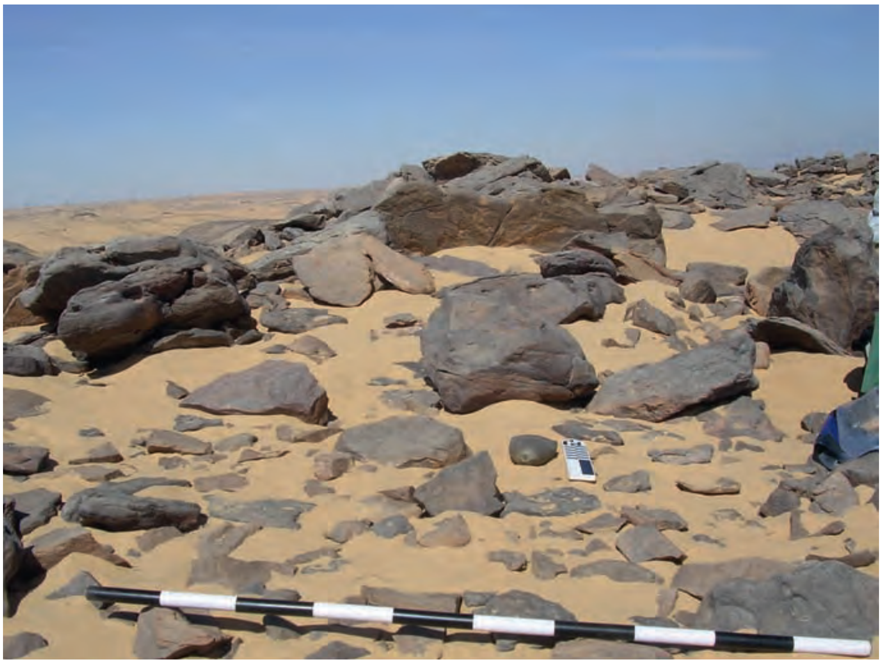

Figure 8. Predynastic grinding-stone quarry, Gebel es-Sawan North, Aswan West Bank.

The grinding stone complex has its origins in the Wadi Kubbaniya, which in itself is an area of key significance as it is associated with the first evidence of Late Palaeolithic semipermanent settlement in Egypt (Roubet 1989, Wendorf and Schild 1989). Extending to the southern borders of the West Bank close to the Old Aswan Dam, the grinding stone complex represents upwards of 80% of silicified sandstone quarrying (Heldal and Storemyr 2007, p. 72, fig. 1). Key to the social construction of the landscape, in relation to grinding stone production, is not only its longevity of 16,000 years, but that production techniques show little change (Heldal and Storemyr 2007, p. 101 fig. 27, 100–102). What is the significance of this in terms of accessing the social construction of the landscape? The concept of *'socially constructed landscapes'* allows us to use a range of theories from archaeology, anthropology and ethnography cross-culturally to answer such a question.

Grinding stone production and its importance in mediating social rela-

Figure 9. Prehistoric rock art near grinding-stone quarries, Gebel es-Sawan North, Aswan.

tions that link people with specific places in the landscape, has come specifically from research of Australian aboriginal culture (McBryde 1997b). Evidence, comparable with that of the Aswan West Bank, has been archaeologically attested over deep time in aboriginal culture, and research has shown the important role that grinding stone production played in maintaining social relations and links with ancestors. Grinding stone quarries were also incorporated into 'dreaming tracks' and were continually revisited over time as special places in the landscape (McBryde 1997b and Bloxam 2007a for a more detailed explanation).

In effect, the concept of a *'socially constructed landscape'* can help in identifying the historical significance of an extensive grinding stone complex in its totality, and describing a rare perspective that links quarrying of a single object with the dynamics of social life on the West Bank across deep time. When grinding stone complexes lie side by side with the 'dynastic ornamental stone complexes', such as at Gebel Gulab and Khnum quarries (Bloxam et al. 2007, Bloxam and Heldal 2008, Heldal 2009) it is possible to use such a perspective to view the extent to which changes to large-scale object quarrying may have impacted on local social relationships. The key to such changes would be any indications from the material remains that characterise the hand of the 'state' and ideas of any monopoly of the resource (see Bloxam 2007a). Although a significant enhancement in production techniques linked to large-object quarrying can be identified, as can its logistical infrastructure, it is not possible to attest from micro-level social infrastructure that these transformations impacted significantly on the social context of quarrying at this time (Bloxam 2007a, p. 13–14). In addition, there are no indicators of ownership or restricted access to the resource. Yet, it is possible to identify a continuity in inscribing of the landscape, particularly related to local gods and those that attest to symbolic links between silicified sandstone and the solar cults (Figure 10) (Bloxam 2007a, p. 7–11).

