

11/9/08

**PHARAONIC NECROSTRATIGRAPHY: A REVIEW OF GEOLOGICAL AND  
ARCHEOLOGICAL STUDIES IN THE THEBAN NECROPOLIS, LUXOR, WEST  
BANK, EGYPT**

by

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11/9/08

## **ABSTRACT**

We present a review of archeological and geological studies on the West Bank as a basis for discussing the geological setting of the tombs and geologically related problems with a view to providing archeologists with a framework in which to conduct their investigations on the restoration, preservation and management of the antique monuments. Whereas the geology of the Upper Nile Valley appears to be deceptively simple, the lithologic succession is vertically variable, and we have recognized and defined several new lithologic units within the upper Esna Shale Formation. We have been able to delineate lithologic (shale/limestone) contacts in several tombs and observed that the main chambers in some were excavated below the Esna Shale in the Tarawan Chalk Formation. We have been able to document changing dip in the strata (warping) in several tombs, and to delineate two major orientations of fractures in the field. Investigations behind the Temple of Hatshepsut, in the Valley of the Kings and around Deir El Medina, have revealed four broad regional structures. We confirm that the hills located near the Nile Valley, such as Sheik Abel Qurna, do not belong to the tabular structure of the Theban Mountain, but are discrete displaced blocks of the Thebes Limestone and overlying El Miniya, as supported by Google Earth photographs.

## **INTRODUCTION**

The royal dynastic civilization of Ancient Egypt was established over 5000 years ago. It had a considerable influence on contemporaneous Mediterranean societies, as well as those of Greece and Rome even though by then (<500 BCE) it was on the decline. Known during the Dark Ages only from texts written by Greek and Roman travelers, its legacy to our western world is being slowly rediscovered (e.g., DesRoches de Noblecourt, 2006).

In the 16<sup>th</sup> century BCE Egyptian rulers moved their capital from Memphis to Thebes on the West Bank of the Nile. Then, for nearly 500 years, following the initiative of the great Queen Hatshepsut, the pharaohs of the 18<sup>th</sup>–20<sup>th</sup> Dynasties (ca 1539-1075 BCE) ordered their tombs to be excavated into the limestones and shales of the Theban Mountain (Fig. 1), away from the funerary temples built on the nearby floodplain, where religious rituals were regularly celebrated.

11/9/08

Forgotten for over 1000 years following the Arab invasion (639AD) of the country, the legacy of ancient Egypt was rediscovered during 1707-1726 by Father Claude Siccard, a Jesuit priest who recognized in the ruins he visited the beautiful monuments that the Greek historian Diodorus (1<sup>st</sup> Century BC) and the Roman writer Strabo (63 BC- 24AD) had celebrated. He rediscovered Thebes and the Valley of the Kings, and described what he saw. Subsequent visitors, such as Richard Pococke in 1743 and James Bruce in 1768, continued to report on the Valley, making maps and sketching the drawings that adorned the walls of opened tombs.

It was the *Description de l’Egypte* (1809-1822), prepared by over 100 scientists and artists who accompanied Napoleon I on his “invasion” of Egypt (1799-1802), that revealed the grandeur of the by-gone Egyptian civilization (e.g., Gillispie, 1994). With copious text and numerous drawings of the monuments and tombs and their hieroglyphic inscriptions and representations, the Emperor’s scientists opened the world of the New Kingdom at Thebes to an incredulous Europe. This encyclopedic work was to fire the imagination of Europeans, and many a person with means traveled to Egypt, some in large parties (e.g., Romer, 1846; Russell, 1869) others as isolated travelers (e.g., Edwards, 1993; Bruwier, M.-C., 2005).

As the *Description* was being written, antique objects were also collected; and thus began a period of active collecting for the benefit of European museums and private collectors. Tombs in the Valley of the Kings were plundered of the artistic wealth that had not already been removed in antique times by local thieves. Between 1817 when Giovanni Battista Belzoni set out for the Valley of the Kings until 1857 when the export of antiquities was finally legislated, statues, jewelry, whole sarcophagi, mummies, mortuary furniture, cut pieces of decorated walls, papyri were removed from the tombs by avid explorers encouraged and protected by Europeans consulates and Pasha Mohammed Ali himself. Egyptian antiquities were exhibited in European museums, exchanged as ransom of wars (such as the Rosetta stone), or sold to private collectors.

In the wake of the French abandonment of Egypt came the victorious English led by William Hamilton, then secretary to the British Ambassador in Istanbul, Lord Elgin—he of the Athenian/Parthenon [Elgin] Marbles notoriety. With the translation by Champollion (between

11/9/08

1822 and 1832) of the hieroglyphic scripts engraved on the Rosetta Stone, Egyptology was born and the way was open for serious scholarship on the pharaonic monuments; this was to begin essentially a decade after the imposition of absolute rule by the Ottoman Turkish army led by an Albanian commander Mohammed Ali who routed and expelled the Mamelukes/Arabs in 1807. The solitary John Gardner Wilkinson (between 1820 and 1833) became interested in the Valley of the Kings for what its tombs would reveal of the antique civilization that produced them. He conducted a systematic survey of the known tombs, established a numbering system still in use today, which associated a tomb number in the Valley of the Kings (KV) to its king and dynasty. France, Prussia, Tuscany began to support scientific expeditions to Egypt, and organized excavation began in earnest. However, with the demand of European museums for additional antiques increasing, the support of Mohamed Ali for the export of the antiquities, the ever-increasing number of curious visitors to the Valley of the Kings, and the lack of infrastructure to supervise nascent tourism, the tombs began to deteriorate seriously. Luxor had become a tourist destination by 1840, but offered no protection of its antique treasures.

The first successful efforts at protecting Egyptian Antiquities were by Auguste Mariette in 1857 who established a service of the Antiquities in Cairo, built a museum there, saw to the end of the market of Egyptian Antiquities, and ensured that no further desecration and vandalism would occur in the royal tombs. Above all, Mariette demanded that the monuments—and the civilization that they represented—be respected. The subsequent discoveries of remarkable tombs, such as those of Hatshepsut (KV20) and Tuthmosis IV (KV43) by Howard Carter in 1903, and ultimately, Tutankhamen (KV62) by Howard Carter in 1922, brought ancient Egypt to the forefront of the archeological community where it has remained ever since. At the same time as John Romer (1978) established a master plan (Theban Mapping Project) for the Valley of the Kings and the whole Theban Necropolis, UNESCO (1979) designated it part of the World Heritage. Since then, a considerable effort under the auspices of UNESCO, national funding agencies, and private benefactors, has been devoted to the restoration of the royal tombs. Early on, this effort triggered specialized conferences (e.g., Wilkinson, ed., 1995), publications and numerous (unpublished) reports addressing climatic, geological and geotechnical problems associated with their restoration. The geological and geomorphologic settings of the Valley were described and their impacts on the deterioration of the tombs were analyzed (Curtis, 1979, 1995;

11/9/08

Curtis and Rutherford, 1981, Monaghan, 1979; Rutherford et al., 1977; Rutherford, 1995). Great attention was given to the devastation induced by recurrent flash floods (Romer, 1977; Weeks, 1995).

Noteworthy among these early studies are those of 1) Curtis (1977) who recognized the large scale slumps along the Theban cliffs, and the occurrence of normal faults, among which the “Valley of the Kings Fault” (his denomination) striking north-south with a displacement of ~ 30 m; and 2) Rutherford et al. (1977) and Rutherford (1995) who described in detail the agents of tomb damage. These seminal studies made possible subsequent investigations that now focus either on the agents of deterioration (e.g., McLane and Wüst, 2000; Wüst and Schlucher, 2000), or on the conservation of specific tombs, as exemplified by the study of KV22 (Amenophis III) by Yoshimura and Kondo (Eds, 2004). Today, an unprecedented effort is being made towards the restoration, conservation and management of the monuments of the Theban Mountain. Tombs are being emptied of the flood debris that had accumulated over the centuries; their walls, ceilings and pillars are being stabilized; where possible, the wall paintings are being restored. To cite a few examples: KV22 (Amenophis III): Yoshimura and Kondo (2004), KV5 (Tombs of the Sons of Rameses): Weeks (2006), KV7 (Tomb of Rameses II): LeBlanc (1996-2000). This ambitious work is facilitated by the invaluable survey of the tombs in the Valley by the Theban Mapping Project (<http://www.thebanmappingproject.com/>) that has provided a complete documentation of their architecture, and the orientation and size of each chamber and corridor. As recognized by Curtis (1977) and Rutherford et al. (1979) and briefly highlighted by Cobbold et al. (2008), the substratum in which the tombs are excavated plays an essential role in this restoration effort.

In 2005, His Excellency Dr. Z. Hawass and the Supreme Council of the Antiquities (SCA) endorsed our proposal to conduct an integrated geoarcheological study of the West Bank of Thebes for preservation and sustainable management of the monuments (tombs and temples). This project has been denominated the Thebes International Geo-Archeological (TIGA) program. We have recently been funded (2008) by the National Geographic Society Research Foundation to conduct a detailed mapping of surface geology (including structural features) and construction of a geological reference section (400 m thick) together with comparable

11/9/08

subsurface studies within selected pharaonic (and other) tombs to place them within a (surface) stratigraphic framework and integration of these data sets in constructing the first GIS-based geological map of the West Bank area at 1/10,000 scale, to provide archeologists with a framework in which to conduct their investigations on the restoration, preservation and management of pharaonic monuments.

We present here a concise review of archeological and geological studies in the vicinity of the Theban Necropolis on the West Bank of the Nile in order to provide a framework for our own investigations in this area. We begin with a brief overview of the peopling of the Nile Valley, and the pre- and dynastic history of ancient Egypt, with particular emphasis on the 18<sup>th</sup>–20<sup>th</sup> dynasties. We then discuss the geological setting of the tombs excavated during these dynasties in the Theban Mountain, and examine the role of lithology and structures (joints and faults) in their deterioration and to be addressed in terms of conservation and management. This is based on a few examples of tombs that we were privileged to visit on two occasions in 2004 and 2006 and our reconnaissance fieldwork.

## **EARLY EGYPTIAN AND PHARAONIC HISTORY**

Recent genetic studies focusing on mitochondrial DNA suggest that two genetic lineages, the M1 and U6 haplogroups, originated simultaneously in western Asia about 45,000 to 40,000 years ago and spread together with modern humans into northern Africa about 40,000 years ago (Olivieri et al., 2006) following shortly upon a migration out of East Africa that may have occurred as recently as 60,000-50,000 years ago (see also Wells, 2002). These early populations may represent the root-stock of the early settlers/inhabitants of the Eastern Sahara who were subsequently to people the Nile Valley, and build one of the first organized civilized states—the Egyptian pharaonic Empire.

