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1. Introduction

PAUL T. NICHOLSON AND IAN SHAW

During the last two decades the nature of Egyptology has gradually changed, and new technological and socio-economic questions are now being asked of the archaeological data. With this change has come a renewed interest in many aspects of Egyptian materials and technology. So great has this interest become that it is no longer possible for the traditional Egyptologist alone to tackle such questions as the composition of materials, provenance and the means by which different types of artefacts were produced. Many new analytical techniques have been developed and applied and the results are now available, providing a great deal more precision than was previously imaginable.

These new approaches currently being adopted in Egyptology are reflected in the structure of this book. Each chapter has been written by one or more specialists, drawing not only on conventional Egyptological skills but also on expertise in the natural sciences as applied to archaeological data. All the contributors are either involved in recent field projects in Egypt (not least the important Egypt Exploration Society excavations at Amarna and Memphis), or at the forefront of laboratory-based analysis of archaeological materials.

It will be obvious to many readers that this volume has been inspired by Alfred Lucas's classic work *Ancient Egyptian Materials and Industries*, which has long served Egyptologists as a standard work of reference. First published in 1926, Lucas's book has been revised several times, most recently in 1962, when it was updated, primarily in terms of its bibliographic references, by J.R. Harris (see Lucas 1926, 1934, 1948, 1962). Even the fourth edition still primarily reflects the analytical work of a single individual employing the necessarily limited equipment available in the 1920s (see Brunton 1947 and Gilberg 1997 for assessments of the life and work of Alfred Lucas). Despite the importance of Lucas's work, it has long been recognised that a more modern multi-disciplinary treatment is required, giving not only the result of analyses and technological investigations but also explicitly stating the means by which they were obtained.

While this current volume will not 'replace' Lucas's work, and is not intended as a revised edition of it, it is hoped that it will provide a free-standing source of reference on its subject. Thanks to modern analytical techniques, some chapters will almost entirely supersede those provided by Lucas, while others will provide updated approaches concentrating on new data and new questions. The study of ancient Egyptian material and technology is a vibrant one, with research being conducted by many scholars all over the world (a situation reflected in the diverse list of contributors here). This is quite unlike the situation in the 1920s and 1930s, when most Egyptologists were interested in linguistic and architectural questions, and Lucas was one of a relatively small group of scholars concerned with the analysis of artefacts. As a result of the new vigour of the subject, this volume will perhaps not enjoy the very long currency of Lucas's work but will, we hope, provide a solid basis for future work.

Here we are fundamentally concerned with the study of the procurement and processing of the raw materials employed by the ancient Egyptians. The book is not meant to be an art historical typology of objects produced in any given material, nor a text book on the scientific analysis of such materials. Each chapter is intended to provide an overview of the current state of research on the material in question. In some cases, this is not possible, either because modern research on certain materials (e.g. leather, meat, basketry) has only just begun or because the quantity of data has become so great in recent years that the most meaningful approaches tend to be those that focus on particular problems (as in the case of the chapters on pottery, stone and mummies).

The basic structure and coverage of the book were finalised at a seminar involving most of the contributors in 1994, when it was agreed that chapters on food technology should be included, as these represent a fruitful area of research that has almost entirely emerged in the years since Lucas's time. The contributors have made every effort to provide explicit information on the scientific analyses conducted, since the lack of such detail has been an increasing problem in judging the value of some of Lucas's conclusions. It was also agreed that some indication of the workings and limitations of relevant analytical techniques was necessary so that non-specialists would be better able to judge the results of earlier and current research.

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Part I.
Inorganic materials

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2. Stone

BARBARA G. ASTON, JAMES A. HARRELL AND IAN SHAW

Introduction

Although most recent research into Egyptian quarrying has tended to concentrate on the large-scale procurement of limestone, sandstone and granite in the Pharaonic period, the exploitation of stone in the Nile valley can be traced back at least as early as 40,000 BP, when the Middle Palaeolithic inhabitants of Middle Egypt were quarrying and working cobbles of chert along the limestone terraces on either side of the Nile (Vermeersch *et al.* 1990). Most of the earliest sites simply consist of pits and trenches for surface extraction, but Site 4 at Nazlet Khater, dating to the Upper Palaeolithic and radiocarbon-dated to 35,000– 30,000 BP, includes vertical shafts and underground galleries which provide a foretaste of the fully developed quarrying techniques of the Pharaonic period. The early chert quarriers used gazelle and hartebeest horns as picks, and several of these were found in the subterranean galleries at Nazlat Khater 4. The excavations also revealed many large hammerstones, apparently used for rougher quarrying.

