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The uppermost deposits of the stratigraphic succession of the Farafra Depression (Western Desert, Egypt): Evolution to a Post-Eocene continental event

M.E. Sanz-Montero[a,*], H. Wanas[b], M.B. Muñoz-García[c,1], L. González-Acebrón[c,1], M.V. López[d,2]

[a] Dpto. Petrología y Geoquímica, Facultad Ciencias Geológicas, Universidad Complutense de Madrid (UCM), C/José Antonio Novais 12, 28040 Madrid, Spain
[b] Geology Department, Faculty of Science, Menoufia University, Shebin El-Kom, Egypt
[c] Dpto. Estratigrafía, Facultad Ciencias Geológicas, Universidad Complutense de Madrid (UCM), C/José Antonio Novais 12, 28040 Madrid, Spain
[d] Instituto de Geociencias (CSIC, UCM), C/José Antonio Novais 12, 28040 Madrid, Spain

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ABSTRACT

This paper gives insight into continental sedimentary deposits that occur at the uppermost part of the stratigraphic succession present in the north-eastern sector of the Farafra Depression (Western Desert, Egypt). Using space imagery to complete the field work, the geology of the area has been mapped and the presence of a N–S oriented fault system is documented. The analysis of the morphotectonic features related to this fault system allows reconstructing the structural and sedimentological evolution of the area. The study indicates that the continental deposits were accumulated in alluvial systems that unconformably overlie shale and evaporitic rocks attributable to the Paleocene–Eocene Esna Formation. The deposits of the Esna Formation show soft-sediment deformation features, which include slump associated to dish and pillar sedimentary structures and provide evidence of syndepositional tectonic activity during the sedimentation of this unit. The outcrops are preserved in two areas on separated fault-bounded blocks. Proximal alluvial fan facies crop out in a dowthrown block close to the depression boundary. The proximal facies are made up mostly by polymictic conglomerates which occasionally contain boulders. The conglomerate clasts are mainly quartz, carbonate, anhydrite satin spar vein, mudrock, ironstone and nummulite fossils. The mid-fan facies consist of trough cross-bedded, rippled and cross-laminated quartzarenites with reworked glauconite grains and carbonate rock fragments, interpreted as deposited by distributary streams. The distal alluvial fan deposits consist of sandy marls that evolve toward the top of the sections into root-bioturbated lacustrine limestone beds that are locally silicified. The limestones are biomicrites containing characea, ostracods and gastropods with fenestral porosity.

A number of features, including clast provenance (mainly from marine Paleocene and Eocene rocks), the observed fractural pattern (N–S direction related to the opening of the Red Sea), and the sedimentary relationships, suggests that the continental deposits were accumulated during the Oligocene–Miocene interval.

1. Introduction

The Farafra Depression is a semi-closed basin situated within the Western Desert of Egypt (Fig. 1a). Structurally, the depression is included in the so called Stable Shelf (Said, 1962, 1990). The Stable Shelf is located towards the south of the Unstable Shelf domain that forms part of the Syrian arc belt (Fig. 1a). This division into two geotectonic domains started during the Late Cretaceous and was synchronic with the closure of the Tethys Sea where the Cretaceous sedimentation took place due to the convergence of the North-African and the European tectonic plates (El-Motaal and Kusky, 2003). The drift of the North-African plate caused uplifting and folding of the Cretaceous depression according to an ENE–WSW direction. Related faults follow the same pattern.

According to El-Motaal and Kusky (2003), the separation of the Arabian plate from Africa that initiated in Oligo-Miocene time through the Red Sea rift enhanced the intensity of the folding and thrusting of the study area. Additional shortening and left-lateral offset along the almost N–S oriented Dead Sea transform fault began in the Miocene and is still active at present.

* Corresponding author. Tel.: +34 913944918.
E-mail addresses: mesanz@geo.ucm.es (M.E. Sanz-Montero), hamdallawanas@yahoo.com (H. Wanas), mbmunoz@geo.ucm.es (M.B. Muñoz-García), lgcebron@geo.ucm.es (L. González-Acebrón), valle.lopez@igeo.ucm-csic.es (M.V. López).
[1] Tel.: +34 913944785.
[2] Tel.: +34 913944796.