There is now a well-documented relationship between climate and prehistoric migrations and settlements (Figs. 2, 3). During the last Glacial Period (~75ka to ~12ka) the Eastern Sahara was an area of hyper-arid warm desert with minimal rainfall, precluding permanent occupation by humans. With the onset of pluvial conditions between latitudes 16<sup>o</sup>N and 24<sup>o</sup>N at ~8500

11/9/08

B.C.E. and the development of seasonal monsoons and savannah-like environments indicative of northward shift of the tropical rainfall belts by as much as 800 km, the development of semi-humid conditions over a vast area stretching from the Western Desert of Egypt, NW Sudan, and nearby Chad and Libya provided the conditions necessary for human settlement(s) (Kuper and Kröpelin, 2006; Kröpelin et al., 2008).

The first well established predynastic culture in the Nile Valley was the Nagada Culture (4400-3000 B.C.E.). The ritualistic/religious and artistic traditions that served to unite the ancient Egyptians for nearly 3000 years were rooted in customs and practices that long predated their formalization in the form of the concept of nationhood and the development of a distinct architecture associated with the burial/preservation of royalty for eternity around 3000 B.C.E. The earliest royal tombs built during the Archaic Period (= Early Dynastic Period; 1<sup>st</sup> and 2<sup>nd</sup> Dynasties) were essentially rectangular structures of mud-bricks, some 5-6 m high, which capped the cliffs/ridges of the desert escarpment overlooking the Nile Valley at Memphis, near modern day Cairo.

Egyptologists generally consider that the history of pharaonic Egypt begins in earnest with the unification (~3100 B.C.E.; dates below are from the chronology of Weeks (ed.), 2001) of upper and lower Egypt by King Menes (Hor-Aha). This event led to the establishment of the first of 30 dynasties that ruled over Egypt for nearly 3000 years from ~3100 B.C.E. until 332 B.C.E. when Alexander the Great conquered the country. Dynastic Egyptian history is customarily divided into three principal “Kingdoms”—periods of national unity: Old, Middle and New Kingdoms—extending for some 1200 years, and separated, in turn, by two intermediate periods—or intervals of political/national disunity lasting ~200 years each (Fig. 3; Table 1). The old Kingdom comprises the 4<sup>th</sup> to 6<sup>th</sup> Dynasties, and is famed for the building of the pyramids (3<sup>rd</sup> and 4<sup>th</sup> Dynasties) and the writing of the Texts of the Pyramids (5<sup>th</sup> Dynasty). The first two capitals of Egypt were located in the Nile Delta near present-day Cairo: Memphis in the 1<sup>st</sup>-8<sup>th</sup> Dynasties and Herakleopolis in the 9<sup>th</sup>-10<sup>th</sup> Dynasties. The Middle Kingdom (11<sup>th</sup> and 12<sup>th</sup> Dynasties) was a time of conquest, to the south into Nubia, and to the northeast into Palestine (Canaan), marked by the seizure of great resources such as the gold mines of Wadi Allaki. The capital was then Thebes (~2000–1782 B.C.E). Middle Kingdom Kings were

11/9/08

initially buried in tombs at el-Tarif and Deir El Bahari on the West Bank at Thebes, and later (Dynasty XII) in a series of large pyramids in northern Egypt. Little is known of the Second Intermediate Period (13<sup>th</sup>-17<sup>th</sup> Dynasties; ~1782–1570 B.C.E.).

The advent of the 18<sup>th</sup> Dynasty (~1570 B.C.E.), beginning with King Amose, marked a remarkable revival in the cultural and military achievements of Egypt which would last through the 18<sup>th</sup>, 19<sup>th</sup> and 20<sup>th</sup> Dynasties. Dynastic power was centered on Thebes except for the short Amarnian episode (Pharaoh Akhenaten, 1359-1342 or 1349-1334 B.C.E.). Religious rituals extended to the West Bank where each pharaoh built his funerary temple and tomb. The former were located on the alluvial plain of the Nile, so as to receive the waters of the annual flood, and the latter deep in the mountain in recessed valleys now known as *Valley of the Kings* (eastern and western branches, the latter also known as *Western Valley*). The tombs of Queens and Nobles were also dug on the West Bank, in the low hills rising from the alluvial plain and dominated by the pyramidal-shaped El Qurn. The ensemble is generally referred to as the Theban Mountain (Fig. 1), an ~5 km-long, roughly isosceles-shaped triangular area that extends from Malqata-Medina Abu to the West, to Dra Abu el-Naga to the East, to the Wadi El Ain (*Western Valley*) to the North, and is demarcated to the southeast by the alluvial plain of the Nile.

Occupation of the West Bank for religious rituals was not new in 18<sup>th</sup> Dynasty Egypt. Temples had already been built there during the Archaic Period, and rulers who preceded the great King Nebhepetre Mentohotep (2161-2010 B.C.E.) were buried at el-Tarif, typically in underground funerary apartments at the end of a long sloping courtyard. However, the first remarkable construction on the Theban Mountain was the mortuary temple of Nebhepetre Mentohotep, the second ruler of the 11<sup>th</sup> Dynasty (Middle Kingdom). This temple in the vast natural amphitheater of Deir El Bahari, was also meant to accommodate the Barque of Amun Ré that crossed the Nile from Karnak on the occasion of the Beautiful Feast of the Valley which he inaugurated and would be celebrated through the New Kingdom. His son, Sankhkare Mentohotep (2010-1998 B.C.E.), was also buried in an adjacent (never completed) mortuary temple. He ordered the construction of a brick temple on Thot Hill over a temple erected there during the Archaic Period. The walls of the new temple were realigned so as to conform to the



11/9/08

astronomical configuration of the time (1000 years later) revealing the importance of astronomical configuration in pharaonic Egypt (which must have caused major concerns for the architect of the tombs of the New Kingdom).

The locations of the tombs of the first two rulers of the 18<sup>th</sup> Dynasty remain unknown. The mummy of King Amose was found in the cache at Deir El Bahari. King Amenhotep 1<sup>st</sup> (1546–1524 B.C.E.) had a temple built at Deir el Bahari at the location where Queen Hatshepsut herself had her temple of million years erected. He also ordered a jubilee portal to be erected at Dra Aboul Naga. This was in line with traditions introduced during the 11<sup>th</sup> Dynasty. These would be irremediably changed during the reign of Queen Hatshepsut (1498–1483 B.C.E.). She introduced religious and funerary rituals that would persist throughout the New Kingdom, at the end of which the pharaohs left Thebes for the Delta area. Her innovations include 1) the separation of the burial sites from the funerary temples, 2) the location of the burial sites in a remote area now known as the *Valley of the Kings*, and 3) a reintroduction of sarcophagi in which to deposit the wooden coffins, a practice lost during the Second Intermediate Period (Vandersleysen, 1995). The separation of temple and burial site meant extensive excavation to reach deep into the rocks and protect the content of the tombs from thieves; the use of sarcophagi, each a massive excavated stone, required corridors broad enough for them to be carried to the (deepest) funerary chambers. Excavation of the first tombs in the Valley of the Kings must have been a challenge, considering the contrasting lithologies encountered by the quarrymen. Soon, however, excavation was restricted to the Thebes Limestone, in several tombs deep enough to reach the contact with the humidity-retaining and easily swelling Esna Shale (see below).

Twenty-five pharaonic tombs have been positively identified in the Valley of the Kings, but those of five pharaohs remain unknown (Table 1). Tombs were also dug for relatives (wives, parents, sons) and for the Nobles who had occupied influential positions. To date, 63 tombs have been discovered in the valley. Eighty-three years elapsed between the discovery of the Tomb of Tutankhamon (KV62) and the recent (2005) find of a redepository tomb (KV63) by archeologists of Memphis University, Tennessee. Many more tombs were dug in the Theban

11/9/08

Mountain. Those of the Queens were regrouped in a short valley at Biban al Harim (*Valley of the Queens*) whereas those of the Nobles were dispersed in the foothills.

Towards the end of the New Kingdom, the pharaohs moved their capital to Tanis in the delta, leaving Thebes under the increasing influence/control of the Clergy of Amon. Numerous tombs were broken into and plundered. In a preservation effort, mummies were transferred at the beginning of the 22nd Dynasty (~900 B.C.E.), and hidden in what is now known as the Deir El Bahari cache (TTT320; Belova and Graefe, 2006). But the unsealed tombs were vulnerable to sudden flash floods that brought in loose pebbles, gravels, and silts from the slope scree; humidity, along with other factors (e.g., human and cattle occupation during the Third Intermediate, and Coptic Periods), contributed to the deterioration of the tombs. Many tombs have been restored, and today the splendors of the New Kingdom sustain active tourism, which, in turn, threatens them by changing air quality and temperature (normally constant low humidity and temperature).

## **GENERAL GEOLOGIC SETTING/BACKGROUND**

Although man-made and conceived by remarkable architects (among whom Inéni and Senenmut) who achieved fame in ancient Egypt, tombs should be seen as akin to natural caves deep underground. Their walls were cut in the massive strata of the Theban Mountain; their sealed doors prevented gas exchanges with the air of the surrounding landscape, resulting in stable conditions that contributed to the pristine preservation of their refined (carving) and colorful (painting) decorations. This is entirely different from a temple made of piled-up cut stones, exposed to the elements (essentially sun and dry air in Thebes), whose structural stability is essentially dependent on the architect's design and choice of stones. The long-term stability of a tomb is dependent on geological factors upon which the best architect would have no control. Most tombs were dug in the lower strata of the Thebes Formation, a fine-grained, beige, almost lithographic, limestone. However, as the excavation proceeded lithologic variations or a different lithologic formation (i.e., Esna Shale) were encountered. At depth, 100 m away or more from the entrance of the tomb, faults and fractures were crossed. Through time, as they

11/9/08

were unsealed, filled with the debris of flash floods, buried under an increasing amount of scree, bathed in humidity, the tombs became destabilized and began to deteriorate (Fig. 3a-f). The preservation and management of many of the Antiquities of the Theban Mountain thus require a full understanding of the geological setting (i.e., stratigraphy and structure).

### **Structure of the Theban Mountain**

As seen from the Nile (Fig. 1), the mesas that stretch east and west of its banks, from Assiut in the North to Aswan in the South, appear to be of tabular structure, exhibiting an exemplary text-book layer cake stratigraphy. This distant view is, however, deceptive, as the view from the hills of Abd El Qurna or from there to the *Valley of the Kings* via the amphitheater of Deir El Bahari quickly reveal. As in the Dababiya area, 40 km to the South and on the East Bank, anticlinal structures and faults have elevated the Tarawan Formation close to the surface, and at almost the same topographic altitude as the formational contact between the Esna Shales and the Thebes Limestone. Thus, in a narrow perimeter (<0.8 km), we find tombs dug into the Tarawan, Esna, and/or Thebes Formation.

