

# A PLIOCENE CLIFF-LINE AROUND THE GIZA PYRAMIDS PLATEAU, EGYPT

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## ABSTRACT

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Escarments bordering the Giza Pyramids Plateau represent the cliff-line of a Pliocene transgression up the pre-Nile ("Eonile") Valley. Geomorphologically, a limestone cliff can be distinguished from a slip-block shore associated with a distinct fining-up sequence. Differences in bedrock lithology and in structure (Joint pattern, faults) are morphogenetic Controls. The pre-Pliocene morphology with escarpments that allowed the development of later cliff-lines is related to deep incision of the Eonile drainage system caused by the desiccation of the Mediterranean Sea during the Messinian.

## INTRODUCTION

Rocky cliff-lines have only rarely been reported from the geological record (Radwanski, 1968, 1969; Surlyk and Christensen, 1974; Bridges, 1975) as compared to the variety of other clastic shorelines (cf. reviews of Elliot, 1978; Heward, 1981). Observations along modern coasts suggest that cliff development is mainly controlled by lithology, bedding differentiation, and structure of bedrock (Wilson, 1952; Trenhaile, 1972). Also most-cliff-lines seem to show a complex development involving — among others — changes in sea level, crustal movements and subaerial processes (King, 1975).

The object of this paper is to describe conspicuous ancient cliffs around the Giza Pyramids Plateau and to discuss controls for the development and morphology of this shoreline.

## GEOLOGICAL SETTING

The Giza Pyramids Plateau is located west of Cairo and represents a NE—SW striking "brachy-anticline" (Omara, 1953). It belongs to the Abu Roash Complex, a group of NE—SW trending synclines and anticlines, referred to a Late Cretaceous tectonic compression (Omara, 1953; Knetsch, 1958).

The Pyramids Plateau is formed by massive limestones and dolomites (nummulitic wacke—packstones) of the Middle Eocene Mokattam Formation, which dips with about 5—10° to the SE. Steep escarpments border the plateau to the north and to the east (Fig.1). Southwards, the Mokattam Formation is overlain by less-resistant sandy marls and marly, weakly cemented limestones (argillaceous mud—wackestones) of the Upper Eocene Maadi Formation. The top unit of the Maadi Formation comprises several meters of massive, partly dolomitized limestones (pack—grainstones) of the so-called "Ain Musa Bed" (for detailed stratigraphy see Strougo, 1977). The Maadi Formation shows a more gentle escarpment toward the Mokattam Formation in the north and to the Nile valley alluvium in the east. The present escarpments represent a Pliocene shoreline and document the transgression of the early Pliocene Sea from the Mediterranean up the pre-Nile valley ("Eonile", Said, 1981, 1982) after the largely continental Oligocene and Miocene times (Mayer-Eymar, 1903; Blankenborn, 1921; Sandford and Arkell, 1939; Said, 1962, 1981; Said and Martin, 1964). A thin wedge of Pliocene Sediments rests discordantly on the Maadi Formation, but only a veneer remains distinct against the Mokattam escarpment (Fig.1).

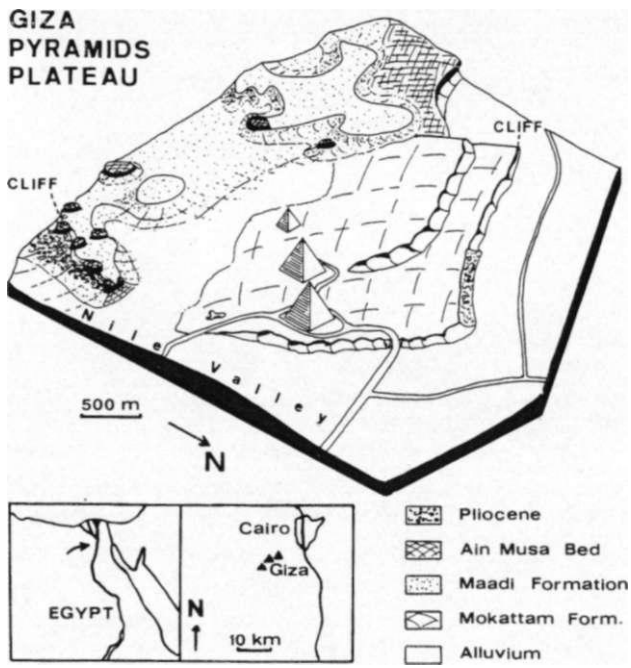


Fig.1. Location and generalized geological block diagram of the Giza Pyramids Plateau, Egypt.