The prehistoric quarrying of such materials as chert was essentially a question of small communities procuring locally available materials in order to produce the tools and weapons necessary for their immediate needs. Although there is evidence to show that such *ad hoc*, small-scale quarrying and mining continued to be undertaken to some extent in the Pharaonic period, in the case of certain materials (e.g. alabaster gypsum at Umm el-Sawwan, galena at Gebel Zeit and perhaps also New Kingdom procurement of travertine at Hatnub, see Kemp 1989: 191, 246–8; Castel and Soukiassian 1985, 1989; Shaw 1994: 111–14), such stones as granite, limestone and gneiss began to be exploited on a large scale for building, sculpture and stone-vessel carving. These large-scale expeditions differed in a number of ways from the quarrying undertaken by small groups of individuals: first they were official operations controlled either by the king or a local provincial governor, secondly they were often commemorated by the creation of rock-carvings and hieroglyphic inscriptions at the quarries themselves, and thirdly a new ideological and political element gradually emerged, whereby the king seems to have exercised a virtual monopoly on the quarrying and mining of many raw materials. The king was able to use this monopoly not only as a means of rewarding officials (by granting them blocks of freshly quarried stone to be carved into sarcophagi or false doors, for instance, see Lichtheim 1973: 18–23) but also as a means of gaining favour with the god's. The reliefs and inscriptions in the treasuries of some of the major Greco-Roman temples indicate that the god's shrine was intended to be a microcosm of the universe, including all the essential vegetable and mineral components (see Aufrère 1991: 731–48, 809–20; Shaw 1998: 253–6). There was therefore not only a practical impetus for mining and quarrying in terms of the acquisition of materials necessary for the creation of temples, tombs and funerary equipment, but also an ideological spur, in that the king was obliged to 'recreate' the cosmos by gathering together its fundamental elements and placing them in the temple treasuries (e.g. the use of black basalt to create temple pavements symbolising the fertile silt of the Nile valley).

The first section of this chapter discusses the general evidence for quarrying, primary processing and transportation of different types of stone in the Pharaonic period. In the second section, specific quarries of the Pharaonic, Ptolemaic and Roman periods are described in the form of an alphabetically arranged list of the various stone types. The third section comprises a short summary of research into ancient Egyptian stone-working technology. The fourth section summarises the current state of the subject in terms of techniques of identification and provenancing of stone.

Quarrying, *in situ* processing and transportation

The creation of the first tombs incorporating stone masonry, in the Early Dynastic élite cemeteries at Abydos and Saqqara (*c.* 3000–2649 BC), was the stimulus for a rapid growth in the quarrying of building stone such as limestone and granite. At the same time, the growing need for tombs to be filled with stone vessels symbolising the wealth of the deceased led to the large-scale procurement of such materials as travertine, alabaster gypsum, limestone breccia, basalt, limestone, granite, granodiorite, greywacke, sandstone, siltstone, andesite porphyry, serpentinite, tuff and anorthosite gneiss, which were the preferred materials for funerary vessels in the Early Dynastic period. It is clear from the jewellery found in some of the First-Dynasty tombs (particularly that of King Djer at Abydos) that such gemstones as turquoise and cornelian were also being heavily exploited in the first two Dynasties (and probably considerably earlier, see Beit-Arieh 1980), along with the various precious metals obtained from the Eastern Desert, the Sinai peninsula and Nubia.

During the Old Kingdom (*c.* 2649–2152 BC), the construction of numerous royal pyramid complexes in the Memphite necropolis resulted in an unprecedented demand for stone which probably peaked in the Fourth Dynasty, when the largest pyramids were built. Lehner (1985: 109) calculates that 9 million tons of limestone alone were quarried between the reigns of Sneferu and Menkaura for the pyramid complexes at Dahshur and Giza. It was also at this time that many other stones began to be exploited on a large scale for buildings: granite and granodiorite from Aswan, basalt from the Fayum and travertine from Middle Egypt.