Preliminary field surveys and studies of the Google Earth images allow us to construct a tentative structural scheme of the West Bank that will form the basis of further investigations (Fig. 4). We distinguish four units of coherent geologic and geomorphologic characteristics. First, a regional **tabular structure** that forms the major part of the Theban Mountain dominated by the prominent El Qurn peak (Fig. 5a). This structure consists of low dipping to sub-horizontal beds of the Esna, Thebes and Miniya Formations. Second, in the southeast, large **tilted compartments** dip 25-35° towards the northwest (Figs. 5b, c). In this complex structural area, the Tarawan Formation crops out locally but there is no evidence to date of the surface occurrence of the underlying Dakhla Formation. Third, towards the northeast, an area of relatively low hills, denominated here as the **northern basin** (Fig. 5d), apparently filled with interstratified conglomerates, clay beds and calcareous-dolomitic playa deposits. The calcareous beds, <10 m thick, were exploited as the “*Steinbrüche der Hatshepsut*” to build the Temple of Del El Bahari (Klemm and Klemm, 1981). These authors assigned an (unlikely) Eocene age to these deposits. The filling of the northern Basin and the tilted compartments, as delineated here

11/9/08

were assigned by Said (1981, Figure 2) to the Armant Formation of “Quaternary” age. Fourth, further to the southeast, lies the **Nile alluvial plain** (Fig. 1).

The regional Paleocene-Eocene succession forms the substratum of the tabular structure and tilted compartments, which both appear to have been affected by at least two NW-SE trending fault zones. We assume that the tabular structure is delineated by landslides parallel to the Nile Valley and hypothesize that the latter formed during the late Neogene (Messinian sea level lowering and concomitant canyon cutting [Aubry et al., in press]).

### **Lithostratigraphy (Figs. 6, 7; Table 2)**

#### ***The Tarawan Chalk***

The term Tarawan Formation was introduced by Awad and Ghobrial (1965). It designates the ~20 m thick chalky limestone that overlies the marls and calcareous clays of the Dakhla Formation, and passes gradually into the gray shales of the Esna Formation (Fig. 7a). The Tarawan Formation consists of a fine-grained homogeneous limestone containing a few layers of grey flint in contrast with the more numerous flints of the Thebes Limestone. The Tarawan limestone was used in the early phases of temple building (Karnak and Luxor temples for example) and in making *bas relief* engravings (de Putter and Karlshausen, 1994, 2003; Van der Heyden, 1997). The ancient Egyptians exploited the Tarawan Limestone in the Dababiya Quarry until at least the 21<sup>st</sup> Dynasty (Daressy, 1888, De Putter and Karlshausen, 1996), as indicated by the carving of the name Smendes, the pharaoh who reigned from about 1069 to 1043 BCE, in one of the quarry faces.

#### ***The Esna Shale***

The term Esna Shale Formation was used as early as 1911 by Ball in comparing the shales that lie above the Chalk at Kharga Oasis with those exposed in the Nile Valley near Esna. However, Beadnell (1905) is generally credited with formal designation of the Esna Shale in providing a full description of the unit at its type locality at Gebel Owaina, on the east side of the Nile Valley, between Esna and Idfu, about 25 km SE of Esna and 8.5 km NE of Sebaia railway

11/9/08

station where the Esna Shale rises ~450 m above sealevel (see El Naggar, 1966: 10-13; 49-51 and Ouda and Berggren, 2003:148 for further discussion of the Esna Shale and its variants).

The Esna Shale is divided into four distinct lithologic units (Aubry et al., 2007): from base to top, Hanady, Dababiya Quarry, Mahmiya, and Abu Had Members (Figs. 7a, b). The Hanady Member consists of light grey massive, compact calcareous shales with conchoidal fracture. Where complete, the Dababiya Quarry Member comprises a 0.6 to 3.7 m thick, characteristic succession of five grey to dark grey shaly to calcarenitic beds, Beds 2 and 3 being phosphatic (Dupuis et al., 2003; Aubry et al., 2007). The base of the Dababiya Quarry Member defines the Global Standard Stratotype-section and Point (GSSP) of the base of the Eocene Series. We have identified a phosphatic layer that probably represents the first or second phosphatic bed in the corridor leading to the second tomb of Senenmut (TT353 at Deir El Bahari).

The El Mahmiya Member consists of dark clayey shales of low carbonate content without prominent bedding. The El Quda bed is a thin phosphatic calcarenite with lenses or scarce pale-colored grains of glauconite. It lies at variable levels (1 to 5 m) above the base of the El Mahmiya Member. The Quda Bed occurs in a small pit in the Senenmut Quarry.

The Abu Had Member exhibits a notable alternation of marl and limestone beds with a few clayey intervals. It is lighter in color and richer in carbonate than the underlying member.

### ***The Thebes Limestone***

The Thebes Limestone Formation was defined by Said (1960) at Gebel Gurnah on the west bank of the Nile opposite Thebes/Luxor for the (predominantly) indurated carbonate section that overlies the Esna Shale Formation, and estimated its thickness at ~300 m. However, examination of the 1/10,000 topographic map of El Qurna indicates that the thickness of the Thebes Limestone may be closer to ~100 m. It outcrops in vertical cliff section(s) behind the famous Temple of Deir El Bahari/Temple of Queen Hatshepsut (18<sup>th</sup> Dynasty) (Fig. 7b).

Said (1960: 279) subdivided the Thebes Limestone into five units/beds (from top to bottom):

Approximate	Bed No.	Description
Top		

11/9/08

		Thickness (m)
1	Yellow, silicified limestone with <i>Gryphaea pharaonus</i> , <i>Ostrea multicostata</i> and <i>Nummulites subramondi</i>	30
2	Nummulitic limestone with <i>N. raymondi</i>	30
3	Limestone with abundant <i>Operculina libyca</i> , <i>Operculina</i> spp., <i>Nummulites praecursor</i> and various echinoids, <i>Heterospatangus lefebvrei</i>	35
4	Marl with scattered bands of flint concretions with abundant pelecypods, <i>Lucina thebaica</i>	75
5	White Limestone with flint concretions with few macroscopic fossils	120
6	Esna Shale with abundant limonitic fossils	55

In an unpublished report (1977), Curtis provides a detail lithologic log of the stratigraphic succession extending from the base of the Valley of the Kings to the top of El Kurn (Fig. 8). He assigned it to the Thebes Formation, subdivided it into four members, and delineated four zones (A-C) in the lower member.

Pharaonic tombs situated within the Thebes Limestone are located predominantly within the lower part of the Thebes Formation (White Limestone, unit 5 of Said, 1960), in agreement with Curtis (1977). However, we have tentatively identified several tombs within levels higher in the Thebes Limestone. It is also possible that tombs are located in (slumped blocks of) the overlying El Miniya Formation in the Tilted Compartments (in the area of the Nobles; Fig. 4). To locate the tombs more precisely in the succession will require more detailed lithologic subdivision of the formations, especially of units 4 and 5 of the Thebes Formation.

### ***(El) Miniya Formation***

The (El) Miniya Formation was defined at Miniya, near Assiut, as “a thick series consisting of white and light-grey limestones which comprise a large number of lithological varieties. The dominant rock type is a thick-bedded small-grained hard limestone with organogenous-detrital material [...] alternating with clayey and organogenous limestones made up of broken and unbroken *pelecypoda*, *gastropoda*, *sea urchin*, *Nummulites* and *Alveolina* shells” (Krasheninnikov and Ponikarov, 1965, p. 13). Said (1960) refers to sections through this formation near El Miniya and Assiut, but no lithologic information seems to be available concerning the formation in the Theban Mountain. Our preliminary surveys confirm that this Formation overlies the Thebes Formation there, a thick marly interval marking its base (Fig. 7a, b). However, the whole succession will require detailed lithologic analysis, especially the lower part that may be present in the Tilted Compartments and contain tombs (e.g., in the area of the Valley of the Nobles, Fig. 5c).

11/9/08

### **Biostratigraphy (Fig. 6)**

Little information is available on the biostratigraphy of the Upper Paleocene-lower Eocene succession of the Theban Mountain. It is reviewed below. However, the biostratigraphic framework developed in the surrounding area (Ouda and Aubry, eds., 2003) is easily applicable to it.

#### ***Planktonic Foraminifera***

The Esna Shale at Gebel Gurnah has been ascribed to the *Globorotalia subbotinae* (lower part of the Esna) and the *Globorotalia aragonensis* Subzone (upper part of the Esna) of the *Globorotalia aragonensis-Acarinina pentacamerata* Zone (Krasheninnikov and Ponikarov (1965; see also Berggren 1964). The overlying Thebes Limestone was ascribed to the *Ac. pentacamerata* Subzone by Krasheninnikov and Ponikarov (1965) and contains a planktonic foraminiferal fauna characterized by, *i. al.*, *Ac. interposita*, *Ac. triplex* (= *Ac. coalingensis*), *Ac. pseudotopilensis*, *Igorina broedermanni*, *Morozovella aragonensis*, *M. caucasica* and *Globigerinella voluta* (= *Pseudohastigerina wilcoxensis*). This association supports the assignment (and restriction) of the Thebes Limestone to the Lower Eocene (Ypresian Stage).

The base of the Esna Shale Formation at Gebel Gurnah was not visible to Said (1962:279) or Krasheninnikov and Ponikarov (1964: 11) when they visited the section of the Valley of the Kings and described its planktonic foraminiferal fauna. In recording the thickness of the Esna Shale Formation as 55 m (Said, 1962) and 56m (Krashenninikov and Ponikarov, 1964), respectively, the lowest part of the exposed section was ascribed to the *Globorotalia velascoensis* Zone (Bolli, 1957) of Landenian Age, Late Paleocene (Said, 1962) and the *Globorotalia subbotinae* Zone of Ypresian Age, Early Eocene (Krashenninikov and Pnikarov, 1964), respectively. The latter (Krasheninnikov and Ponikarov, 1964:11) stated that Said's (1962) assignment of the Esna Shale at Gebel Gurnah to the Late Paleocene was incorrect and based on his/Said's (incorrect) concept/record of *G. velascoensis* for the conical *Globorotalia* species (i.e., *G. caucasica*, *G. aragonensis*) recorded in the Esna Shale Formation (Said, 1962:

11/9/08

pl. 1, figs. 2a-c). However, this is incorrect inasmuch as *G. caucasica* occurs only rarely in the uppermost part of the Esna Shale Formation, whereas *G. velascoensis* is a common component of the lower part of the Esna Shale Formation (see Berggren and Ouda, 2003).