## DESCRIPTION: COASTAL PALEOMORPHOLOGY

Geomorphologically, two distinct shoreline types can be distinguished:

### 1. *Limestone Cliff* (Fig.2)

The northern border of the Pyramids Plateau is characterized by two steep escarpments, each of which being about 30 m high. They are subdivided by an almost flat terrace, which may exceed 100 m in width. As shown diagrammatically in Fig.1, the eastern border of the plateau corresponds to the lower part of the northern escarpment.

The nummulitic limestones and dolomites exposed in quarries along the lower part of the northern escarpment are intensively bored by *Lithophaga* (Fig.2A, B), *Polydora*, *Cliona*, etc. and encrusted by balanids, serpulids, oysters, and brachiopods. (The fauna is being studied systematically by Dr. F. Hamza, Cairo.) The bored and encrusted zone can be followed laterally for several hundred meters, but then becomes indistinct due to intensive weathering. Vertically, it seems to be restricted to no more than about 10 m and shows at least two distinct "notches" (Fairbridge, 1966), where borings are exceptionally abundant (Fig.2A, B). The slope of the original cliff surface varies between 40° and 90°. Although no basal shore-platform has been found, poorly sorted conglomerates, including pebbles and boulders more than 1 m across are associated with the cliff-line in a talus-like manner. Many of these boulders are also bored and encrusted (Fig.2C). In plan view, the cliff-line has a distinct directional trend (NE—SW), but in detail its course is highly differentiated (see rose diagram in Fig.4C). Fig.2C shows a fissure in limestone bedrock which is filled with a chaotic mass of cliff-talus conglomerates and boulders. Additionally, there are isolated limestone outliers some tens of meters across, which are bored from several sides (Fig.2D). The outcrops allow a detailed reconstruction of the complex cliff-paleomorphology and emphasize the intensive physical and biological corrosion (cf. Neumann, 1966; Schneider, 1976; Torunski, 1979) of Eocene bedrock during exposure to the Pliocene Sea.

In contrast to the northern escarpment, no distinct cliff-talus deposits are present along the eastern escarpment of the plateau. *Lithophaga* borings are also scarce and indistinct. This is most probably caused by more intensive weathering and the lack of a protective drape of cliff-talus deposits which cover much of the northern cliff.

### 2. *Slip Block Shore* (Fig.3)

The Upper Eocene Maadi Formation, which overlies the Middle Eocene Mokattam Formation, is exposed in the southern parts of the Pyramids Platform (Fig.1). This is caused by the SE-dip of the Eocene rocks in the area. The Maadi Formation consists of a sequence of soft marly limestones and