In essence, we get a sense of continuity even through periods when resource exploitation transformed the landscape quite significantly. We may be able to visualise this continuity through the inscribing of the landscape and from grinding stone production as key activities that linked people, perhaps in kin groups, with these places through ancestry. We may consider that restriction of access to this resource, rather than materially visible, was socially constructed via such groups over time (Bloxam 2007a, p. 13). As suggested, perhaps 'social restriction' may be embodied in the fact that the grinding stone production methods, their shape and other attributes imply continuity with little change over time, something that would not be expected if procurement was open to 'outsiders' or transformed into a monopolised industry (Figure 11).

The concept of a *'socially constructed landscape'* allows us to include all material remains of a landscape, even where authenticity has been compromised by

Figure 10. New Kingdom (2nd millennium BC) rock engravings: left image depicts a lion/lioness that can be associated with the wrath of the sun god. Right depiction of the baboon usually associated with solar worship. Khnum Quarries, Aswan West Bank.

later activities, to be historically significant. Today, artisan quarrying for local house building indicates that these resources remains important places (Figure 12), and although such low-key activities today may continue to impact on authenticity, it helps us visualise how the dynamics of this landscape extend into the present day. In sum, historical and informational value lies in the fact that the landscape's totality has no clear boundaries and it authenticates a rare 'storied' landscape, which at its core, tells us about human engagement with its natural resources from the earliest tool makers of the Lower–Middle Palaeolithic to the present.

Statement of significance: the Aswan West Bank

In drawing up a statement of significance for the Aswan West Bank, it is necessary to evaluate the outcomes of this assessment of historical and informational values in terms of scale. It is then possible to compare the landscape holistically with other known ancient quarry landscapes locally, nationally and internationally. Viewing the Aswan West Bank as a *'socially constructed landscape'* a strong case can be presented for the Aswan West Bank being of 'global' significance, as it represents a unique case in being the last known ancient quarry landscape where exploitation of a single resource can be characterised through deep time from the earliest tool makers. Key places across the landscape can be isolated that characterise this longevity, largely in terms of the grinding stone complex. If global historical and informational values can be attributed to an ancient quarry landscape, then the statement of significance would indicate to decision makers that there is a strong case for World Heritage nomination through UNESCO criteria of 'outstanding universal value' (see above and Bloxam 2007a, p. 15–18, where this is discussed further).

Value assessments by decision makers and stakeholders would be urged to take further this holistic view in terms of assessing economic, aesthetic and other values that fall in their domain. Moreover, in terms of the Aswan West Bank, World Heritage sites already exist in the locality to the south and east (see Storemyr et al. 2007, p. 179) and the importance of making efforts to expand these already existing boundaries northwards up to the Wadi Kubbaniya can be stressed. Although viewing the landscape in its totality is key to identifying global significance, key areas, or 'best project' can also be isolated where material remains and quarry complexes characterise historical and informational value in their own right. This is discussed below.

Contact landscapes

This concept has been designed to identify historical values of an ancient quarry landscape holistically due to its connections, via consumption of its products, with other places of historical significance. This concept can only be applicable if expert analyses can provide secure evidence of connection between the resource and the consumption of its products in a given depositional context. In relation to the Aswan West Bank, deploying the *'contact landscape'* concept would be problematic given that the source of silicified sandstone objects still needs further research.