Planktonic foraminifera occur sporadically in the Thebes Limestone at Gebel Gurnah, and include, i.al., *Acarinina interposita*, *Ac. pentacamerata*, *Ac. triplex*, *Ac. pseudotopilensis*, *Igorina broedermanni*, *Morozovella aragonensis*, *M. caucasica*, *Pseudohastigerina wilcoxensis*, *Subbotina patagonica/rosnaesensis* group. The stellate *Astrorotalia palmerae* has not been observed (see also Krasheninnikov and Ponikarov, 1964: 11). This suggests assignment to Zone P8/E6 and possibly P9/E7. It is not yet possible to determine whether the Thebes Limestone Formation can be assigned to more than a single planktonic foraminiferal zone.

#### ***Calcareous Nannoplankton (Fig. 4)***

The Tarawan Chalk–Esna Shales–Thebes formational succession in Upper Egypt, between Qena to the North and Esna to the South, belongs to Zone NP6 to NP12, questionably extending into Zone NP13 (Aubry et al., 1999; Ouda and Aubry, Eds., 2003). The upper Esna Shale (El Hanadi Member) and the lower 20 m of the Thebes Limestones in the cliffs at Gebel Gurnah were assigned to Zones NP10 through Zone NP12 (Perch-Nielsen et al., 1978; El Dawoody, 1984; in these papers, the authors informally referred the Hanadi Member as, respectively, the Gurnah Calcareous Shales and Thebes Calcareous Shale). This is in agreement with our studies (Aubry, unpublished) showing that the upper 40 m of Esna Shale at Gebel Gurnah span the interval of Subzones NP10a to NP10d and Zone NP11 (the latter is ~ 20-25 m thick). These authors also reported the NP9/NP10 zonal boundary at the contact between the “Upper Owaina Shale” (El Naggari, 1966) and the Hanadi Member, a contact that requires investigation. The biostratigraphic age of the upper part of the Thebes Limestone and the Minia Formation remain indeterminate in terms of calcareous nannofossil stratigraphy.

Studies of the Tarawan Chalk/Limestone, which separates the lower Esna Shale (Hanadi Member) and underlying Dakhla Shale Formation, have shown that the Tarawan Chalk/Limestone belongs to Zone NP8 (Tantawy, 1998; papers in Ouda and Aubry, eds., 2003).



11/9/08

The lithostratigraphic units in which the tombs of the pharaohs (and lesser nobles and attendants) were excavated in the Valley of the Kings, Valley of the Queens and adjacent areas are located in the biostratigraphic interval from Zones P4 and NP8 (Tarawan Chalk) to at least Zones E5-6 and NP12 (lower Thebes Limestone; unit 1 of Said [1960]. Note that our preliminary investigations suggest that some tombs may be situated in stratigraphically higher levels within the upper Thebes and Minia Formations). The Paleocene-lower Eocene zones are shown in Figure 6.

### **Geochronology**

Correlation of Cenozoic biostratigraphic zones and magnetostratigraphy has led to an Integrated Magnetobiochronologic Scale (IMBS) (Berggren et al., 1995) which has provided, in turn, a temporal framework for the interpretation of events in earth history. This chronology has recently been supplemented by one based on orbital cyclostratigraphy, the Astronomical Time Scale (ATS), extended to the Paleogene (Luterbacher et al., 2004; Gradstein et al., 2004). While the Paleocene/Eocene boundary GSSP is globally correlatable its numerical age and those of bracketing events have remained elusive owing to (i) difficulties in determining precisely the duration of Chron C24r and the location of the PETM/CIE in Chron C24r in terms of orbital cyclostratigraphy, (ii) the ongoing problems of locating radioisotopically dated ashes (i.e., -17 ash) in Chron C24r, and (iii) lack of agreement on the age of the Fish Canyon Tuff (FCT) monitor. Current research (Westerhold et al., 2006; Storey et al., 2007) based on re-dating of the -17 ash and/or integrated radioisotopic age dating and astronomical calibration is converging around an age of ~ 55.8-55.9 Ma for the P/E boundary (vs 55.0 Ma in BKSA95 and 55.5 Ma in Berggren and Aubry, 1996).

The pharaonic tombs at Gebel Gurnah are thus situated in a stratigraphic succession that spans a temporal interval of ~ 7 m.y., from ~ 57 to 50 Ma (Berggren et al., 1995; Fig. 9).

## **GEOLOGY OF THE TOMBS OF THE NEW KINGDOM**

11/9/08

The most imposing tombs are obviously those of the pharaohs (with the exception of the tomb (KV5) of the sons of Rameses with its 120 rooms, still being excavated by Professor Kent Weeks. The quality of their workmanship (completion of the excavation, carving and painting) depended much on the duration of the reign of the pharaoh. On occasion, at the premature death of a pharaoh, a tomb was rapidly fitted for use by the deceased king. Thus KV62 (King Tutankhamen) is a small tomb with a single main chamber. Sometimes, the unexpected death of a pharaoh prevented completion of his large tomb, resulting in unfinished polishing of the walls (situations that offer insights into the methods and techniques used during excavation and decoration). The design of tombs changed through the dynasties. The earliest tombs (18<sup>th</sup> Dynasty) were of the Bent Axis type, the central corridor bending 90° one or more times; they sloped down quickly into the mountain. In later tombs (19<sup>th</sup> and 20<sup>th</sup> Dynasties) the corridors, horizontal or gently sloping went straight into the rock.

The configuration of the tombs has, at least theoretically, considerable importance with regard to the local geology. As seen in a three-dimensional framework (x, y, z axes), tombs of the Bent Axis type are shallow (21–87.9 m) along the horizontal (z) axis, deep (8–27 m; with the exception of KV 20=96.294 m) along the vertical (y) axis. Unless these tombs follow the local bedding, they may cut through subtle lithologic variations, and the likelihood that they cross major lithologic boundaries increases. However spatially confined along the z-axis, they are less vulnerable to the effect of the major faults of the Theban landscape (unless built in their vicinity) than tombs of the Straight Axis type. The greater the length (up to 118.6 m along the x-axis) of the tomb of the Straight Axis type, the greater the chances of the excavation intersecting complex structures (e.g., faults). Tombs dug almost horizontally are generally expected to exhibit lithologic homogeneity. In contrast, tombs that penetrate straight into the rock but at a strong angle are likely to cross through different lithologies. These tombs (Steep Straight Axis type) are among the most vulnerable to deterioration, as exemplified by KV17 (Seti 1; 19<sup>th</sup> Dynasty) which is ~137 m long and 28.7 m deep (y-axis; tunnel excluded). Rutherford et al. (1979) and Rutherford (1995) illustrated lithology-related deterioration in the royal tombs. We build here on their study.

11/9/08

In KV17 (Seti 1), the floor of the lowest chambers is the roof of the Esna Shale, a rock unit that absorbs humidity. The paintings and *bas-reliefs* that decorate their walls have been considerably damaged by humidity seeping from the Esna Shale into the limestone (Fig. 10a). KV 20 (Hatshepsut; 18<sup>th</sup> Dynasty) is another case. The entrance of this tomb of the Bent Axis type is situated just at the base of the Thebes Limestone, but much of the twisted corridors were cut through the Esna Shale. Several interpretations have been given of the unusual shape of the tomb, among which the suggestion of a symbolic function (Desroches de Noblecourt, 2002). A straightforward explanation is that lithology may have caused major problems for the quarrymen, who attempted to alleviate them by re-orienting the corridors. It is even possible that the quarrymen had hoped to reach the Tarawan Limestone, the upward vertical chalk-shale-limestone sequence seen in the nearby hills of the Hassassif being in all likelihood known to them. When discovered by Carter (1903-1904; see Romer, 1981), the deepest chambers in KV20 were still accessible, although the ceiling had partly collapsed. In 1994, the burial chamber was filled with flash-flood debris (<http://www.thebanmappingproject.com/sites/>), and conditions in the tomb are now dangerous. The entrance of TT353 (tomb of Senenmut, Hatshepsut's famous architect; also of the Bent Axis type) opens on a steep corridor through the Esna Shale. This corridor leads to the decorated chamber now famous for its painted astronomical ceiling (the earliest example in pharaonic Egypt; Dorman, 1991). The fine-textured lithology of the Tarawan Chalk explains the beautiful preservation of the latter, as well as of the fine carvings of the walls.

Nobles from the 18<sup>th</sup> Dynasty, such as Jeruef, also had their tombs excavated in the Tarawan Chalk (Fig. 10b). Because the topography of the El Assassif hills has probably been reshaped through successive episodes of excavations (first as tombs were dug; then when thieves searched for them; more recently because of archeological interest), it is unclear how far below ground the Tarawan lay when the tombs were quarried. The ceilings of many of these tombs have now collapsed, and the delicate engravings on the walls, some of which still retaining their original colors (Fig. 10c), are exposed to the elements. However, there is little structural damage in these tombs that, with a minimal amount of intervention, can be restored and preserved.

11/9/08

The determinant role of lithology on the aging of tombs through centuries cannot be better demonstrated than by comparing the essentially well preserved 18<sup>th</sup> Dynasty tombs in the Tarawan Chalk and a 19<sup>th</sup> Dynasty tomb such as KV7 (Rameses II). Located at the lowest topographic point in the valley, it was excavated at a low stratigraphic level in the Thebes Limestone. As the corridors cut through older levels of the limestone, excavation was increasingly closer to the Esna Formation. Located 15 m below the entrance, and ~88 m from it on the horizontal z-axis, the 8-pillared funerary chamber was quarried just above the contact between the Thebes and Esna Formations, resulting in considerable damage. The swelling of the Esna Shale has caused significant deterioration, with dislocated floors that have been thrust upwards and vertically split pillars (Fig. 10d), cracked walls with lateral displacement (Fig. 10e), and with ceilings which would collapse if it were not for the extensive means deployed to stabilize them (Fig. 11a) (Leblanc, 1997c). Volumetrically ((2286.43m<sup>3</sup>) KV7 is the second largest tomb in the Valley. This in itself would have required uniform integrity of the encasing rock. It can only be conjectured that the architectural return to the Bent Axis type in this tomb (the only tomb of this type built after the 18<sup>th</sup> Dynasty) resulted from difficulties related to lithologic weaknesses encountered by the quarrymen as they quarried deeper (87.9 m along the z-axis, the deepest of its type) in the mountain.

