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Facies analysis and sequence stratigraphy of the Eocene successions, east Beni Suef area, eastern Desert, Egypt

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ABSTRACT

Three Eocene stratigraphic successions east of the Beni Suef area are described and measured. These successions are made up of four rock units that are from base to top: Qarara (upper Lutetian), El Fashn (Bartonian), Beni Suef, and Maadi (Priabonian) formations. A detailed facies and sequence analysis unravels the stratigraphic framework and constructs a depositional model for the Middle-Upper Eocene succession. Ten microfacies types were grouped into four facies associations on a homoclinal ramp that compose the Upper Lutetian-Priabonian succession exposed in the east Beni Suef area. The depositional environment varied from a shallow to deep ramp setting. Four third-order depositional sequences were identified in the studied sections. The sequence boundaries are paleosoil horizons that can be traced throughout the entire outcrop area. Missing biozones are also evidence of the sequence boundaries. The history of these sequences mirrors the eustatic sea-level changes and the local tectonics in the region. Each sequence comprises facies associations that make up lowstand and/or transgressive and highstand systems tracts. The lowstand systems tract (LST) deposits are mainly sandstone facies and in Sequences 3 and 4 at Gabal Abyiad and Gabal Homret Shaibun respectively. The transgressive systems tract (TST) of Sequence 1 is dominated by nummulitic facies at Gabal Diya. The shale, mudstone and wackestone facies with planktic foraminifera and echinoids dominate the TST of Sequences 2 and 3 at Gabal Abyiad and Gabal Homret Shaibun respectively. The highstand systems tract (HST) of the studied sections is characterized by benthic foraminifera and bryozoan wackestone and packstone facies.

1. Introduction

The Eocene stratigraphic sequence in Egypt generally shallows up reflecting continuous and progressive uplift of the African craton, which resulted from the compressive tectonics between Africa and Eurasia (El Hawat, 1997). The marine Eocene rocks were deposited in narrow, elongate tectonic basins that formed arms of the Tethys Sea and were separated by elongate structural ridges that formed during Late Cretaceous tectonic activity (Salem, 1976).

In general, a wide transgression of the Paleocene carbonate platform was followed by a slight regression of the shoreline during the Early and Middle Eocene. According to the paleogeographic maps and the distribution of the marine Eocene rocks (Said, 1962, 1990), the Lower Eocene shoreline extended south of latitude 23°30′N. However, the Middle Eocene shoreline reached southern Egypt at latitude 27°N. The observed facies variation has been considered as evidence of rapid regression of the sea northward during the Middle Eocene times (El Hawat, 1997; Sallam et al., 2015b; Wanas et al., 2015).

The Middle Eocene successions from Assiut to Cairo form shoaling up cycles of bioclastic algal limestone rich in *Nummulites gizehensis*, echinoids and oysters. This facies association was deposited in tidal flat, lagoon, shoals and shelf-edge environments (Philobbos and Keheila, 1979). The Middle Eocene shallowing event is recognized in different areas of Egypt (Abul-Nasr and Thunell, 1987; Strougo et al., 1992; Sallam et al., 2015b; Wanas et al., 2015) and is consistent with the global eustatic lowering of the sea level that marked the end of the Middle Eocene (Haq et al., 1987). By Bartonian–Priabonian transition time, a major compressional event resulted in a regional unconformity, which extends from southeastern Sirt, to the north Western Desert, the Nile Delta, Gulf of Suez, the northern Red Sea and into southern Israel (Guiraud et al., 2005).

The stratigraphy and paleontology of Eocene rocks in the study

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area have attracted the attention of many researchers (Bishay, 1966; Omara et al., 1977; Bassiouni et al., 1974; Hassan et al., 1978; Strougo and Azab, 1982; Boukhary and Abdelmalik, 1983; Mansour and Philobbos, 1983; Abd-Elshafy et al., 1983; Abdallah et al., 1983; Strougo et al., 1984; Haggag, 1986; Strougo, 1986; Philip et al., 1991; Obaidalla and El Ayyat, 2001; Abd El-Gaied and Abd El-Aziz, 2005; El-Dawy and Dakrory, 2005; Abd El-Aziz and Abd El-Gaied, 2006; Hegab and Abd El-Wahed, 2016). However, facies analysis and sequence stratigraphy have not been seriously attempted for the Eocene succession in the study area except for the work of Gharieb (2003). Our work, therefore, describes in detail the stratigraphic sequence framework of this Eocene succession. These results are based on understanding the stratigraphic setting and the sedimentary facies of the Middle-Upper Eocene successions in the east Beni Suef area.

2. Material and methods

Three stratigraphic outcrops of the Middle-Upper Eocene successions on the eastern side of Beni Suef were measured, sampled and described: 1) at Gabal Diya (Latitude 28° 35′N and Longitude 30° 59′E), 2) at Gabal Abyiad (Latitude 28° 44′N and Longitude 31° 00′E) and 3) at Gabal Homret Shaibun (Latitude 29° 09′N and Longitude 31° 17′E) (Fig. 1). The lithological features and sedimentary structures were described bed-by-bed in the field and associated fossils collected, defined and identified. Indurated rock samples were thin-sectioned and investigated under a standard polarised microscope. During field work key sedimentary surfaces in the studied stratigraphic sections were described and recorded.