# PLIOCENE CLIFF

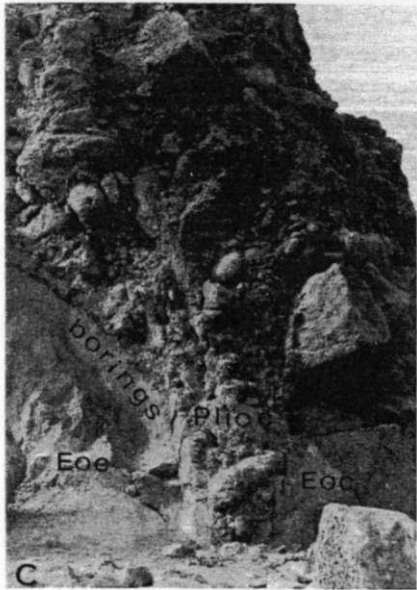
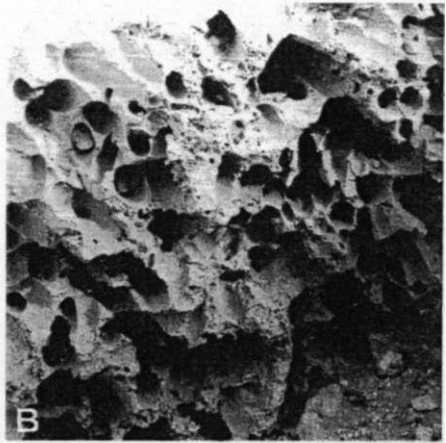
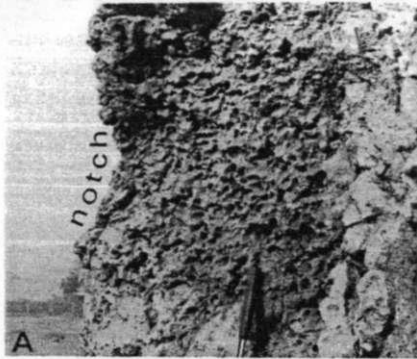
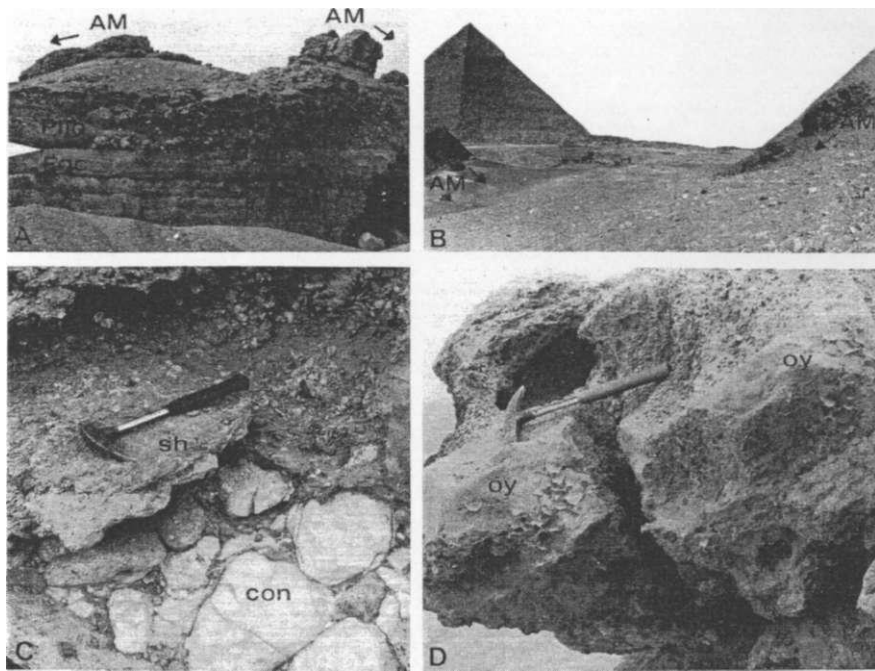


Fig.2. Limestone cliff at northern escarpment of Pyramids Plateau as exposed in quarries along Fayum road. A. Distinct "notch" which is extensively bored by *Lithophaga*. B. Close-up of *Lithophaga*-boreholes. C. Cliff talus deposits with bored boulders and conglomerates in a karst cavity of Eocene bedrock. D. Eocene nummulitic bedrock with *Lithophaga* attack from three sides.



**Fig. 3.** Some characteristic features of the slip-block shore south of the Pyramids. **A.** Angular disconformity (white arrow) with Pliocene conglomerates resting on Upper Eocene bedded limestones and marls. Note *AM* = Ain Musa slip blocks showing variable strike and dip (black arrows). **B.** Scattered Ain Musa (*AM*) slip blocks, lying discordantly on eroded Upper Eocene. Arrows indicate dip of blocks. **C.** Pliocene basal conglomerate (*con*) followed by shell accumulations (*sh*) as lower part of the fining-up transgressive shoreline sequence. **D.** Isolated cliff boulders with borings and encrusting oysters (*oy*).

sandy marls with some intercalated shell beds and sandstones. The top unit is formed by several meters of massive, partly dolomitized limestones of the "Ain Musa Bed".

A wedge of Pliocene deposits overlies the Maadi Formation with an angular disconformity, that dips with 10–20° towards the Nile valley (east). This disconformity is well exposed at Gebel Gibli Ahram, 300 m south of the Sphinx (Fig.3A, white arrow). The "Ain Musa Bed" is mostly not in-situ within the Eocene sequence, but became disintegrated into isolated large blocks, each of which being several meters to a few tens of meters across. These Ain Musa blocks lie discordantly and with variable strike and dip within the Pliocene deposits (Fig.3A, black arrows), or on the partly eroded Maadi Formation (Fig.3B, black arrows).

