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Original article

Calcareous nannofossil biostratigraphy and paleoclimatology of the Paleocene succession, Tenida area, Western Desert, Egypt

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Abstract

This study is a preliminary quantitative analysis of Paleocene calcareous nannofossil assemblages of the Tenida area (Egypt) in order to establish a detailed biostratigraphic framework as well as to reconstruct the paleoclimatic trends. A total of 48 samples with an average sample spacing of 1.5 m allowed the identification of 63 calcareous nannofossil species belonging to 19 different genera. The preservation of the studied samples varies from poor to moderate and is characterized by the frequent presence of small frangible placoliths, and nannoliths. This study recognizes three calcareous nannofossil biozones in the Danian-Thanetian time interval; *Chiasmolithus danicus* (NP3) Zone, *Ellipsolithus macellus* (NP4) Zone, and *Heliolithus kleinpellii* (NP6) Zone. Moreover, the multivariate statistical analysis of the calcareous nannofossil communities reveals a relationship between the distribution of these nannofossil assemblages and variations in paleoclimatic trends. Accordingly, the relative abundances of *Coccolithus pelagicus* in addition to nine calcareous nannofossil genera along with the diversity and preservation indices of calcareous nannofossil elements have been used to elucidate changes in paleoclimatic trends. Based on the cyclic change from cold to warm climates, it was possible to subdivide the Paleocene Period recorded in the Tenida section into four paleoclimatic intervals. The oldest is a global cooling trend spanning 2.01 Myr long, starting in the early Paleocene (Danian) during the deposition of the lower part of the Kharga Shale Member. This cooling trend is followed by a ~0.56 Myr warming trend during deposition of the middle part of the Kharga Shale Member that was followed by a return to a cooling mode, with an estimated duration of roughly 1.67 Myr. The last interval includes a 0.39 Myr long period at the Selandian/Thanetian boundary interval, which is dominated by a global warming trend during deposition of the upper part of the Upper Kharga Shale Member.

Keywords: Calcareous nannofossil; Biostratigraphy; Paleoclimatic analysis; Danian/Thanetian; Dakhla Oasis; Western Desert

1. Introduction

Lateral facies variations, paleoenvironmental changes, and sedimentation breaks are all characteristic features of the Paleocene succession exposed at Tenida along the eastern escarpment face of the Dakhla Oasis, Western Desert, Egypt. Consequently, the regional geology of the Western Desert is complex (Hermina, 1967). The calcareous nannofossil biostratigraphy of the Dakhla Oasis has been the subject of a few previous works (El-Dawoody and Zidan, 1976; Faris, 1984; Faris et al., 1999; Tantawy et al., 2001; Khalil and Al Sawy, 2014). The latest Paleocene–Eocene succession was examined for nannofossils by El-Dawoody (1977) and Youssef (2015), but a similar study for the Paleocene interval is still missing. The present work offers the first calcareous nannofossil biostratigraphic study of the Paleocene succession in the Tenida area.

The Paleocene represented an epoch when the climate system was undergoing dramatic shifts during a period of elevated greenhouse gas levels (Zachos et al., 2008; Westerhold et al., 2011). Previous paleoclimatic reconstructions during the Paleocene reveal a somewhat history of initial long-term cooling followed by warming, with various rapid transitions and short-term events (Zachos et al., 2001). The paleoclimatic evolution of the uppermost Cretaceous to Eocene in the Dakhla Oasis has been the subject of numerous studies (Abd El-Hameed and Faris, 1984; Bassiouni et al., 1991; Tantawy, 1998; Bolle et al., 2000; Youssef and Mutterlose, 2004; Youssef, 2015). Unfortunately, no detailed study on the reconstruction of sea surface water temperature of the exposed Paleocene succession has been published so far. The present study is the first attempt to reconstruct the paleoclimatic trends of the Paleocene

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succession exposed in the Tenida area of the Dakhla Oasis, based on calcareous nannofossils and their preservation index. Several relevant paleoclimatic evolution studies have been conducted in nearby areas including Adatte et al. (2002), Scheibner and Speijer (2008), Dallanave et al. (2012), and Giraldo-Gómez et al. (2016) in Turkey, Italy, and Jordan regions. The present study aims to construct a high-resolution biostratigraphic framework and depict the paleoclimatic trends of the Paleocene succession exposed in Tenida with the specific end goal to validate the palaeogeographic evolution of the Dakhla sub-basin. This purpose contributes primarily to the sub-surface geology of the North-Western Desert, which is one of the principal petroleum regions in Egypt, where there are potential source rocks and hydrocarbon reservoirs.

