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Geologic history of the Neogene "Qena Lake" developed during the evolution of the Nile Valley: A sedimentological, mineralogical and geochemical approach

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ABSTRACT

Siliciclastic and carbonate sediments were laid down in southern Wadi Qena and around the Qena Nile bend (Middle Egypt) in a lacustrine–alluvial environment which dominated a relatively wide lake, the "Qena Lake" that interrupted the Nile course during the Neogene time. These sediments are represented mainly by the oldest dominantly lacustrine chocolate brown mudstones of the *Khuzam Formation* that accumulated nearer to the center of that lake (now forming a 185 m terrace above sea level), overlain by the dominantly lacustrine carbonates and marls of the *Durri Formation* which accumulated during semi-arid conditions, mainly nearer to the periphery of the lake (now forming 170, 180 and 185 m terraces a.s.l. in the studied sections). The water level of the "Qena Lake" reached 240 m. above sea level, as indicated by the maximum carbonate elevation reached in the region. Finally fanglomerates of the *Higaza Formation* with its chert and limestone conglomerates accumulated during torrential periods at higher elevations (forming 240, 300 and 400 m terraces a.s.l.). These three formations accumulated in this particular area before and during the unroofing of the basement rocks of the Eastern Desert, west of the watershed. According to the known Early Miocene initial development of the Nile Valley, beside the occurrence of similar deposits of Oligocene age along the eastern side of the basement range, the earlier known Pliocene age given for these sediments in the Qena area is here questioned. It might belong to earlier Miocene?–Pliocene times.

As the basement rocks of the Eastern Desert were still covered by Cretaceous–Paleogene sedimentary rocks while the Khuzam, Durri and Higaza Formations were accumulating in the Qena Lake region, it is believed, contrary to the belief of some authors, that the basement rocks of the Eastern Desert were not the source of these sediments. The carbonate petrographic study, beside the X-ray, and the11 major oxides and 22 trace elements analyses, all point to that the mudrock sediments of the oldest Neogene Khuzam and Durri Formations of the "Qena Lake" phase were carried out and entered the area of southern Wadi Qena and around the Qena Nile bend mainly from the south. The intermediate igneous rocks of southern Egypt and northern Sudan were the main source areas. Additional contributions had possibly come from the weathering of the non-marine to brackish Cretaceous (pre-Campanian) shales of southern Egypt.

Accumulation of conglomerates with mixed igneous and sedimentary clasts followed (forming 7 terraces in Wadi Qena, ranging from 240 m in the north to 140 m a.s.l. in the south), constituting the newly introduced Late Pliocene formation; *El Heita Formation*. These conglomerates were mainly drained from the then exposed basement rocks of the middle parts of Wadi Qena, and cut through the older Neogene sediments. Later on, after the lake became connected to the northern parts of the Nile Valley, the lake water level was lowered to 180 m a.s.l., and another lake with this lower level was formed (Isawiyya Lake). With the successive lowering of water level the younger well known *Issawia*, *Qena*, *Abbassia and Dandara* Formations accumulated successively; nearer to, and within, the present Nile Valley.

1. Introduction

The name "Qena Lake" denotes here a Neogene phase in the Nile history in which different facies associations representing

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environments of a lacustrine–alluvial fans complex accumulated at southern Wadi Qena and around the Qena Nile bend in middle Egypt. This Neogene phase is the bulk work of the present paper, whereas other later phases will be dealt with shortly when discussing the paleogeography near the end of this paper.

Philobbos (1969), Abdel Rahman (1980), Philobbos and Abdel Rahman (1990) and Ismail (2009) surveyed earlier works and mentioned that Barron and Hume (1902), Blancknehorn (1901, 1910, 1921), Ball (1903, 1907, 1939), Willcocks (1904), Arldt (1911), Gregory (1920), Awad (1928), Sandford and Arkel (1929, 1933, 1939), Sandford (1929, 1934), Huzzayin (1941), Said and Issawi (1964), Butzer and Hansen (1968), Giegengack (1968), Wendorf and Schild (1976), Hamroush (1980), Said (1975, 1981, 1983, 1990a, 1993) and Issawi (1983) were the most important authors who contributed to the geological history of the Nile basin.

Early workers including Barron (1869, in Barron and Hume, 1902), Beadnell (1900), Blanckenhorn (1900, 1921), Barron and Hume (1902), Sandford (1929), Ball (1939) and Said (1981, 1990a) believed in the existence of a long marine gulf (estuary?) along the Nile Valley which received sediments from its sides. Blanckenhorn (1900) believed in the existence of a series of half-brackish lakes with important streams flowing into them forming the oldest terraces, and also cones of detrital materials at their mouth. On the other hand, Barron and Hume (1902) introduced the idea of the existence of a fresh water lake near the mouth of Wadi Qena into which the sands were carried and deposited, and now found below limestones and marls. Philobbos and Abdel Rahman (1990) gave some information about the distribution of sediments in a fresh water lake that occupied the area around the Qena Nile bend. Sameeh et al. (1998), based on geochemical analyses, believed that the continental sediments of the oldest formation at the base of these "Qena Lake" sediments were derived by fresh waters provided by numerous wadis coming from the Eastern Desert of Egypt. On the other hand, El-Haddad (2007) emphasized tectonics as an important factor that controlled the distribution of the Neogene and younger sediments in this area.