Between the Ain Musa blocks, the Pliocene deposits, though variable, show a fining-up sequence (Fig.4A). The lower part includes an unsorted

boulder conglomerate (Fig.3C, bottom); many of the clasts are bored and encrusted by oysters (Fig.3D). The conglomerates pass upward into patches of sandy shell accumulations (Fig.3C, top): *Ostrea cucculata* dominates in the "*Ostrea cucculata* Bed" (about 10m thick); *Chlamys scabrella* and *Pecten benedictus* in the "*Pecten benedictus* Bed" (about 2 m thick). These coquinas are overlain by several meters of low-angle laminated sandstones with *Clypeaster aegypticus* (Mayer-Eymar, 1903).

Using Walther's law of facies succession or current ideas along similar lines (e.g. Walker, 1980), the overall fining-up sequence observed in the Pliocene deposits may be interpreted as the result of landward migration of facies during a transgressive episode of the Pliocene Sea (Fig.4).

## DISCUSSION

Escarpmnts along the Giza Pyramids Plateau (and others along the Nile valley) were initially created by extensive down-cutting of the pre-Nile ("Eonile") drainage System as a response to desiccation of the Mediterranean Sea during the Messinian (Hsü et al., 1977; Said, 1981, 1982). The rising early Pliocene Sea invaded the oversteepened Nile "canyon" to form a long, narrow gulf that reached as far south as Aswan and had an average width of 12 km (Said, 1982).

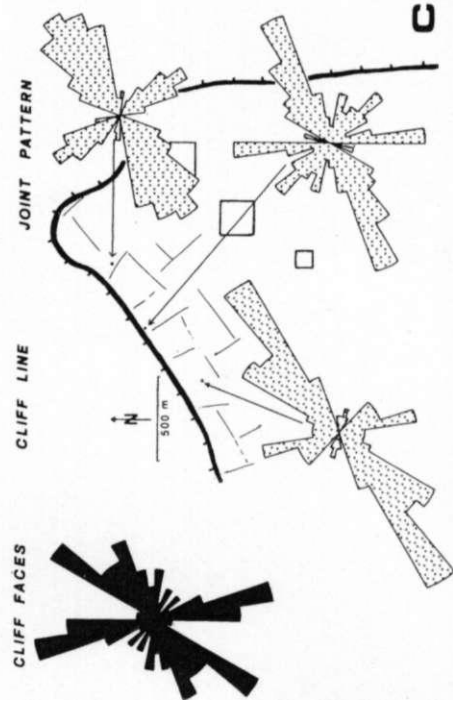
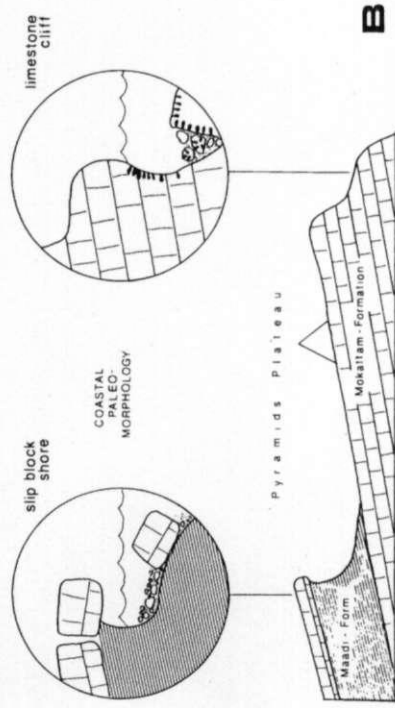
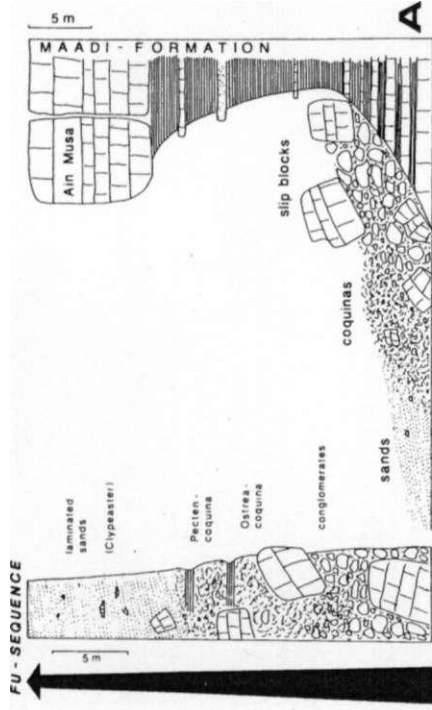
The escarpments formed by the Messinian Event served as shorelines for the transgressing Pliocene Sea. This is demonstrated by various geomorphological (e.g., cliff-slopes; intertidal notches, Fairbridge, 1966; slip blocks), sedimentological (e.g., cliff-talus deposits; karstic weathering), and ecological features (e.g., *Lithophaga* boreholes, cf. Schneider, 1976, fig.14) that are typical for cliff-lines. Although not all of these features are preserved along the entire length of the escarpments around the Giza Pyramids Plateau, it can be inferred that the Pliocene shoreline followed the present escarpments.