Lithology, combined with architectural design, explains the differences in preservation among tombs. Thus the lowest chambers of KV17, at the contact with the Esna Shale, have suffered minor damaged compared to those in KV7. KV17 was cut at a steep angle, only the lower rooms reaching the Esna shales. Instead, the whole of KV7, excavated at a much lower angle, was close to the Esna. This signifies that restoration in the Valley of the Kings must be dealt with tomb per tomb, as is true for all monuments of the Theban Mountain.

The architects of the Theban necropolis understood the destructive effect of flash floods that occurred at a decadal frequency. In antique time, once the burial had taken place, the tombs were sealed using techniques that would prevent rushing waters from entering them (Romer, 1981). However, once unsealed (by robbers), nothing would protect the rock-laden waters to rush in, depositing layers upon layers of the pebbles and silts that had littered the hills in which the tombs were excavated (Figs. 11b, c). The devastating effect of these repetitive flooding

11/9/08

events is considerable. In the short term, large pebbles scrape the painted and sculptured walls; thin silts plaster the walls. In the long-term, the flood deposits may retain humidity, creating a humid atmosphere causing the loosening and cracking of the painted plaster. Cycles of increased humidity and desiccation contribute to the formation of gypsum over painted plaster and carved rocks (Fig. 11d), and to the exfoliation of limestone (Fig. 12a). When the debris is removed, ceilings collapse further (see also Guillaume and Emery-Barbier, 1996, and American Research Center in Egypt [ARCE], 2003).

The disposal of the removed fillings on the hills nearby the tombs, at least in the early years of Egyptologic exploration, contributed an undesirable effect on the atmosphere of the tombs (see Rutherford, 1995). The finer components of these materials block pores and fissures in the underlying limestone, thus contributing to the sealing of the tomb and retention of the anomalously high humidity.

Less obvious, but of major concern, is the geological structure of the Theban Mountain itself (Fig. 4). Circulation of water along faults and joints increase the destabilizing effect of unfavorable lithologies (Figs. 12b-d). In KV11 (20<sup>th</sup> Dynasty, Rameses III) a fault cuts through the funerary chamber (REF), serving as a conduit for ground waters. In reference to KV43 (18<sup>th</sup> Dynasty, Thutmosis IV), Romer (1981, p. 192) wrote "...now the fine old tomb is changing. For reasons that are still obscure, although we are working hard on solutions, parts of the cliff into which the tomb was cut, are moving. Old cracks in the limestone cliffs, which the ancient masons had cut through as they quarried the tombs' chambers are moving again; tiny heaps of splintered stone lie at the bottom of these cracks as the pressure of the rock movement once again pushes one surface against the other. And the surface of the walls, which were plastered and painted, has been loosened and is cracked. These effects of the moving cliffs can be countered, but it will take much time and effort".

Finally, sheer pressure from overlying rocks on the walls and ceilings of large chambers contributes to further deterioration of the tombs made vulnerable by lithologic and structural weaknesses, by massive penetration of rain water and by the distance of the topographic surface above the tombs.

11/9/08

## DISCUSSION

Despite appearances to the contrary, the Theban Mountain, and the Valley of the Kings in particular, is geologically complex. As seen from afar, the cliffs that dominate the Nile Valley exhibit a deceptively monotonous tabular structure. Upon closer examination, however, the mountain is seen as comprised of several structural units, each with different lithostratigraphy, and characterized by varying regional tectonic behavior. Tombs excavated in these different units thus have aged differently and developed various sets of problems. As explained above for the KV tombs, the state of preservation of the tombs is the combined consequence of the architectural type, the location of the tomb with respect to local topography, lithology, and the presence of faults and joints. These problems have been compounded by the effects of flash floods.

The preservation and management of the Thebes Mountain thus require a strong geological component. Each of the 62 tombs of the Valley of the Kings has been carefully surveyed in 3D (Theban Mapping Project; <http://www.thebanmappingproject.com/>). They now need to be incorporated into the Theban Mountain lithostratigraphy and structural framework. Only then will it be possible to understand fully the damages that tombs have undergone, to predict forthcoming problems, and to determine remedies to restore and preserve them.

The first step in such an endeavor is to establish a geological map of the Theban Mountain, at a 1/10,000 scale, using existing topographic maps. With strategically located reference sections through the Upper Paleocene Tarawan Chalk to the Middle Eocene El Minya Limestone it will be possible to correlate via biostratigraphy and physical logging individual beds or groups of beds across the mountain and to establish cross sections. Subsequently, it will be possible, using mostly physical logging, to incorporate the tombs into these cross sections, and thus into the geological structure of the mountain.

It is generally assumed that religious symbolism guided the architectural plans developed by the architects of the pharaohs. This may be mostly true for temples; but to respect a pre-

11/9/08

conceived, symbol-laden pattern when quarrying a tomb is another matter. The first architects of the New Kingdom had no means of knowing the rock types and associated structural complexity that might be encountered as the excavation proceeded. The change in style of the tombs from the 18<sup>th</sup> to the 21<sup>st</sup> Dynasty may have been essentially pragmatic. The experience gained from the excavation of KV 20 probably taught architects to avoid the Esna Shale. The stylistic change from the Steep Straight Axis to the Low Straight Axis may indicate that once a “good” stratum had been encountered, it was best to quarry it through. The entrances of most tombs with the Low Straight Axis type were located lower than the entrances of the Steep Straight Axis type, and excavating at a low angle was the best means to avoid encountering the Esna Shale.

It is unknown whether architects kept a record of the orientation of tombs in the mountain. It seems that this would have been difficult. The fact that the quarrying of new tombs needed to be diverted because of contact with the chamber of an older tomb suggests that the position of tombs in the Theban Mountain was essentially unknown to pharaonic architects. Chamber J1 of KV 47 and Chamber Ja of KV 32 were adjacent, the two tombs being oriented perpendicular to one another. Less than 1 m separates Chamber 1 of KV9 and Chamber G from the overlying KV12 (Theban Mapping Project; <http://www.thebanmappingproject.com/>). However, the study of open-air monuments indicates that the 18<sup>th</sup> Dynasty architects achieved astonishingly precise measurements (e.g., in the Chapel of Hatshepsut; Burgos and Larché, 2006). The location of the tombs in their full geological context may thus reveal unexpected talents of the architects of the Theban necropolis.

## CONCLUSIONS

18<sup>th</sup>-20<sup>th</sup> Dynasty (~ 1539-1075 BCE) pharaonic (and other nobility) tombs located in the Theban Mountain, West Bank, Upper Nile Valley (opposite modern day Luxor) have been excavated in a variety of lithologies varying from Chalk (Tarawan Formation), Limestone (Thebes and El Minia Formations) to Shale (Esna Formation) ranging in age from Late Paleocene to Middle Eocene (~ 57-50 Ma).

11/9/08

Our preliminary field investigations in the Theban Mountain, West Bank, including examination of selected tombs have shown that whereas the geology of the Upper Nile Valley appears to be deceptively simple, the lithologic succession is vertically variable, and we have recognized and defined several new lithologic units within the upper Esna Shale Formation (Aubry et al., 2007). We have delineated lithologic (shale/limestone) contacts in several tombs (e.g., KV17, Seti I; KV7, Rameses II), and determined/confirmed that the main chambers in some (e.g., TT353, Senenmut; TT192, Jeruef) were excavated below the Esna Shale in the Tarawan chalk. We have been able to document changing dip in the strata (warping) in several tombs (as in Rameses III), and delineate two major orientations of fractures in the field. Investigations behind the Temple of Hatshepsut, in the Valley of the Kings and around Der El Medina, have revealed broad regional structures. Our preliminary surveys confirm that the hills located near the Nile Valley, such as Sheik Abel Qurna, do not belong to the tabular structure of the Theban Mountain, but are discrete displaced blocks of the El Miniya Formation (which normally overlies the Thebes Formation), as supported by Google Earth photographs. The state of preservation of the tombs is the combined consequence of the architectural type, the location of the tomb with respect to local topography, the lithology and the presence of faults and joints. Flash floods and ensuing humidity have only compounded these problems.

The pharaonic civilization, established ~5000 years ago and lasting ~3000 years, united people who may have gathered along the Nile Valley to find refuge from the pressure of climatic change. It is one of the most fascinating achievements of human history. It has had a significant impact on the development of the western world in often unsuspected ways, both practically (e.g., the 365-day-year) and traditionally (as reflected in ritual celebrations; Desroches de Noblecourt, 2004). The discovery of the art of this civilization is a popular tourist theme that the Egyptian government is, understandably, eager to strengthen. However, this magnificent art, a main source of understanding of this ancient civilization, is now threatened by pollution engendered by tourism and modern agricultural practices. Massive tourism has its costs, and it is a matter of urgency that we should heed the warning given by Romer (1981, p. 192) that “The royal tombs were never meant to be visited by thousands of people”.



11/9/08

### **Acknowledgements**

We have conducted our investigations on the Theban Mountain with the cooperation and support of the Geology Department of the University of Assiut. We wish to extend our thanks to His Excellency Zahi Hawass, Secretary General of the Supreme Council of the Antiquities, Cairo, for his support of our project. We have benefited significantly from generous advice and documents provided by Kent Weeks, Christian Leblanc, C. Rodriguez-Navarro, Hourig Sourouzian, and colleagues in the French, Japanese, Italian, Spanish and Swiss archeological missions on the West Bank. We acknowledge a particular debt of gratitude to John Pye, dealer in rare books of Brockton, MA for lending us his only extant copy of the now out-of-print of *The Valley of the Sun Kings* (1995), edited (and signed!) by Richard Wilkinson. Comments by Rushdie Said and two anonymous reviewers as well as suggestions from Max Coleman, Scientific Editor at Terra Nova, are gratefully appreciated and materially improved the quality of our paper.