The *'contact landscape'* concept can be

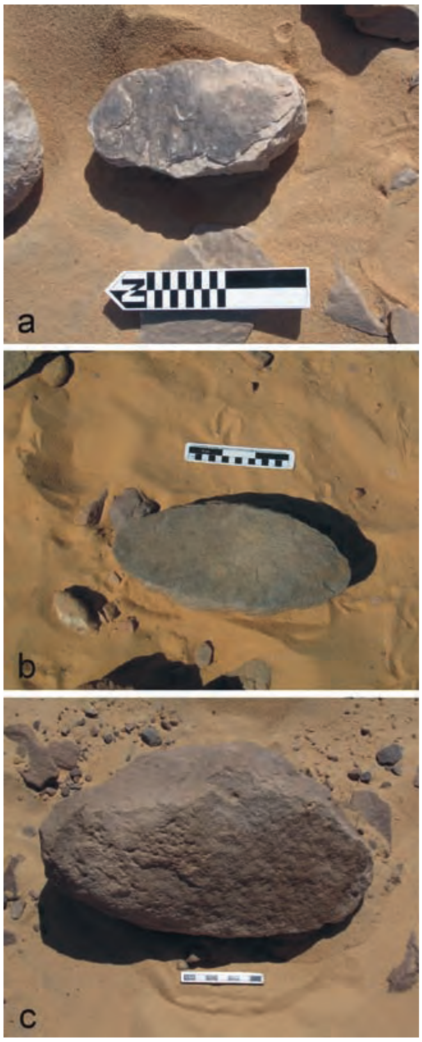

Figure 11. Grinding stone rough-outs: (a) Late Palaeolithic; (b) New Kingdom; (c) Ptolemaic–Roman Period.

Figure 12. Present-day artisan quarrying for house building on the Aswan West Bank.

applicable to ancient quarry landscapes where deposition of its products can be in close proximity to the resource, such as a city of major historical significance, and/or may have been incorporated into important monuments more distant from the resource. In addition, distribution of products may occur even further afield, as many quarry landscapes of antiquity became sources of stone that were distributed widely across the ancient world, and so we may say that they were at the epicentre of great trade systems (Bloxam and Heldal 2008, p. 142). This concept also takes a holistic approach to a quarry landscape, similar to *'socially constructed landscapes'*, and is particularly applicable when it is difficult to make a strong case for historical and informational values being attached to specific material remains therein. For instance, there may be scant if any remains that characterise the social context of quarrying and logistics. Or in other words, as opposed to the Aswan West Bank, the quarry landscape may not stand comparatively well in terms of a scale of values, either locally, nationally or internationally, in its own right.

Quarry landscapes in direct proximity to historically significant cities or monuments of antiquity may almost completely loose their identity and authenticity. In some instances, this is because they were almost entirely incorporated into the fabric of the historic city, or in others, totally eclipsed by their proximity to spectacular monumental sites such as the Giza Plateau Pyramids, or the city of Petra. However, in both instances, their proximity to such key monumental sites usually means they are protected and conserved by default, as they fall within the boundaries of such heritage sites. The quarries in the city of Sagalassos are typical examples of the former, where the few remains of the resource have been reused as foundations of later buildings and/or as structural walls (see Figure 3). Survey of the quarries at Sagalassos and their chronological use for building the city, has provided new perspectives for interpreting the city's evolution (Degryse 2007, Degryse et al. 2008, p. 281–287). Here, the extent to which these resources were consumed to create the city goes as far as incorporating spoil heap material into the construction of buildings, contributing further to the almost complete invisibility of some of the quarry complexes surrounding Sagalassos. Significantly, the resource was also consumed for an entirely different purpose, such as burials, whereby many of the building stone quarries take on the identity of necropolis that surround the city (Degryse et al. 2007, p. 19–20, Degryse et al. 2008, p. 272–276, 287–288). The burials are either directly into the resource, or sarcophagi were quarried from extracted blocks, used and deposited almost in the same context (Figure 13) (Degryse et al. 2007, 2008).

Statement of significance: Sagalassos

Within the concept of a *'contact landscape'* it is possible to make an historical and informational value assessment of the scant remains of the quarry complexes of Sagalassos within their broader context as being integral to the city. Importantly, such a statement would focus historical values where the idea of 'contact through consumption' has almost entirely consumed a stone resource. The few extant remains of the quarry complexes that sur-

Figure 13. Quarries transformed into burial places, Sagalassos, Turkey.

round the city authenticate and provide key historical and informational value as to how building of an ancient city, and burial of its dead, profoundly impacted on local resources over a relatively short time depth (appr. 700 years).

In assessing historical and informational values in terms of scale the task is less easy, as there are little comparative data from other quarry landscapes in Turkey. However, several Roman Period cities in Turkey, such as Termessos, also heavily exploited local resources for buildings and burials (Pekridou 1985, Roos 1985). Hence, the Sagalassos quarry complexes are not unique on a national or global scale, although they are representative of a specific type of 'contact through consumption' quarry landscape that is important at local and regional levels. It is also important to include the Sarıkaya quarries, located 5 km from the city, and which are part of the 'greater' Sagalassos quarry landscape, into any significance statement (Degryse et al. 2008, p. 279–281). Characterised by one large remaining quarry face (Degryse et al. 2008, p. 280) these quarries are also part of this *'contact landscape'* given that consumption included stone from this resource. Unlike the quarries immediately surrounding the city, the authenticity of Sarıkaya is gradually being compromised by modern agriculture. In terms of informational value, these quarries are key in determining the largely unknown 'internal' logistics within the greater Sagalassos quarry landscape.