3. Stratigraphy

The stratigraphy of Eocene rocks has been reviewed by many authors for different outcrops in north Egypt (Höntzsch et al., 2010; El-Fawal et al., 2013; Sallam et al., 2015a,b; Abuseda et al., 2015; Tawfik et al., 2016), and different depositional systems have been proposed for the various lithologies of the Eocene rocks. The exposed sections in the area under investigation are divided into four rock-units (Table 1) from base to top: Qarara (upper Lutetian), El Fashn (Bartonian), Beni Suef, and Maadi (Priabonian) formations. A detailed descriptions of these rock-units follow below.

3.1. Qarara Formation

This rock-unit was named by Bishay (1966) for the limestone successions (170 m) exposed east of Maghagha in Gabal Qarara. The limestone succession is unconformably underlain by the Middle Eocene Maghagha Formation, which is composed of limestone and marl with minor reddish clay interbeds and *Nummulite* banks at the base (Said, 1990). In the study area, the Qarara Formation is about 120 m thick at Gabal Diya (Fig. 2). The lower part of this rock unit is composed of variably coloured mudstone with gypsum veinlets, glauconites, iron concretions and siltstone lenses (Fig. 3A and B). The lower part of the Qarara Formation at Gabal Qarara is topped by the highly fossiliferous bed termed the *Tympanotonos aegyptiacus* bed by Strougo and Azab (1982). It is locally characterised by the presence of reptilian teeth, and plant remains. The middle part of the Qarara Formation is characterised by the occurrence of several *Thalassinoides* horizons (Fig. 3C). The limestones here are intercalated with glauconitic shale and fossiliferous marl with echinoids, oysters, *Carolia* sp., and other bivalves. Moreover, the middle part of the Qarara Formation is characterised by the presences of several *Nummulites gizehensis* banks (Fig. 3D). The bases of the *Nummulites* banks are undulating and characterised by the development of scouring and imbrications. The upper part of the Qarara Formation is a yellowish sandy, fossiliferous limestone and marl intercalations with *Nummulites* sp., large gastropods and echinoids. This part of the Qarara Formation is exposed at the base of Gabal Abyiad, where the facies change laterally to argillaceous limestone, and yellow marl with gypsiferous mudstone intercalations. This part weathers with a bouldery appearances, honeycomb structures and *Thalassinoides*. Moreover, planktic foraminifera are dominant in this part. The Qarara Formation is of Late Lutetian age (Bishay, 1966; Omara et al., 1977; Mansour and Philobbos, 1983; Kenawy et al., 1988).

3.2. El Fashn Formation

This term was introduced by Bishay (1966) to describe the limestone and marl intercalations exposed at El Fashn area. In the Gabal Abyiad section, the El Fashn Formation measures 135 m thick (Fig. 2), and unconformably overlies the Qarara Formation (Fig. 4A). The base of this rock-unit is bedded chalky limestone with chert nodules and bands that are overlain by shale with gypsum veinlets. The chert nodules are parallel to the bedding plane and vary in shape and size. The upper part of El Fashn Formation consists of yellowish white limestone intercalated with marl. The limestone is fossiliferous, highly bioturbated, and lensoidal in shape. At the Gabal Diya section the El Fashn Formation is 10 m thick. It consists of chalky white limestone with chert nodules and bands (Fig. 4B and C). It is bioturbated at the base and highly fossiliferous with large gastropods (Fig. 4C). The presence of planktic foraminifera such as *Truncorotaloides rohri* and associated spinose forms, especially *Morozovella* spp., *Truncorotaloides* spp., and *Acarinina* spp. support the late Middle Eocene (Bartonian) age of the El Fashn Formation (Abd El-Gaied, personal communication).

3.3. Beni Suef Formation

Bishay (1966) introduced this name to designate the succession exposed at Gabal Homret Shaibun. In the present study, this rock-unit is subdivided into the El Qurn and Tarbul members from base to top as follows:

3.3.1. El Qurn Member

Farag and Ismail (1959) introduced this name as a series to describe the exposed succession east of the Helwan area. However, Mansour et al. (1982) considered it a member of Beni Suef Formation at Gabal Tarbul. The El Qurn Member unconformably overlies the El Fashn Formation. This unconformable relationship is marked by a paleosol horizon (50 cm thick) of red, gypsiferous, hematitic and limonitic mudstone (Fig. 4D). The El Qurn Member is composed mainly of gypsiferous shale with lenticular beds of yellow siltstone. The shale beds are intercalated with yellow marl and argillaceous limestone. In the present work, the Upper Eocene El Qurn Member is described for the first time from the top of the Gabal Abyiad area as composed of shale and sandstone beds capped by a hard limestone bed (Fig. 5A and B).

3.3.2. Tarbul Member

This member was first introduced by Mansour et al. (1982) at Gabal Tarbul to describe a 60 m thick unit of argillaceous limestone and marl topped by dolomitic limestone beds. In the present work, this member is 22 m thick and consists of several shallowing upward cycles. Each cycle starts with yellowish white marl capped by argillaceous, bioturbated nummulitic limestones that form ledges. The bases of each nummulitic limestone is characterised by scour and fill structure (Fig. 5C).

The occurrence of *Nummulites striatus* and *Nummulites beaumonti* indicates the earliest Late Eocene Epoch (Kenawy et al., 1988). Moreover, the presence of *Nummulites striatus* indicates the Late