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11/9/08

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11/9/08

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11/9/08

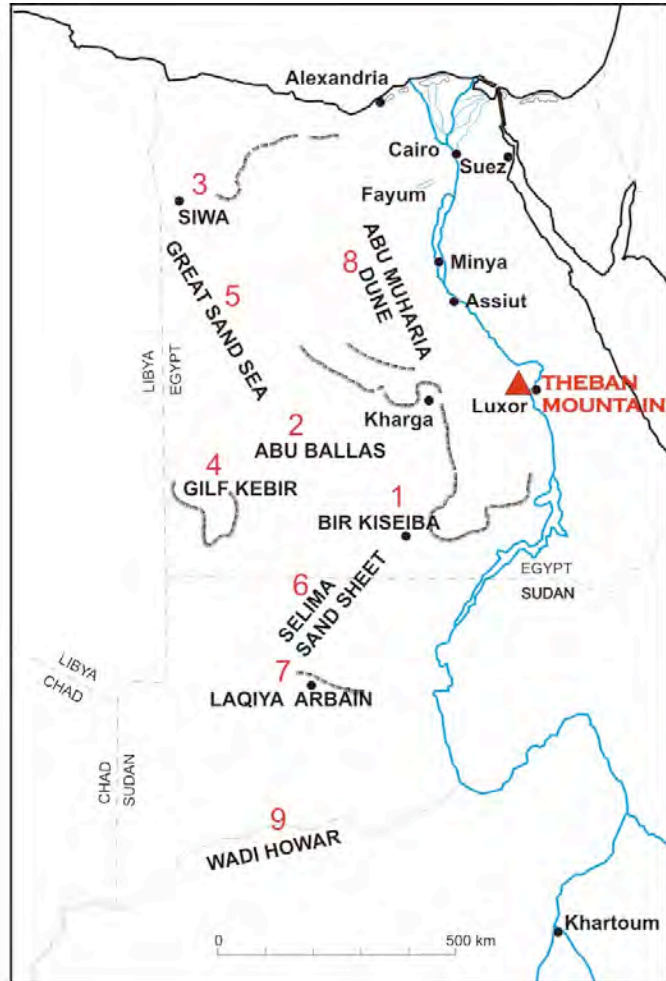
**Figure Captions**

Figure 1. The Theban Mountain seen from the East Bank, near Luxor. The pyramidal shape of the El Kurn dominates the landscape. The alluvial plain of the Nile extends from the river to the foothills of the “mountain”.



11/9/08

Figure 2. Map of Egypt. The Nile Valley runs south-north from Sudan to the Mediterranean Sea, separating the eastern and western deserts. It was populated by people who migrated from the west (see Figure 3).



11/9/08

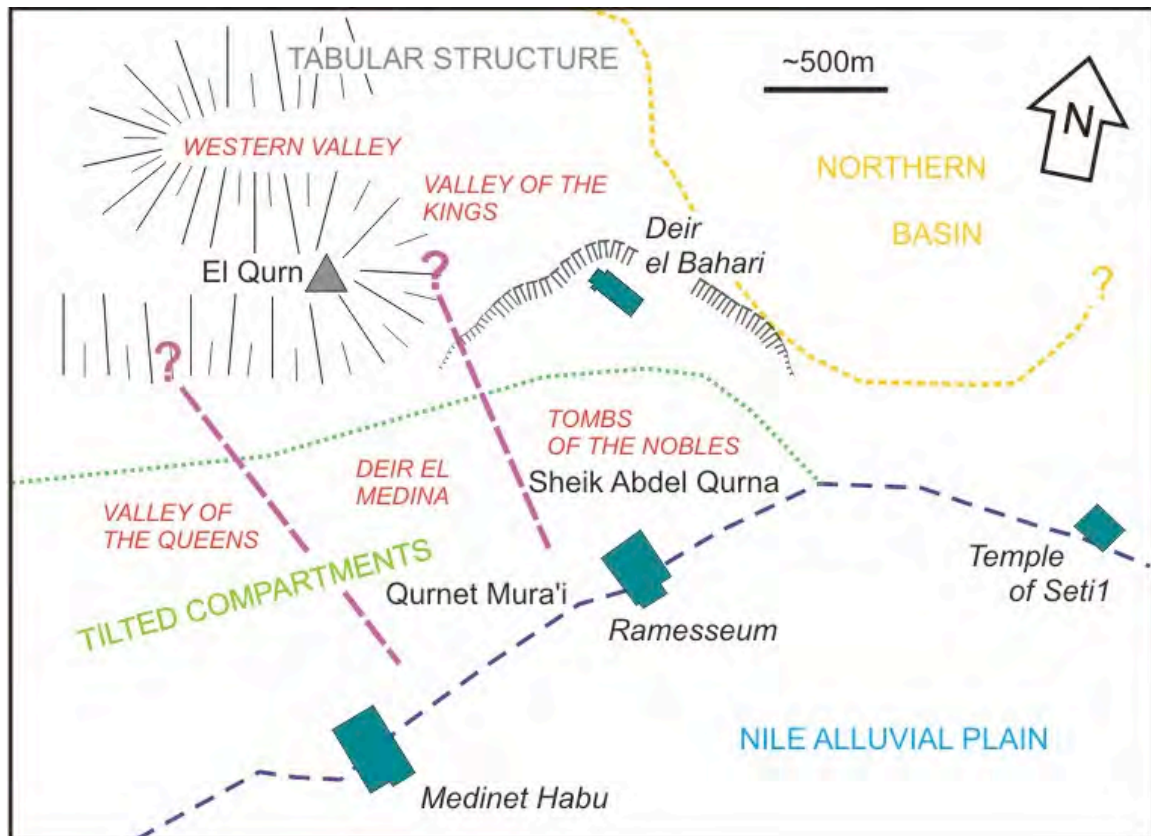
Figure 3. History of settlement in the Nile Valley and vicinity (modified after Kuper and Kröpelin, 2006, Fig. 1). Localities shown in Figure 2.

Four distinct phases of occupation following the late Pleistocene/Holocene introduction/transformation of Pluvial conditions: a) the Reoccupation Phase (8500-7000 B.C.E.; early Neolithic) denoted by early settlements in the Egyptian Sahara by presumed hunter-gatherers and evidence of the earliest ceramics in the Old World—the so-called “wavy-line” decorated pottery; a notable feature of this period is, as the authors observe, the lack of evidence for settlement in the Nile Valley with the exception of El Kab; b) mid-Holocene Formation Phase (7000-5300 B.C.E.), characterized by relatively widespread human settlements with the introduction of advanced technology in the form of bifacial implements rooted in the Levant, and domestic livestock (sheep, goats) in addition to domestic cattle; the first evidence is seen of farming communities in the Fayoum; c) mid-Holocene regionalization (5300-3500 B.C.E.; late Neolithic and Chalcolithic Age), characterized by a return to desiccation conditions and the gradual exodus from the Egyptian Sahara and the concomitant settlement along the Nile Valley; d) Late Holocene marginalization (3500-1500 B.C.E.; Bronze Age), characterized by a further exodus/retreat from the Eastern Sahara to northern Sudan and cultivation of the Nile Valley by increasingly sophisticated farming communities that learned to adapt the annual flooding of the Nile River to provide a relatively prosperous life-style and the gradual development of a civilized (i.e., pharaonic) society.



11/9/08

Figure 4. Structural setting. Map established on the basis of the “tourist map” of the Theban Necropolis at 1/10 000 published by the Geological Survey of Egypt (1922) following preliminary field and Google Earth observations. The well-known pharaonic necropolis are shown in relation to the structural elements of the Theban Mountain. Dark blue dashed line: limit of the alluvial plain of the Nile. Green dotted line: listric fault separating the tabular structure from the tilted compartments. Yellow dotted line: limit of the northern basin. The Temple of Hatshepsut is dominated by cliffs in the Thebes Limestone.



11/9/08

Figure 5. Selected examples of structural styles of the Theban Mountain.

- a. The tabular structure. View towards the southwest of the cliffs overhanging the Western Valley where the tabular structure of the topmost part of the Thebes Limestone Fm is exposed (cliff in low right of the photograph) and the overlying Minia Fm. This latter shows its three characteristic cliffs.
- b. Southwards view of the tilted compartment of the Valley of the Queens. The tombs seem dug in the Thebes Limestone Fm and are overhung by the top of this formation which makes a steep cliff. Above and to the right (west) the hill is formed by the Minia Fm which dips  $\sim 30^\circ$  westwards.
- c. Southeastern view from the Deir el Bahari showing the tilted compartments of Sheik Abd el Qurna (Valley of the Nobles). Note the ramps leading to the entrance of tombs. In the background, the tilted block of Deir el Medina. In the foreground to the right, the horizontal succession of the Esna Shales Fm. and the very base of the Thebes Limestone Fm., unaffected by the tilting.
- d. Contact (dashed) between the tabular structure (note the tomb entrances) and the northern basin (note the curved bedding, the coarse blocks, and the absence of tombs). Northwards view from Deir el Bahari plain showing the contact between the tabular horizontal succession Esna Shale Fm-Thebes Limestone Fm (with numerous tombs) and the southern limit of the northern basin (cliff without tomb to the right).



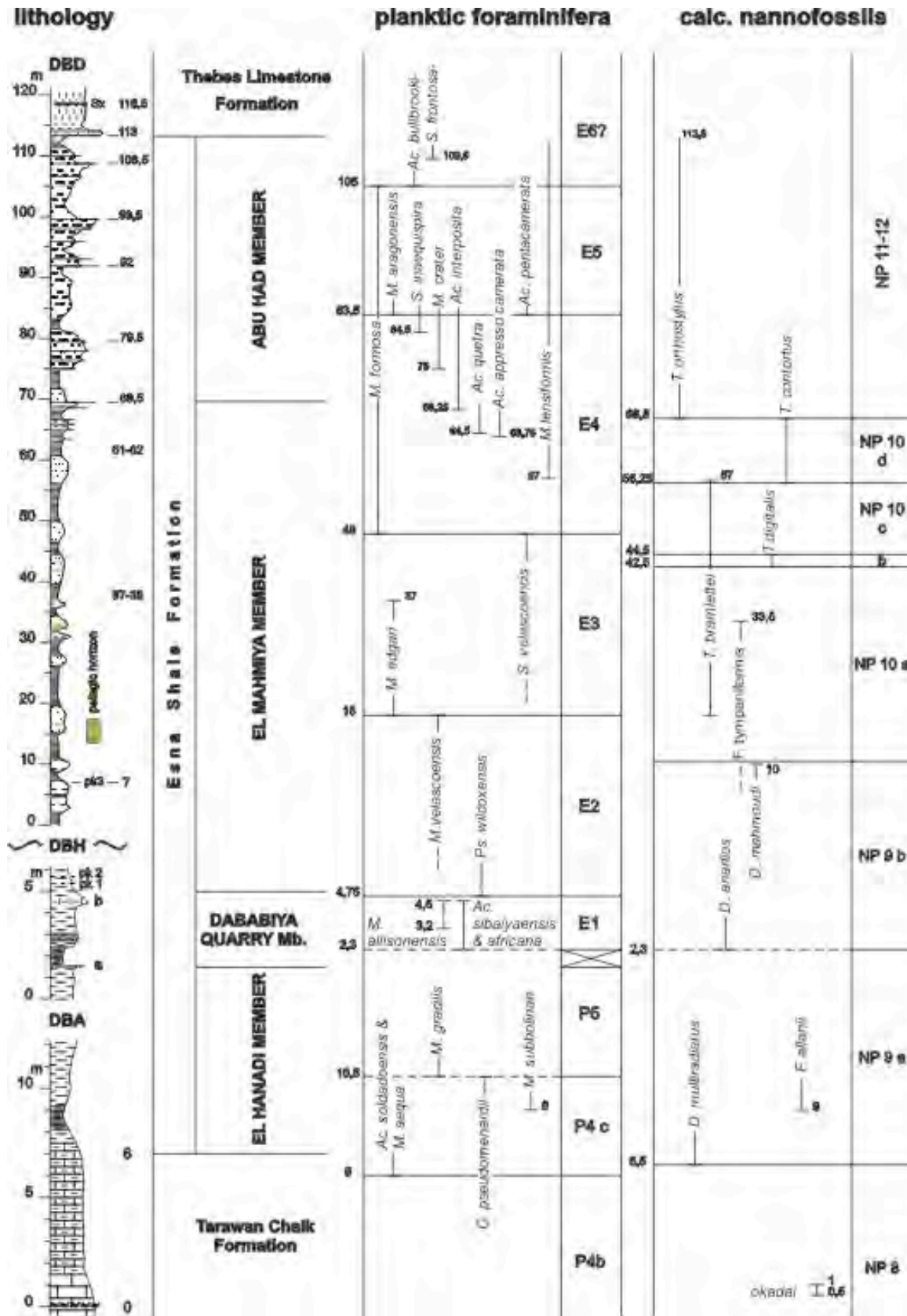


11/9/08

Figure 6. Lithostratigraphic framework (modified after Aubry et al., 2007, Fig. 8; correlation to the E-zones scheme is shown).