Soft-stone quarrying methods

The vast majority of quarrying during the Pharaonic period was concerned with the procurement of the two principal 'soft stones' used for ceremonial, religious or funerary structures: limestone and sandstone (the quarries for which are discussed below). Limestone, virtually all deposits of which are found at numerous locations between Cairo and Esna, was exploited from the end of the Early Dynastic period until the Eighteenth Dynasty (after which its importance as a building stone went into decline). Sandstone, on the other hand, is found in Upper Egypt, from Esna down to Sudan, and was used in the south from the Eleventh Dynasty onwards. Most of the important surviving temples of the period between the Eighteenth Dynasty and the Roman period were constructed from sandstone.

Outcrops of limestone and sandstone most suitable for quarrying were those having a uniform colouration and fine texture, at least moderate hardness and thick layers with widely spaced vertical fractures. The ancient quarrymen would identify a single rock layer (or series of layers) with the requisite properties and then quarry it at one or more places along the margins of the Nile valley, wherever it was best developed. In many cases it was the quality of the rock rather than its accessibility that dictated where a quarry was located. This is evident from the fact that many ancient quarries are found on the upper slopes of hills and escarpments rather than at their base, where similar but lower quality rock occurs.

Blocks of sandstone and limestone were extracted by the following means, more than one of which might sometimes be combined in one quarry:

(1) large open excavations;
(2) the removal of the vertical faces or horizontal tops of cliffs; and
(3) the excavation of deep adits and galleries (usually in order to reach the best quality rock).

All three of these methods were used for limestone and travertine. However, with the exception of some Middle Kingdom galleries in part of the Gebel el-Silsila sandstone quarry, all sandstone and hardstone quarries were 'open-cut' (i.e. not of the gallery type).

The open-cut process generally comprised a number of stages, beginning with the removal of surface material such as sand or rubble. The next step usually consisted of the marking of the cleaned surface either with painted lines or sequences of chisel-cut indentations in order to indicate where the rows of blocks were to be cut out (each separated from the next by a trench ranging from at least 20 to 60 cm in width, depending on the sizes of the blocks). These trenches were then excavated to a depth which was usually at least 30 cm below the bases of the blocks, thus leaving rows of rock stumps, as in the case of the limestone quarry beside the Fourth-Dynasty pyramid of Khafra at Giza.

In the case of limestone and travertine, the removal of blocks from a vertical cliff face was sometimes the first stage in a process of deeper gallery-style extraction (see Owen and Kemp 1994 for a discussion of the common ground between the excavation of rock-tombs and quarries at Amarna), usually when the better quality stone was covered by an upper layer of poorer quality material. The initial face would be scaled by a series of steps cut into the outer face of the rock. The workers would then carve out a corridor along the ceiling of the gallery, thus allowing them to cut down behind the front row of blocks, detaching rows of blocks from the top downwards, gradually moving backwards deeper into the gallery.

Hard-stone quarrying methods

Of all the hard stones available in Pharaonic Egypt, granite and granodiorite were the only ones that were used for building purposes on anything like the scale of limestone and sandstone. The granite quarries at Aswan, which were exploited from the First Dynasty onwards, are the only hard-stone quarries that have been studied in any detail (e.g. Clarke and Engelbach 1930; Röder 1965; Arnold 1991: 36–40; see Fig. 2.3), although there have been recent detailed studies of both quartzite and gneiss quarrying (see Klemm *et al.* 1984 and Stross *et al.* 1988 for quartzite, and Harrell and Brown 1994 for gneiss). On the basis of surviving buildings and other monuments, Röder (1965) estimates that 45,000 cubic metres of stone were removed from the Aswan quarries in the Old Kingdom, when it seems likely that the loose boulders spread across the surface would have been exploited (Reisner 1931: 71). It was in the New Kingdom, however, that the largest quantities of granite seem to have been quarried, including numerous Eighteenth- and Nineteenth-Dynasty colossal statues and obelisks.