Associative historical landscapes: the Aswan West Bank

As discussed earlier, it is necessary to find ways to connect quarry landscapes, or complexes within them, to key events of historical significance. 'Best projections' are vital to a statement of significance, particularly if a quarry landscape is under pressure from modern development.

The concept of an *'associative historical landscape'* can only be applicable where secure dateable contexts related to material remains exist. In addition, it is necessary to have other sources of information (from written sources) that can provide the contemporary historical backdrop to quarrying of the resource. Such information would largely have been assessed during micro-level interpretation (Bloxam and Heldal 2008, p. 19–112). As with the previous landscape concepts, *'associative historical landscapes'* might be applied to an ancient quarry landscape in its totality, but only if the material remains are largely related to one historical epoch. For example, in the Northern Faiyum (Caton-Thompson and Gardner 1934, Harrell and Bown 1995, Bloxam and Storemyr 2002, Bloxam 2003) and at Chephren's quarry in Upper Egypt (Engelbach 1933, 1938, Harrell and Brown 1994, Shaw and Bloxam 1999, Bloxam 2003), extensive quarry landscapes are largely related to Old Kingdom quarrying and so are key places where the transition to the early Egyptian state, characterised by monuments of global significance (the pyramids), can be associated with an almost revolution-like change to 'industrial-scale' quarrying at these places (Bloxam and Heldal 2007, Bloxam and Heldal 2008, p. 143).

For the purposes of this case study we shall return to the Aswan West Bank, because its multiple period and complex material remains present the most challenging example of how the concept of *'associative historical landscapes'* can work. Moreover, it provides an important case study into how to make 'best projections' of historical and informational values across such an extensive and complex landscape.

To make 'best projections' or define boundaries around complexes of material remains that need to be preserved over others, we need to be able to clearly assign historical and informational values to those that best authenticate and can be connected with historically significant events. The 'dynastic ornamental quarry complex' at Gebel Gulab and Khnum quarries is one area where we can demonstrate this, because they provide additional indirect evidence towards understanding a key transformative stage in the mid 2nd millennium BC.

The historical backdrop to early New Kingdom (18th Dynasty, 1550–1295 BC) quarrying for ornamental objects on the Aswan West Bank is set against the reign of Amenhotep III and his solarising of the major cults of Egypt. At this time, the king identified himself with the sun god Ra and became the key religious orthodoxy (Kozloff et al. 1992, p. 76, 110). The implications of this ideological and religious change had a direct connection with the explosion of silicified sandstone quarrying on the Aswan West Bank, due to the 'solar' symbolism attached to the stone's properties (Baines 2000, Quirke 2001, Bloxam 2007b). Arguably this reached a peak during the Amarna Period, where large-scale use of the stone led to the creation of some of the finest objects (Figure 14) (Bloxam 2007b, p. 44–45). The ancient quarries at Gebel Gulab and Khnum quarries specifically authenticate this New Kingdom explosion in ornamental stone quarrying in the form of partially finished objects, ceramic data, transport infrastructure and epigraphic data related to solar cults (Heldal et al. 2005, Bloxam et al. 2007, Bloxam and Heldal 2008, p. 127–129) (see Figure 1).

Figure 14. Head of Nefertiti in silicified sandstone, Amarna Period (New Kingdom 18th Dynasty). Egyptian Museum, Cairo.

After a brief hiatus, Seti I of the early 19th Dynasty (1294–1279 BC) reinitiated silicified sandstone quarrying for ornamental objects in his desire to model himself on Amenhotep III (Brand 2000, p. 128, 360). However, his ambitions to remove large objects from Gebel Gulab and Khnum quarries were never realised, given his early death after only 15 years as king. The remains left from this last episode of New Kingdom ornamental quarrying, particularly at Khnum quarries where an obelisk base and two partially worked statues and/or obelisks remain unfinished, lie as testament to these unfulfilled ambitions (Figure 15). Although this period of large-scale exploitation is only a minor blip (80 years) in the history of quarrying across the Aswan West Bank, it tells us about key historical changes that led to the laying down of the most highly visible infrastructure across the landscape.