Such differences in opinion regarding the environmental conditions and source of sediments, beside the scarcity of detailed sedimentological studies, initiated the present detailed work. We reconstruct the geologic history of the "Qena Lake", using sedimentological, mineralogical, and geochemical characteristics of its sediments. We aim mainly to elucidate the lateral facies changes and paleogeography of the sediments of the oldest phase of the Nile history, and we evaluate whether the lake was closed, receiving sediments only from its sides, or more open system being fed by water and sediments from the south.

2. Geographic and geologic setting

Cretaceous, Paleocene and Eocene sediments that pre-date the development of the Nile River are exposed on both sides of the Nile Valley and in major tributary valleys. Due to the gentle northwestward dip (1–2°) of such sediments, the oldest rocks are generally exposed in the south and east, covering basement rocks and are gradually covered northwestwards by the younger sediments. Eocene carbonates cap the plateau that extends on both sides of the Nile Valley down to Cairo area in the north.

In the area of the Qena Nile bend in middle Egypt (Fig. 1A) the plateau is dissected by valleys, of largest of which are Wadi Qena, Wadi El-Qirayyah, Wadi Abu Silimat and Wadi As Sarayy. These left the isolated mesas of Gabal Abu Had, Gabal Qirayyah, Gabal As Sarayy between the wide mouths of the mentioned valleys. The Neogene Qena Lake sediments lie in the relatively low-lying wide areas of the mouths of these valleys, skirting their sides and surrounding the mesas. Table 1 summarizes the names of the Cretaceous–Paleogene rock units that crop out in the mapped area as well as the rock units of the Neogene "Qena Lake" phase and the younger sediments as used in the present work.

3. Material and methods

The stratigraphic sequences cropping out in south Wadi Qena and around the Qena Nile bend were carefully mapped. A detailed geological map was prepared using aerial photographs of the scale 1:40.000, and Landsat Images of the scale 1:100.000 (Figs. 1A–1C). Twelve stratigraphic sections were measured and described in some detail (Figs. 2–4). The vertical and lateral variations of the different facies identified in the area were investigated carefully and the interrelationship between the lithostratigraphic units and the different recognized terraces are discussed in some detail.

For the sedimentological study two hundred and thirty-five rock samples were collected. Detailed carbonate–siliciclastic petrographic facies analysis and point counting was done for 76 thin sections cut in soft and indurated samples representing the limestones, claystones, siltstones and sandstones of the Neogene of southern Wadi Qena and around the Qena Nile bend area.

Twenty-seven representative bulk samples of the Neogene mudrocks were subjected to X-ray diffraction analysis to identify the mineralogical composition of these sediments and quantify the percentages of the minerals in each sample. In order to study more thoroughly the clay mineral content, the clay fraction (<2 μm) of these bulk samples was studied to identify the clay minerals and calculate their relative proportions. The weathering conditions and source areas of these mudrocks are discussed. The 27 samples were analyzed to determine the major oxides and trace elements content in order to evaluate the provenance of these rocks.

Finally the different sedimentological phases of development of the Neogene sediments in the study area as well as the different environments of the Neogene Qena Lake sediments are discussed in some detail.

4. Spatial distribution, petrography and sedimentary environments of the Neogene sediments

Four main rocks units constitute the basal sediments of the oldest Neogene phase of the "Qena Lake" which occupied the southern Wadi Qena area and the Qena Nile bend in middle Egypt. These are the Khuzam Formation (dominantly fine siliciclastics), Durri Formation (dominantly lacustrine carbonates), Higaza Formation (conglomerates entirely made up of limestone and chert) and El Heita Formation (conglomerates of mixed sedimentary, igneous and metamorphic components). The following is a detailed description of their characteristics.

4.1. Khuzam Formation

The basal lacustrine sediments in the area consist of claystones and siltstones recording fine grained sedimentation toward the center and base of the ancient lake. These compose the Khuzam Formation which grades upwards into lacustrine marls and limestones (including algal oncolites in southern Wadi Qena and Wadi Abu Silimat) of the Durri Formation.

4.1.1. Nomenclature

Philobbos and Abdel Rahman (1981, 1990).

4.1.2. Synonymy

The Khuzam Formation was called Melanopis Stufe by Blancknehorn (1901, 1921), the chocolate brown clays of the Gulf