Paleocene and Lower Eocene (sub)tropical marine stratigraphic sections have customarily been subdivided into a sevenfold and fourfold planktonic foraminiferal zonal scheme, respectively (Berggren and Miller, 1988; Berggren et al., 1995; Berggren and Norris, 1997; Olsson et al., 1999). Paleocene Zones P1 and P4 are subdivided, in turn, into three subzones each. The Paleocene zonation has recently been modified with a revised nomenclature, while a new sevenfold zonal scheme (Zones E1-7) has been proposed for the Eocene, spanning the lower Eocene (Berggren and Pearson, 2005).

Martini's (1971) zonal scheme (9 Paleogene nannoplankton [NP] zones) has generally been applied to the upper Paleocene-lower Eocene stratigraphy of the Nile Valley. Zones NP9 and NP10 are now subdivided into, respectively, two and four subzones (Berggren et al., 1995; Siesser and Bralower, 1992; Aubry, 1996). Whereas there has been disagreement as to the recognition of the NP9/NP10 zonal boundary (Bybell and Self-Trail, 1995), and the four-fold subdivision of Zone NP10 (Raffi et al., 2005), the subzonal framework used here has been successfully applied in several independent studies conducted in the Nile Valley (e.g., Tantawy, 2006, Faris and Strougo, 1998; Dupuis et al., 2003) and is thus confidently used here.

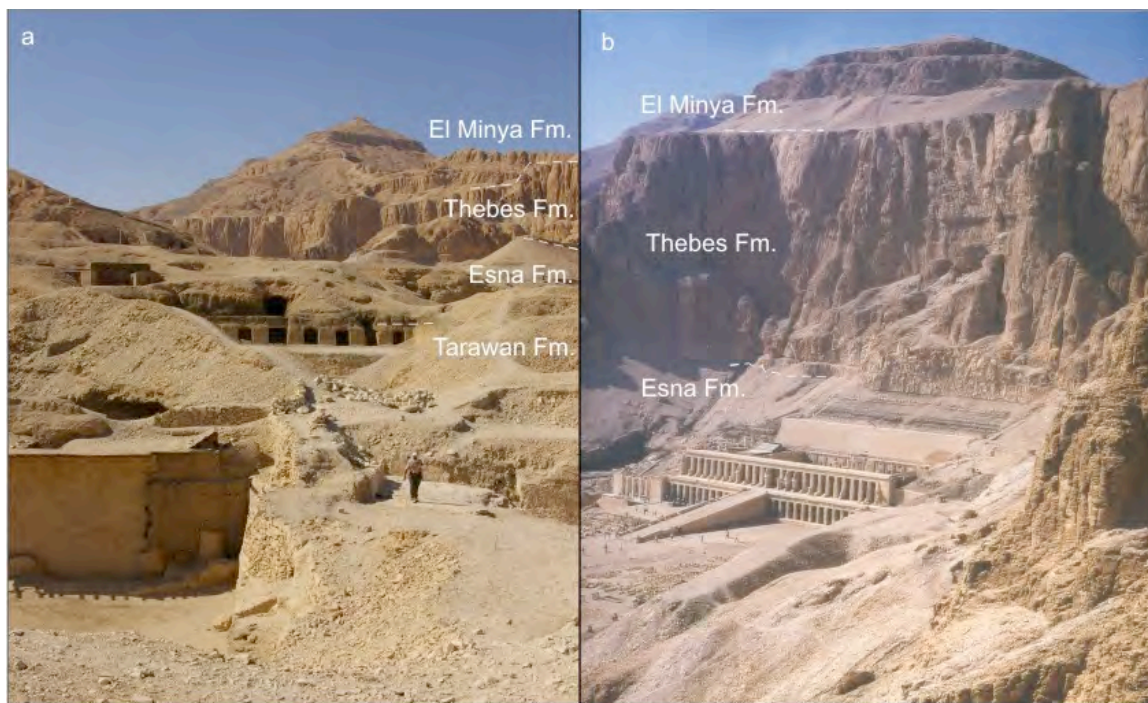


11/9/08

Figure 7. Selected views exhibiting the best exposures of the upper Paleocene-middle Eocene succession in the Theban Mountain.

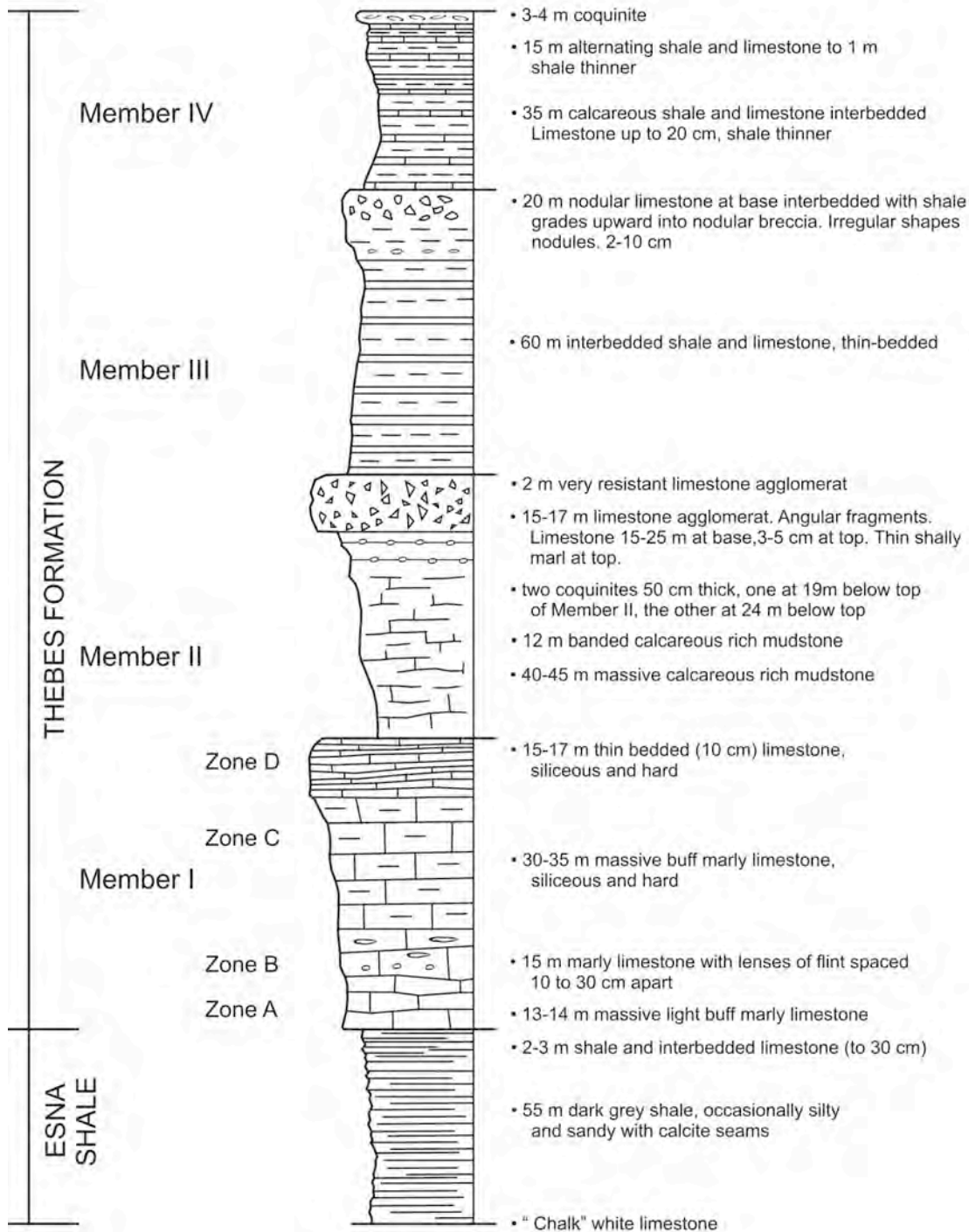
a- Lithostratigraphic succession from the Tarawan Chalk (foreground) to the El Minya Limestone (top of El Qurn in the background), as seen from the village of Sheik Abdel Qurna. The contact between the Tarawan Chalk and Esna shale is marked by a row of tombs just below it. The finely stratified upper part (El Abu Had Member) of the Esna Shale is well exposed below the cliff forming Thebes Limestone to the right.

b- Thebes Formation overhanging the Temple of Deir El Bahari. The contact between the Thebes and Esna Formation is seen at the level 0. The thinly bedded El Abu Had Member (Esna Shale) is well exposed behind the Hatshepsut temple.