What about the less visible material remains of ancient quarrying? In several areas across the Aswan West Bank there are other complexes of much more mundane and hard-to-see material remains where 'best projections' of historical and informational values should also be made. For instance, the earliest period of grinding stone production at Wadi Kubbaniya dating to the Late Palaeolithic. Particularly hard to visualise, these material remains authenticate and can be associated with a key transformative period in Egyptian prehistory linked to two main themes: the greater use of stone types in the manufacture of tools and a change in subsistence patterns that broadened from just hunting to include (wild) floral resources such as wild wheat, barley and nut-grass tubers (Wendorf and Schild 1989, p. 820–821). Some of the earliest known semipermanent settlements of this period where these subsistence changes occurred are located in the Wadi Kubbaniya (Figures 16 and 17). It is also here where we can associate how such transformations can be connected with a dramatic increase in silicified quarrying for the objects necessary to process these floral resources: grinding stones (Figure 18). Associated with the remains of one these earliest semipermanent settlements of the Late Palaeolithic (18,300–17,000 years ago), the exploitation of silicified sandstone sources 300 m away authenticate where the story of grinding stone quarrying across the West Bank began at this key phase in prehistory (Roubet 1989).

Statement of significance: the Aswan West Bank and 'best projections'

With reference to the 'dynastic ornamental stone complex' we can identify historical and informational values in two ways: first, in specific elements of mate-

Figure 15. Partially worked large object of the New Kingdom late 18th–early 19th Dynasty (Osirid statue or truncated obelisk) still attached to bedrock in Khnum quarries, Aswan West Bank.

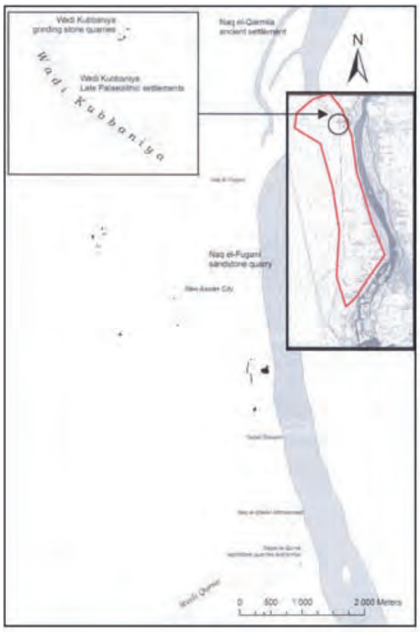

Figure 16. Main map shows location of the Late Palaeolithic settlement and associated grinding stone quarries in the Wadi Kubbaniya, Aswan West Bank. Inset map shows their location in terms of the Aswan West Bank ancient quarry landscape as a whole.

rial remains at a micro level; and second, within the complex as whole in terms of its historical significance at a macro level. For instance, at a micro level, historical and informational values would be specifically connected with the networks of quarry roads on and near Gebel Gulab. In terms of scale they would be of global importance, as they probably represent the best preserved examples of an ancient road system linked to quarrying from this period of the 2nd millennium BC. In addition, they form the most visible aspects of this quarry landscape. Hence, we could argue for global historical value and also informational value in what this road system would yield about still poorly known aspects of overland transportation at this time.

The quarries and social infrastructure, however, have comparable and in some cases better, material examples as observed in the granite quarries on the Aswan East Bank (Klemm and Klemm 1993, Klemm and Klemm 2008, p. 233–249, also see Kelany et al. 2009). Historical values may only occur at a local scale of importance, although as informational value, where direct connections between stone properties, symbolism and royal consumption in antiquity can be characterised, this would be at least of national importance. These 'best projections' and those assigned to other areas of material remains would then be combined with the assessment made holistically of the landscape. Figure 7 shows how these can be represented on an overall map. Thus providing decision makers with several planning options and onto which other values would then be added.

Dynamic landscapes

This concept is an approach to how we articulate historical and informational values of a quarry landscape where authentic material remains are almost completely integrated into modern developments, such as a city. Hence, the quarry landscape is characterised through elements linked to other purposes, such as buildings and how they occur across a 'cityscape'. It is possible, of course, to apply this concept to places such as Sagalassos, and at the other end of the scale to the Aswan West Bank, in terms of past and more recent reuse (Storemyr et al. 2007), and it is important to be aware that there are many contradictions when it comes to evaluating acts of destruction and reuse (Bloxam 2007c, p. 119–131). It is necessary to think about macro-level interpretation of quarry landscapes in terms of where authentic remains are almost totally compromised and to articulate and project historical and informational values onto the 'living' cultural landscape.