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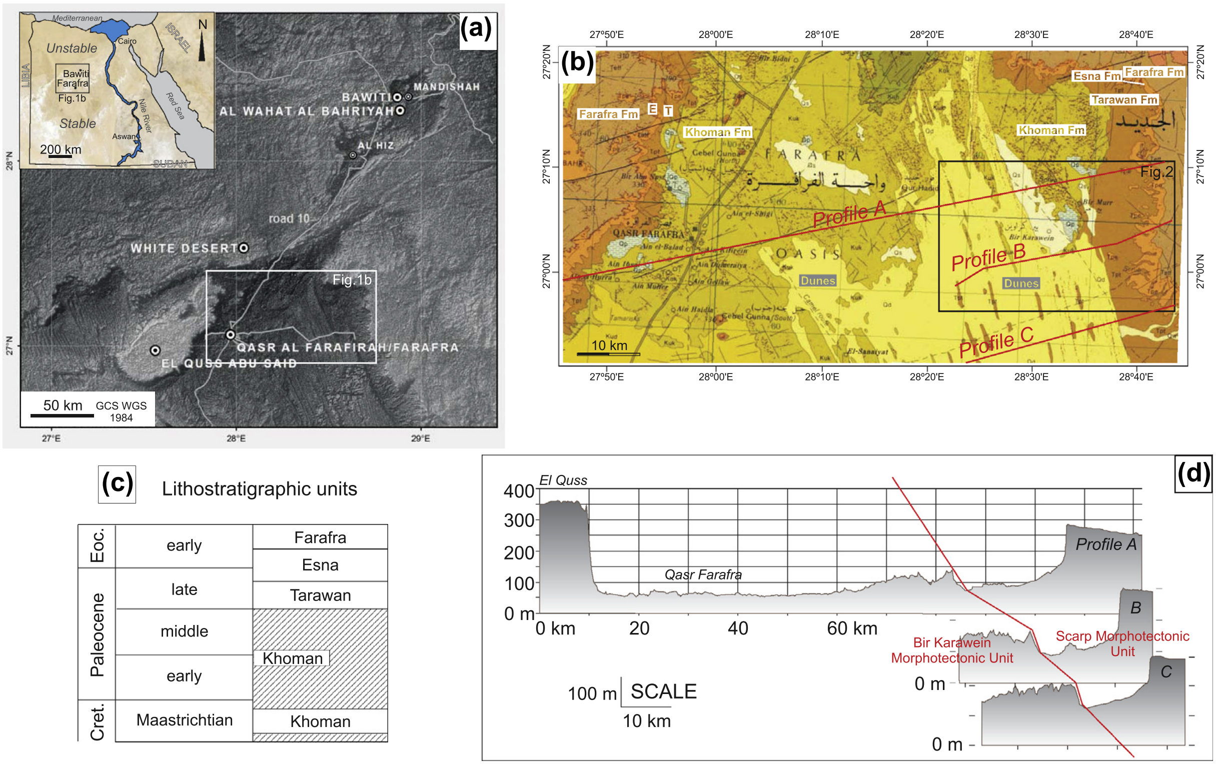

Fig. 1. (a) Location map of the study area. (b) Geological map of the northern part of the Farafra Depression (Conoco, 1987). (c) Upper Cretaceous to Paleogene lithostratigraphic units for the Farafra Depression after Hermina (1990). (d) Three profiles showing the different topographic features of the selected morphotectonic units. The trace of the profiles is shown in Fig. 1b. Profile b lies along the study outcrops.

After folding, there were periods of heavy rainfall during Oligocene (El Agami, 1989). The depression center was excavated due to the combined action of running water and wind, generating the Farafra Depression. The depression is limited by scarps and contains a record of the marine Upper Cretaceous to Eocene sediments (Fig. 1b and c) (Said, 1962; Youssef and Abdel-Aziz, 1971; Werner and Herrmann-Degen, 1981). The depression and its cliffs are sculptured in four marine sedimentary formations, namely the Maastrichtian Khoman Formation and the Paleogene Formations: Tarawan, Esna and Farafra (Fig. 1c). The Khoman Formation consists of chalk deposits that cover most of the depression area. The erosion of this carbonate formation has generated spectacular and geomorphologically attractive shapes, best represented in the White Desert Area National Park (Fig. 1a).

In the north-eastern scarp the sedimentary succession is composed of the Esna and Farafra Formations. The Esna Formation is widely distributed in Egypt and neighboring regions. It consists mainly of marine shales (Said, 1962) and is dated by planktonic foraminifera as late Paleocene, reaching the early Eocene in the area of Gebel Gunna (Abdel-Kireem and Samir, 1995), located 50 km towards the W of the study area. The Esna Formation is conformably covered by the Farafra fossiliferous limestones (Figs. 1 and 2).

Recently, in his study of the Farafra Depression, Wanas (2012) indicated the presence of continental deposits toward the upper part of the stratigraphic succession located at the eastern part of the depression. Despite the area has been object of different studies (Said, 1962, 1990; Issawi, 1972; Issawi et al., 1999; Tawadros, 2001), a geological framework for the continental record has been hampered by the lack of structural reconstructions, the poor age control as a result of a poor fossil record and the sparsity of the outcrops. The object of this study has been to place the uppermost deposits of the stratigraphic succession in a more specific geological context, and to get a better knowledge of the Post-Eocene evolution of the Farafra Depression and its possible relation to the Red Sea opening.

2. Methods

The study area (Fig. 1b) was recognized and 15 samples were collected from four representative stratigraphic sections (Fig. 2). Due to the area characteristics (a sand desert with scarce roads) we analyzed satellite images, and digital topographic models, which allowed us to cover more extensive areas and to complete the tectonic, geomorphologic and sedimentologic information available.

Three types of remotely sensed data were used: (1) Visible and infrared imagery of the Earth́s land from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), sensor on board the satellite Terra that provide multiresolution (15, 30 and 90 m) and 14 wavelengths from visible light to thermal infrared bands; we used ASTER images acquired in years 2010 and 2011. (2) Digital topographic maps from the Shuttle Radar Topography Mission (SRTM) of the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA). (3) Images of the surface of the Earth from July 1982 to November 2011 with a spatial resolution of 30 m, from the Landsat Thematic Mapper (TM) sensor on board Landsat 4 and 5. The data were integrated in a Geographic Information System, with WGS 84 as Coordinate System.

Thin sections of all samples were prepared and studied by standard petrography. Samples with high evaporite content were performed without water and were not covered with lack to avoid their alteration. The thin sections with carbonate were stained by using Lindholm and Finkelman (1972) method to facilitate carbonate distinction.