11/9/08

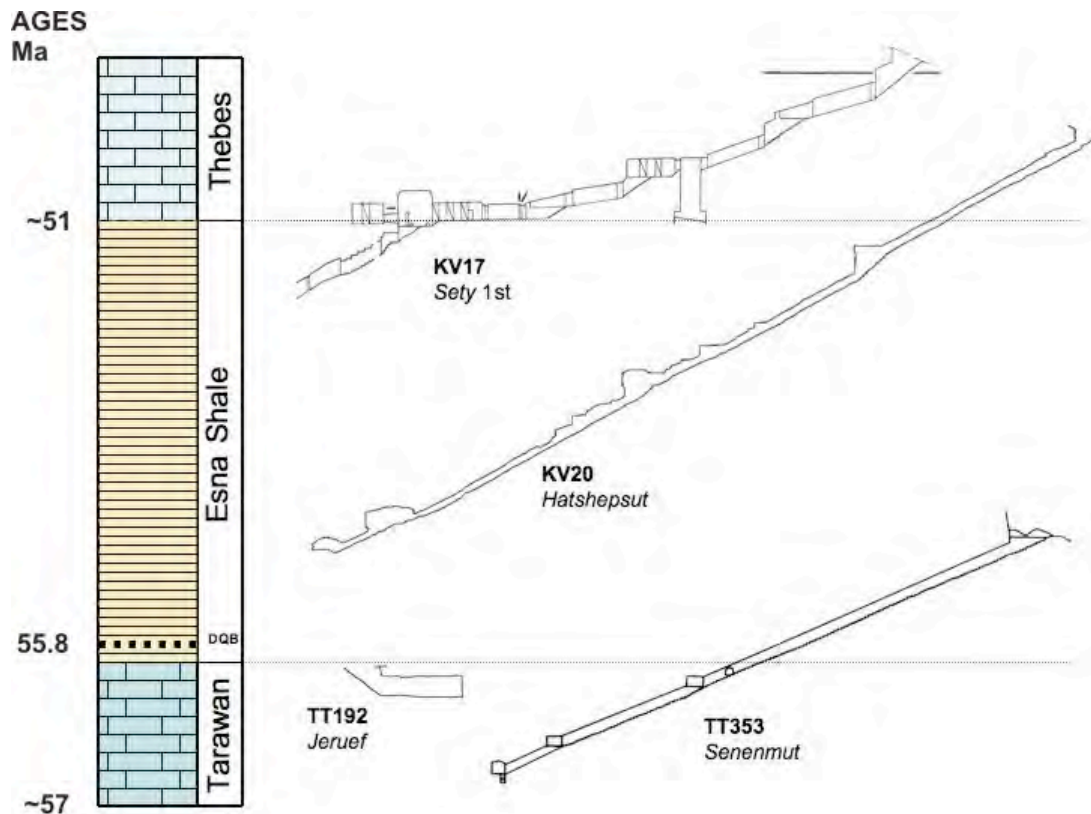
Figure 8. Lithostratigraphic framework of the Thebes Formation (after Curtis, 1995, Fig. 1).



11/9/08

Figure 9. Lithostratigraphic profile of selected tombs. The tunnel-shaped KV20 is the most exceptional tomb of the Valley of the Kings, being both the longest and the deepest. Its entrance is located in the lowermost part of the Thebes Limestone (marked by Foundation deposits in the name of Hatshepsut by Carter, in Romer, 1981, p. 192) and it penetrates the contact with the underlying Esna Shale at a steep angle. The lower chamber, which contained the cartouche-shaped quartzite sarcophagus of Queen Hatshepsut (the first pharaoh to have been buried in the valley), was carved in the Esna Shale, and for this reason its walls were not decorated.

According to Romer (1981, p. 193) the Tarawan Chalk was only 5 m from the bottom of the tomb. The uppermost chamber in TT353 is famous for its astronomical cycle, the first of its kind.



11/9/08

Figure 10. Details of preservation of tombs.

- a. Deterioration of paintings on Thebes Limestones just above the contact with the Esna Shale (forming the floor of chamber). Funerary Chamber, KV17.
- b- Tombs of the Nobles excavated at different depths in the Tarawan Limestone. Hills of Cheik El Qurnah.
- c- Engraving (dancers) on Tarawan Chalk, Tomb of Jeruef. Note preservation of original colors.
- d- Dislocated floor and vertically split pillar in chamber adjacent to funerary chamber in KV7, due to pressure caused by the water-induced swelling of the underlying Esna Shales. (see also Rodriguez-Navarro et al., 1996).
- e- Cracks and lateral displacements (5mm) in the wall of room adjacent to funerary chamber in KV7.



11/9/08

Figure 11. Details of preservation of tombs (cont.)

a- Extensive technical deployment to strengthen the ceilings in the funerary chamber of KV7.

b- Stratified, grain-sorted filling resulting from flash-floods which have poured into unsealed tombs over the centuries, bringing in scree deposits from the flanks of the Theban Mountain.

Preserved remnant of flash-flood deposit in KV18.

c- Other example of stratified filling. Note here the large blocks of rocks, evidence of the powerful erosive effect of flash floods.

d- Gypsum precipitation on walls, causing the destruction of carved hieroglyphs. Main corridor in KV7.





11/9/08

Figure 12. Details of preservation of tombs (cont.)

- a- Exfoliation of limestone at the vicinity of joints, KV5.
- b- Cracks associated with joints cause the collapse of ceilings, KV11.
- c- Diabolo-shaped pillars typically occur in tombs whose structure has been weakened by uneven pressure from the surrounding rocks.
- d- Deposit of iron oxide and other minerals along a joint due to water circulation along it.



11/9/08

**Table Captions**

<b>PERIOD</b>	<b>DYNASTIES</b>	<b>DATES</b>	<b>BURIAL</b>	
<b>Early Dynastic Period</b>	1 <sup>st</sup> –2 <sup>nd</sup> Dynasties	3100–2700		
<b>Old Kingdom</b>	3 <sup>rd</sup> –6 <sup>th</sup> Dynasties (	2700–2184	Pyramids, Giza Plateau, Saqqara	
<b>First Intermediate Period</b>	7 <sup>th</sup> –9 <sup>th</sup> Dynasties	2184–2040		
<b>Middle Kingdom</b>	9 <sup>th</sup> –12 <sup>th</sup> Dynasties (Sesostris	2040–1782	Thebes, East Bank (Karnak)	
<b>Second Intermediate Period</b>	13 <sup>th</sup> –17 <sup>th</sup> Dynasties	1782–1570		
<b>New Kingdom</b>	18 <sup>th</sup> –20 <sup>th</sup> Dynasties	1570–1070	<b>WEST BANK (Thebes)</b>	<b>LITHOLOGY</b>
	18 <sup>th</sup> Dynasty:			
	Amhose 1	1570–1546		
	Amenhotep 1	1546–1524	<b>Funerary Temple (DEB)</b>	
	Thutmosis 1	1524–1518	(KV20)/KV38	Thebes
	Thutmosis II	1518–1504	unknown	
	Thutmosis III	1504–1450	KV34	
	Hatshepsut	1498–1483	KV	Thebes
			<b>KV20</b>	Thebes–Esna
	(Sennenmut)		(TT353)	
	Amenhotep II	1450–1419	KV35	
	Thutmosis IV	1419–1386	KV43	
	Amenhotep III	1386–1349	WV22	
	Amenhotep IV	1349–1334	?WV25	
	(Jeruef)		(TT192)	<b>Tarawan–Esna</b>
	Semenkhakara	1336–1334	unknown	
	Tutankhamen	1333–1325	KV62	<b>Thebes</b>
	Ay	1325–1321	WV23	
	19 <sup>th</sup> Dynasty:			
	Rameses I	1293–1291	KV16	
	Seti I	1291–1278	<b>KV17</b>	<b>Thebes–Esna</b>
	Rameses II	1278–1212	KV7	<b>Thebes–Esna</b>
	Merenptah	1212–1202	KV8	
	Amenmeses	1202–1199	KV10	
	Seti II	1199–1193	KV13	
	Siptah	1193–1187	KV47	
	Tausert	1187–1185	KV14	
	20 <sup>th</sup> Dynasty:			
	Horemheb	1321–1293	KV37	

11/9/08

Setnakht	1185–1182	KV14
Rameses III	1182–1151	KV11
Rameses IV	1151–1145	KV2
Rameses V	1145–1141	KV9
Rameses VI	1141–1133	KV9
Rameses VII	1133–1126	KV1
Rameses VIII	1126	unknown
Rameses IX	1126–1108	KV6
Rameses X	1108–1098	KV18
Rameses XI	1098–1070	KV4

**Thebes****Third Intermediate****Period** 21<sup>st</sup>–25<sup>th</sup> Dynasties 1070–664**Late Period** 26<sup>th</sup>–30<sup>th</sup> Dynasties 664–332**Graeco-Roman****Period** 332–+395

Table 1. Chronology of the three kingdoms, their dynasties, and pharaohs of the 18<sup>th</sup> through 20<sup>th</sup> Dynasty. Reference number of tombs (Wilkinson, 1837), and lithologies in which they were excavated (when observed by us). Relative and numerical chronology from Weeks (ed., 2001). For reasons given in Romer (1981) and Vandersleyen (1995), these chronologies are inconsistent between authors (compare Baines and Málek [1981], Vandersleyen [1995], Weeks [ed., 2001], Hawass [ed., 2003]). The relative chronology of the New Kingdom, however, essentially conforms to that of Manetho, the Egyptian priest of the Ptolemaic Period (as translated by Waddell, 1940). Bold face: lithology in which the funerary chamber was quarried. In (): Tombs of two 18<sup>th</sup> Dynasty nobles described in Fig. 9.

Said (1960) Awad & Ghobrial (1965)	El Naggar (1966)		Khalifa (1970)		Abdel Razik (1972)		Dupuis et al. (2003)		Aubry et al (2007)		
Thebes Formation Said (1960)	Thebes Formation	Thebes Limestone Mb.	Thebes Formation	Shaghab Mb.	Thebes Formation	Serai Limestone Mb.	Thebes Limestone Mb.	<b>Thebes Limestone Formation</b>			
				Dabbabiya Mb.							
				Hamidat Mb.							
Esna Shale Said (1960)	Thebes Formation	Thebes Calcareous Shale Mb.	Esna Shale	Abu Had Mb.	Esna Formation	Esna 3	<b>Abu Had Member</b>				
		Owaina Formation		Upper Owaina Shale Mb.		Esna Shale	"El Shaghab" Mb.	Esna 2	<b>El-Mahmiya Member</b>		
	<b>El Quda Bed</b>										
	Dababiya Quarry Beds							<b>Dababiya Quarry Member</b>			
	Owaina Formation	Upper Owaina Shale Mb.		Esna Shale		Esna Shale	"El Shaghab" Mb.	Esna Formation	Esna 1	<b>El Hanadi Member</b>	
<b>El Hanadi Member</b>											
Tarawan chalk Awad & Ghobrial, (1965)	Middle Owaina Chalk Mb.		Tarawan Chalk		Tarawan Chalk		Tarawan Chalk		<b>Tarawan Chalk Formation</b>		

11/9/08

Table 2. Lithostratigraphic framework for the upper Paleocene-lower Eocene succession in the Luxor area (from Aubry et al., 2007, table 1).