The quarry complexes surrounding Sagalassos were part of such dynamics in the past and it is possible to see that integration into the city 'frozen' in time, given that they are under protection by the antiquities organisation (Degryse 2007, p. 64–65). Use of the concept of *'dynamic landscapes'* provides a way of visualising such processes *in action* in, for example, modern cities that are still evolving. In some instances the way that buildings are located, sometimes irregularly across a city skyline, may indicate their placement inside or on top of disused quarries (see Figure 2). For instance in Ankara, creation of the city over time has almost completely obliterated traces of the andesite quarries that were the main sources of building stone (Caner-Saltık et al. 2007). In Old Ankara, andesite bedrock formed the foundations of the Citadel area, hence the quarries after use became part of the fabric of the city we see today.

Figure 17. Late Palaeolithic settlement remains in the Wadi Kubbaniya, Aswan West Bank, with grinding stone. Background: Late Palaeolithic grinding stone workshop situated in-between the low hills.

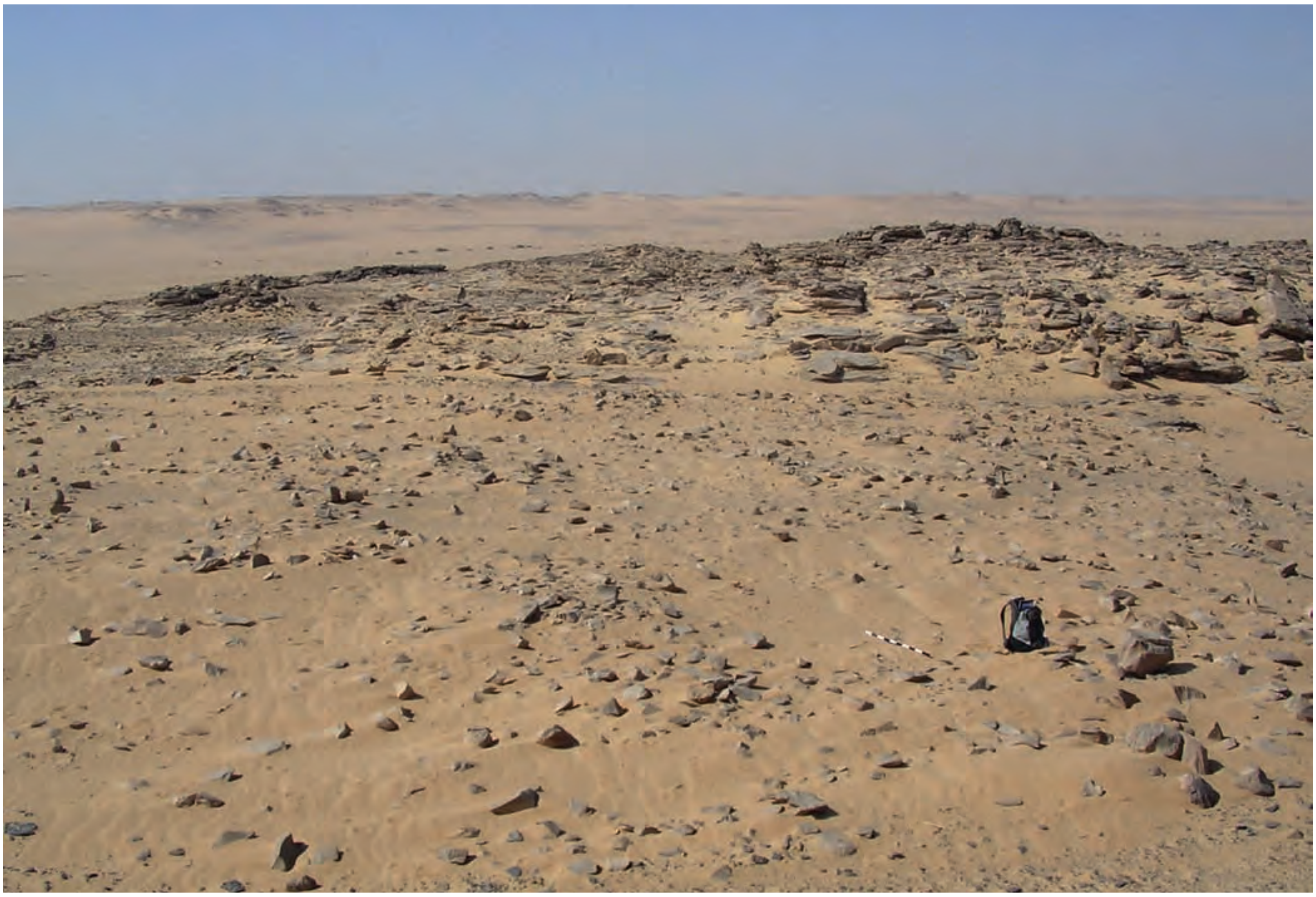

Figure 18. Late Palaeolithic grinding stone workshop, Wadi Kubbaniya, Aswan West Bank. Background: the settlement areas inside the Wadi Kubbaniya.

Statement of significance

The question remains as to how it would be possible to assign historical and informational values to quarry landscapes when there are no material remains at all? In the case of Ankara, historical value would be placed on how the use of resources reflects human agency over time, for example, how utilisation of the local resources characterise the fabric of the modern city, even down to colour. Arguably, this would be an expert value in terms of aesthetics. In addition, historical and informational values should also reflect ingenuity over past generations of builders who recognised 'extinct' quarry complexes as valuable foundations for the buildings we see today. As mentioned above, there may be some contradiction here in terms of placing 'values' onto destructive actions of historical remains, as would be expected in such circumstances. Yet, in Ankara, as opposed to places such as Sagalassos, there is perhaps a vision of what *may* have happened to a quarry landscape (in a *'contact landscape'* perspective) where consumption of a primary resource in close proximity to a city that was not abandoned.

Hence, we also have informational value in terms of how we compare cities of the past that were abandoned, with cities of today. In terms of scale, Ankara as a major capital is of global significance, but in terms of integration of quarry complexes into its fabric in a present-day cityscape then this is not unique, but nevertheless representative at a national level of importance. Moreover, we have to articulate that 'lost' quarry landscapes of the past make up far more of our modern cities and towns than realised, and in some instances their layout may be directly attributed to the extinct quarries they may lie on top of.