Two principal factors seem to have controlled the development and morphology of the Giza cliff s:

(1) Bedrock lithology. The Middle Eocene nummulitic limestones and dolomites (Mokattam Formation) outcropping in the northern and eastern parts of the Pyramids anticline favored the formation of a steep cliff because (a) they are very massive and thickly bedded, and (b) they are hard and relatively resistant to weathering (Fig.4B).

In contrast, the more terrigenous Upper Eocene Maadi Formation, outcropping in the southern parts of the Pyramids anticline, was more susceptible

**Fig.4. A. The observed Pliocene "fining-up sequence" (left) may be interpreted as a shoreline sequence caused by migration of coastal facies belts (right) during a transgressive episode of the Pliocene Sea. B. Schematic diagram illustrating the influence of bedrock lithology on the morphology of Pliocene clifflines around the Giza Pyramids Plateau. Not to scale. C. Diagram documenting structural control of shoreline trends: the shoreline directions correspond to the Joint pattern in the Eocene bedrock; in the east, a major fault along the Nile valley margin (Knetsch, 1953) might be an additional factor.**



to rapid shore erosion because (a) it comprises a thin-bedded limestone/marl sequence and (b) it is much softer and more susceptible to mechanical and chemical weathering. The hard and well-cemented Ain Musa Bed at the top of the Maadi Formation, however, was much more resistant to weathering. Thus, the massive Ain Musa Bed appears to have been undercut by coastal erosion. Consequently, the Ain Musa disintegrated into individual rock units that eventually moved seaward as slip blocks (Fig.4B) and became integrated into the Pliocene shoreline deposits. This Interpretation is supported by the fact that Ain Musa blocks are clearly out of place and show highly variable strike and dip values along the supposed shoreline (Fig.3A, B). In conclusion, shoreline paleomorphology was controlled by the lithology of the shore-forming bedrock (Fig.4B).

(2) Structure. The overall trends of the northern cliff-line corresponds to the predominant direction of joints in the Eocene bedrock following the strike of the Pyramids anticline (NE—SW) (Fig.4). Similarly, rose diagrams depicting the direction of individual cliff facies show the same maxima as rose diagrams of the Joint pattern (Fig.4C). The NNW—SSE direction of the eastern shoreline follows a major fault along the Nile valley (cf. fig.1 in Knetsch, 1953), and is also represented as a subordinate maximum in the rose diagrams (Fig.4C). Thus, the direction of shoreline trends is controlled by structural features in the Eocene bedrock.

During the Pliocene transgression, relative changes of sea level are suggested by two facts:

(a) The occurrence of at least two intensively bored "notches" indicates a multiple origin of the limestone cliff north of the pyramids. Whether or not the prominent terrace separating the lower from the upper escarpment represents a shore-platform of yet a higher sea level remains unclear. Caused by the lack of a protective veneer of cliff-talus deposits, recent weathering seems to have obliterated any distinctive features.

(b) Coastal onlap of Pliocene on Eocene bedrock and a fining-up sequence associated with the slip-block shore south of the pyramids document transgression during a relative rise in Pliocene sea level. This corresponds well to the curve of Vau et al. (1977), who suggest a global rise in sea level during early Pliocene times.

## CONCLUSIONS

Fossil cliff-lines provide the rare opportunities to "place one's finger" on ancient sea levels, which are commonly marked by an intertidal notch and by specific organisms like *Lithophaga*. Two shoreline types, morphologically controlled by (a) bedrock lithology and (b) structure, can be recognized in escarpments around the Giza Pyramids Plateau. The Plateau formed a "peninsula" within the Pliocene gulf invading the "Eonile canyon". Initial formation of these escarpments is related to steep downcutting of the pre-Nile drainage system due to desiccation of the Mediterranean during the Messinian



(Hsü et al., 1977; Said, 1981, 1982). Thus, the transgression of the Pliocene Sea from the re-flooded Mediterranean up the pre-Nile valley was facilitated by the erosional relief caused by the Messinian Event.