2. Regional setting

2.1. Geological setting

The Tenida section is situated along the eastern escarpment face of the Dakhla Oasis, Western Desert, Egypt (Lat. 25° 32′ 00″ N, Long. 29° 23′ 00″ E; Fig. 1). Different authors have studied the geology and geomorphology of the Dakhla Oasis (e.g., Beadnell, 1905; Hermina et al., 1961; Said, 1962; Mansour, 1973; Wycisk, 1993).

The main topographic feature of the Dakhla oasis is the steep scarp, which bounds the depression of the oasis on its northern side. The depression of the oasis extends from Tenida in the east to El-Mawhoob towards the west (Fig. 1). The depression outcrops in the Nubian red clays and has been exhibited by a vast plain. It extends from the Kharga Oasis in the east to the farthermost west of the Dakhla Oasis and continues out towards the south and southwest. Its floor continuously blends southward into the Nubian Sandstone higher plain (Brookes, 1993).

The floor of the plain is composed mainly of red clays similar to the Quseir Formation and covered in some localities by alluvium deposits, which are partially cultivated. Typically, the successive sedimentary formations within the Dakhla depression, dip steadily northward and consequently, every formation has an extensive outcrop. In general, these formations expose at the cliff to the north of the basin and do not appear in the oasis depression itself (Ezzat, 1976). The Cretaceous-Eocene succession is a primary sedimentary cover in Dakhla Oasis and was subdivided into some mappable lithostratigraphic units. The units are relegated into two categories: Jurassic-Campanian sequence, predominantly continental but with marine intercalations, and the Campanian-Lower Eocene transgressive-regressive open marine sequence (Hermina, 1990).

2.2. Lithostratigraphy

The Paleocene sedimentary sequence exposed in the Tenida area of the Dakhla Oasis is represented by the following three formally defined formations, arranged from oldest to youngest as follows: Kurkur Formation, Upper Kharga Shale Member and Tarawan Formation (Fig. 2). Both Kurkur and Tarawan formations yield rare calcareous nannofossils, while the Upper Kharga Shale Member of the Dakhla Formation is richly fossiliferous.

The exposed part of the Kurkur Formation at Tenida is 16 m thick and made of massive dark brown dolomitic limestone with silty shale interbeds (Fig. 2). The limestone is fossiliferous with bivalves and echinoids. Moreover, the Kurkur Formation is wholly interfingered and occurs as a thin tongue on top of an unconformable surface within the Kharga Shale Member of the Dakhla Formation (Hermina, 1990). The unconformity represented the Cretaceous/Paleogene (K/Pg) boundary, which typifies a regional unconformity in the Western Desert and was recorded by many authors (e.g., Luger, 1985; Hewaidy, 1990; Abdel-Kireem and Samir, 1995; Tantawy et al., 2001). In the study area, this boundary is marked by the presence of a 20–30 cm thick brownish phosphatic and conglomeratic siltstone band (surface A; Fig. 2).

The Kharga Shale Member, identified as the upper member of the Dakhla Formation, was separated into Lower and Upper Kharga Shale members (Luger, 1985). The Upper Kharga Shale Member is composed of a 23-m thick mainly gray to greenish-gray calcareous shale, partly phosphatic and organic-rich with a few mudstone interbeds (Fig. 2). Its lower boundary probably represents an unconformity surface that marks an abrupt discontinuity in facies and calcareous nannofossil content between the Kurkur and Dakhla formations. It is distinguished by an irregular surface of bioturbated shaly limestone with chert fragments (surface B; Fig. 2).

On the other hand, the Tarawan Formation forms the top escarpment face of the eastern plateau surrounding the Dakhla Oasis. It unconformably overlies the Upper Kharga Shale Member of the Dakhla Formation. The Kurkur/Upper Kharga Shale Member contact is marked by an irregular surface of bioturbated marl to silty shale with limestone nodules, and few ferruginous sandstones as an effect of burrowing at the top of the Dakhla Formation (surface C; Fig. 2). The Tarawan Formation is up to 25 m thick and made of is massive to thick-bedded chalky and argillaceous snow-white limestone.

3. Material and methods

3.1. Sample preparation

The Paleocene vertical outcrop of the Tenida section had a total thickness of about 76 m and was sampled with an average sample spacing of 1.5 m (Fig. 2). Forty-eight samples were studied for calcareous nannofossil assemblages. The samples were carefully cleaned and all weathered material removed. Nannofossil slides were produced using the random settling technique of Geisen et al. (1999), which allows the determination of absolute concentrations of calcareous nannofossils (N specimens/g sediment).

The taxonomic concepts of various authors were used to identify the calcareous nannofossils in this study (Aubry, 1984, 1988, 1989, 1990, 1999; Perch-Nielsen, 1985; Bralower and Mutterlose, 1995; Bown, 2005; Fornaciari et al., 2010). The biostratigraphic schemes adopted are those of Martini (1971) and Okada and Bukry (1980). Besides, the biostratigraphic zonal