Undoubtedly the most important source of knowledge on granite quarrying is the so-called 'unfinished obelisk', which is located in the northern quarries (a few kilometres to the southeast of the centre of modern Aswan; see Fig. 2.4) and probably dates to the 18th Dynasty (see Engelbach 1922; Habachi 1960; Arnold 1991: 37–9). Work on this obelisk, nearly forty-two metres in length, was abandoned at a relatively late stage in the process of its extraction, when significant cracking became apparent. After removing the weathered upper layers of the granite, a trench was excavated, thus marking out the shape of the obelisk, still attached to the bedrock. The surrounding trench has a width of about 0.75 metres and is divided into a series of 0.6–metre-wide working areas (marked out by vertical red lines down the side of the trench), which would have been able to accommodate as many as fifty workmen around the obelisk at any one time. It is clear from the surviving marks made by the quarry-overseers on quarry-faces at Aswan, that the depth of each trench was regularly assessed by lowering a cubit rod into it and marking the top of the rod with a triangle. Once the trench had reached the necessary depth, the workers would gradually undercut the block, a process which was just beginning in the case of the unfinished obelisk. Finally, in order to move the quarried obelisk from its matrix, one end would have to be quarried out completely, thus allowing the obelisk to be pushed horizontally out (a considerably easier task than attempting to pull it vertically upwards out of the hole).

Quarrying tools

There is some uncertainty as to the kinds of tools used for the quarrying of soft stones during the Pharaonic period (see Arnold 1991: 33). The tool marks preserved on quarry walls suggest that some form of pointed pick or axe was used during the Old and Middle Kingdoms, followed by the use of a mallet-driven pointed chisel from the Eighteenth Dynasty onwards (Klemm 1988). In the case of a small number of blocks, a very large stone chisel seems to have been used, judging from the presence of 2.5 cm-wide grooves (see Arnold 1987: pls. 9d and 33b). R. and D. Klemm argue that the majority of the tool marks were made by soft copper chisels in the Old and Middle Kingdoms and harder copper or bronze chisels from the New Kingdom onwards (with the characteristic patterns possibly allowing specific chronological phases to be identified, e.g. a herringbone sequence of marks in the Eighteenth Dynasty). There appear, however, to be at least two problems with the Klemms' proposed sequence of copper tools: firstly the actual surviving chisels (albeit found at construction sites rather than quarries) tend to have a broad, flat cutting edge rather than a point, and secondly the harder forms of copper alloy were already available in the Old and Middle Kingdoms (see Chapter 6, this volume). Chert was also used for stone-working (for further discussion see section on the uses of chert below).

The question of the types of tools used for the extraction of granite and other hard stones is equally controversial. On the basis of long sequences of rectangular wedge holes at the Aswan quarries (see Fig. 2.5), it was once assumed that the granite was removed by inserting wetted wooden wedges into the holes and levering the blocks away from the bedrock. There are now two fundamental objections to this theory: first, that wooden wedges, even when expanded by soaking them in water, would almost certainly not have been strong enough to fracture the granite (although for an extremely laborious but successful attempt see Zuber 1956: 202), and secondly, that the wedge holes have never been dated any earlier than the Ptolemaic period, by which time iron wedges would have been available (Röder 1965). Judging from various studies of the quarries at Aswan (Arnold 1991: 37–9; Aston 1994: 15–18, fig. 6; Engelbach 1922, 1923; Klemm and Klemm 1993: 305–53; Zuber 1956) and the implications of experimental projects (Stocks 1986a, 1986b; Zuber 1956), the actual process of extraction in the Pharaonic period seems to have involved the excavation of open-cut quarries, using hammerstones (e.g. dolerite) to gradually remove the stone from the surface downwards.

There are at least three other instances of extraction marks left by pounders in Egyptian quarries. In the quartzite quarry at Gebel Gulab (on the west bank at Aswan), a broken obelisk inscribed with the name of the Nineteenth-Dynasty ruler Seti I survives *in situ* near the quarry-face from which it was extracted (see Habachi 1960: 225–32; see also Fig. 2.6). The quarry face shows definite traces of the use of stone pounders. The second instance is to be found at Qau el-Kebir, where Clarke and Engelbach (1930: 18) noted marks left by stone pounders in a limestone quarry characterised by unusually dense, hard rock. The third piece of evidence for extraction with pounders is a set of marks in the greywacke sandstone–siltstone quarry at Wadi Hammamat, which were photographed by Klemm and Klemm (1993: 414) and may well date to the Pharaonic period.