Concluding remarks

The objective of this paper has been to review a methodology, developed during the QuarryScapes project, that can be used to identify the significance of ancient quarry landscapes to decision makers, heritage authorities and a wider public. It has looked at ways in which assigning historical and informational values, from an expert perspective, may be applied to ancient quarry landscapes and how developing a theoretical screen using 'four concepts of landscape' can aid in the articulation of significance. These concepts have been designed to assist visualisation of at worst the invisible, and at best, often confusing sets of material remains within their broader historical context. The information provided in a 'statement of significance' in relation to an ancient quarry landscape in terms of a scale of values, would then be integrated into other frameworks of value assessment.

These macro-level concepts of landscape allow us to take both a holistic view of an ancient quarry landscape and also to 'best project' where historical and informational values may be attached to specific material remains within the landscape. Best projections being a planning tool used by decision makers when landscapes are under pressure from modern development. Yet, it is important to stress that the idea is *not* to 'squeeze' quarry complexes into just one type of macro-level assessment but rather, as the case studies demonstrate, deploy the concepts that are most relevant to the material remains that one may be dealing with (see Bloxam and Heldal 2008, p. 147, Table 36). Moreover, such macro-level perspectives can also help experts recognise historical and informational values in ways that may not have been previously realised and so enable a feedback mechanism onto the micro-level remains. In essence, a methodology for macro-level interpretation always needs to be reassessed and should be flexible if it aims to be transferable across the ranges of ancient quarry landscapes and their locations.

Some may argue that applying this methodology to put across historical and informational values 'glosses over' other key areas of significance of ancient quarries, particularly related to technologies. However, this view may miss the point when it comes to engaging the broader public in the debate as to why ancient quarry landscapes should be seen as an important cultural heritage. What this methodology can allow us to do is separate the scientific specifics of ancient quarries that are largely of interest to us, from the bigger story of significance that they may collectively convey. Moreover, comparative analysis of ancient quarry landscapes to assess a scale of values at local, national and international levels gives us the means to identify if global significance can be applied. Hence, the development and use of this method might assist not only in registering and protecting more of these landscapes as archaeological sites, but even help in some instances to build a case for World Heritage status.

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