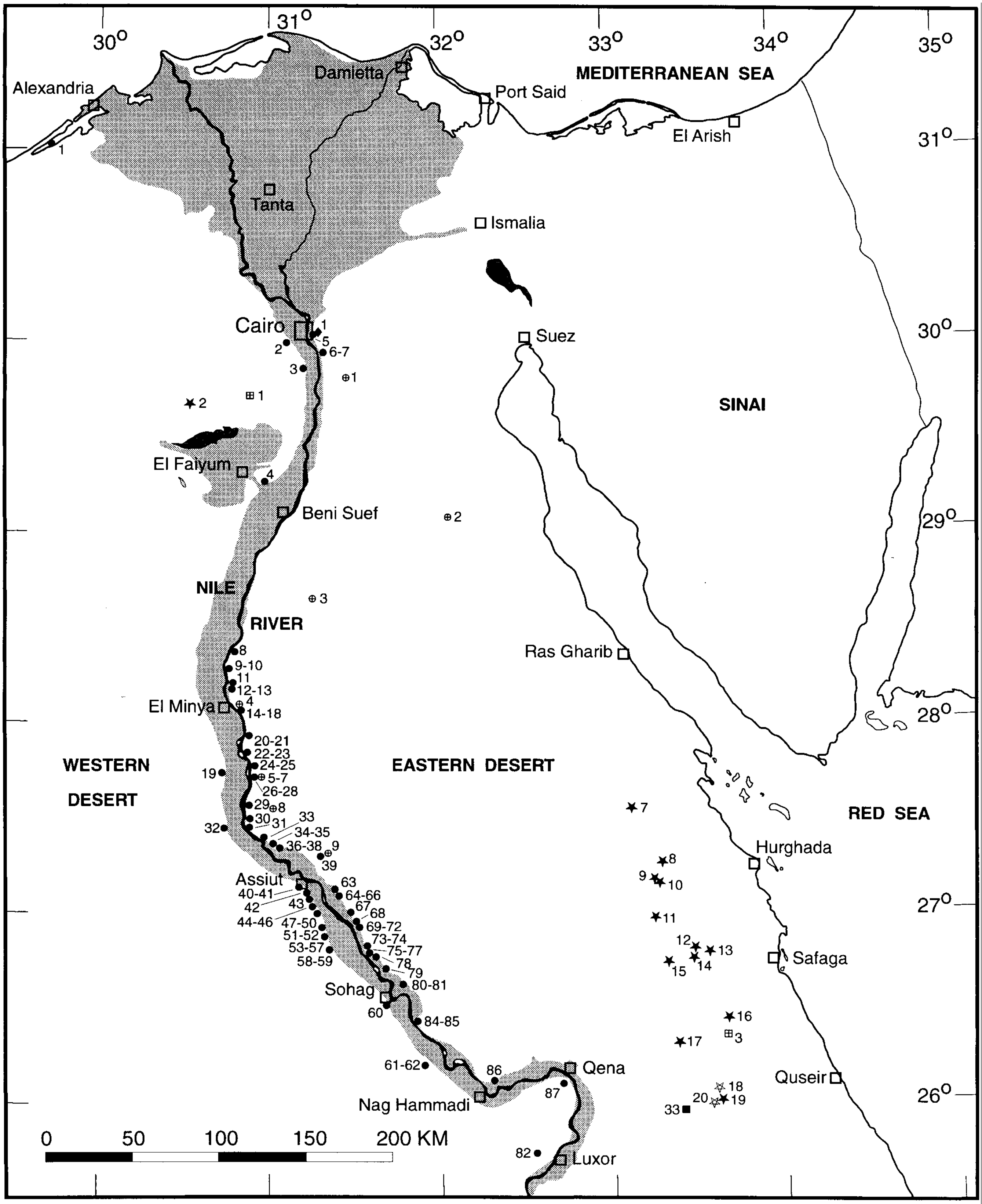

Figure 2.1 *Map of Egypt from (a) Luxor to the Mediterranean and (b) Kerma to Luxor, showing locations of the known ancient hard-stone and soft-stone quarries.*

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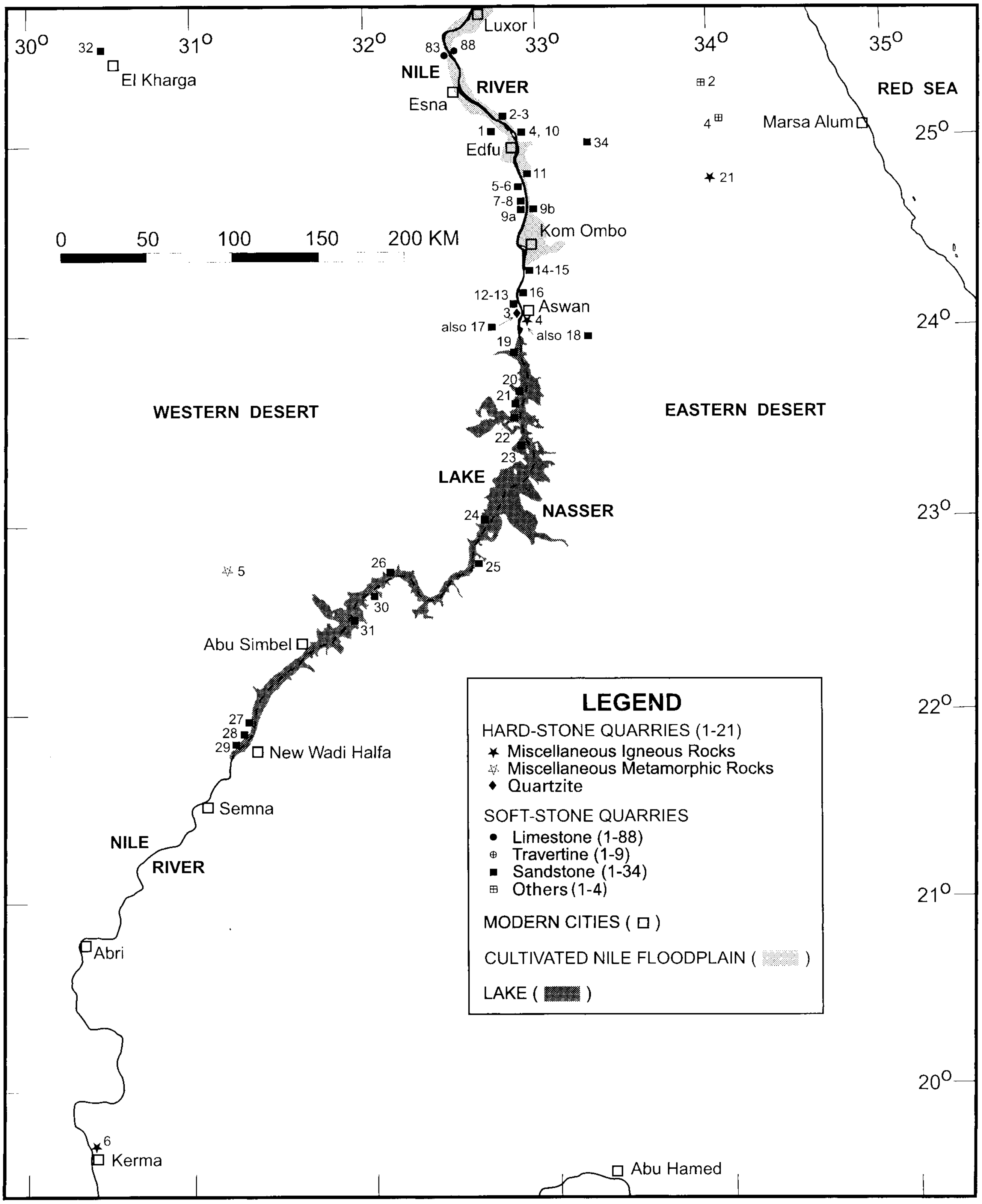


(b)

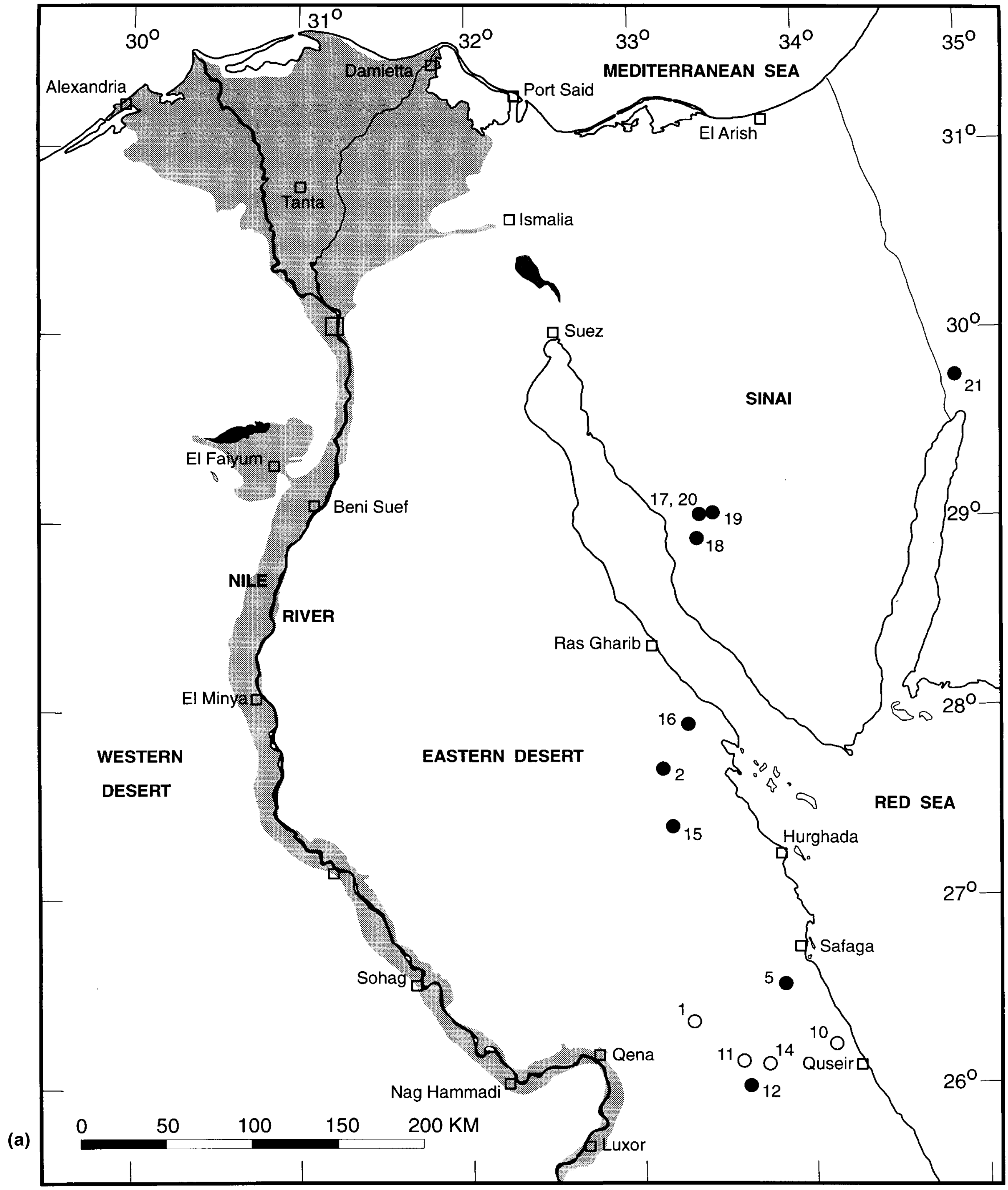
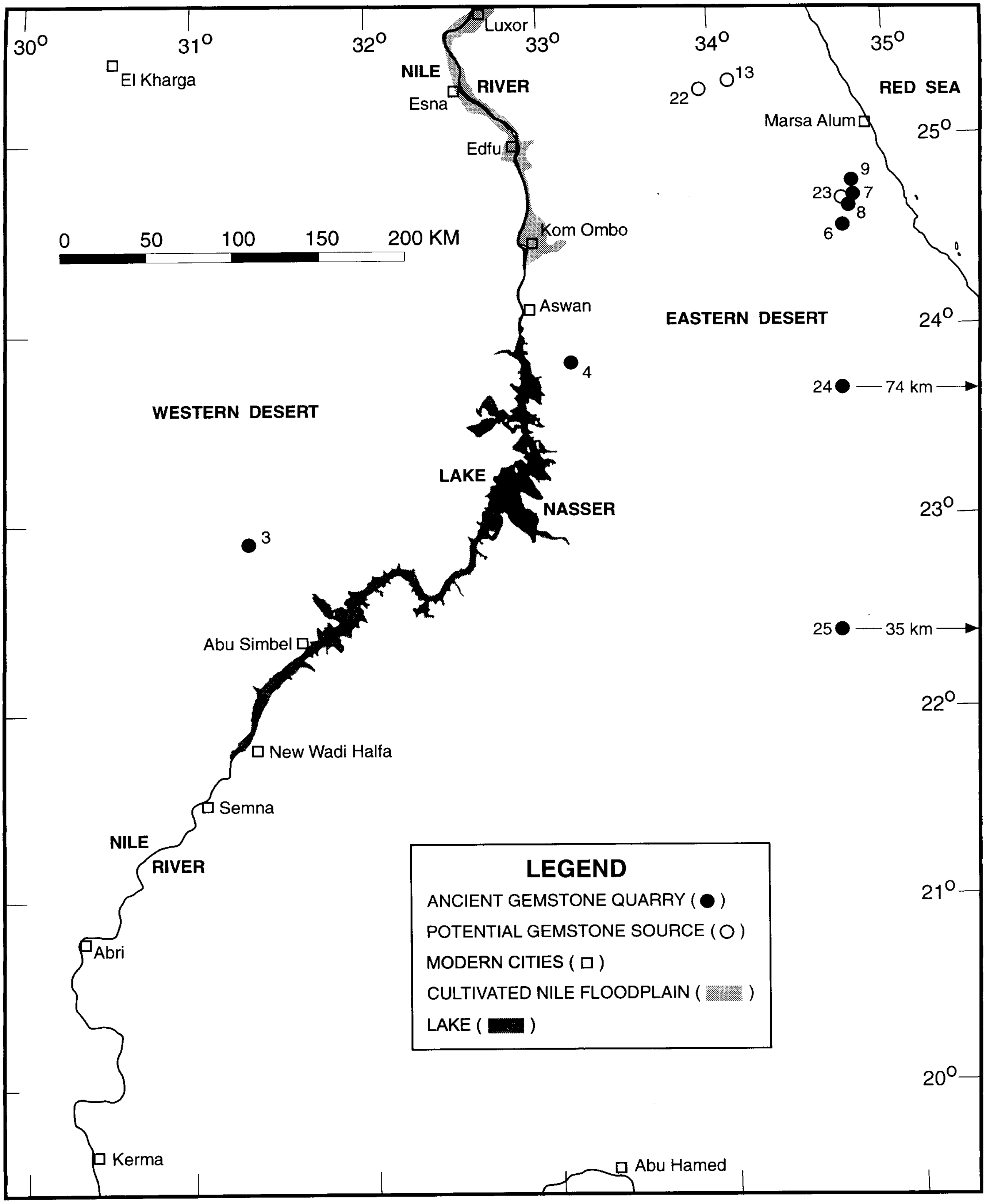


Figure 2.2 Map of Egypt from (a) Luxor to the Mediterranean and (b) Kerma to Luxor, showing locations of quarries and probable ancient sources of gemstones.


30°
31°
32°
33°
34°
35°
Luxor
El Kharga
NILE
RIVER
Esna
22
13
RED SEA
Marsa Alum
25°
Edfu
9
23
7
8
6
0 50 100 150 200 KM
Kom Ombo
Aswan
EASTERN DESERT
24°
4
24
74 km
WESTERN DESERT
LAKE
NASSER
23°
3
Abu Simbel
25
35 km
22°
New Wadi Halfa
Semna
NILE
RIVER
LEGEND
ANCIENT GEMSTONE QUARRY (●)
POTENTIAL GEMSTONE SOURCE (○)
MODERN CITIES (□)
CULTIVATED NILE FLOODPLAIN ( )
LAKE ( )
21°
Abri
20°
Kerma
Abu Hamed

(b)