Journal of African Earth Sciences 105 (2015) 85–92

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

Larger benthic foraminiferal turnover across the Eocene–Oligocene transition at Siwa Oasis, Western Desert, Egypt

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ARTICLE INFO

Article history:
Received 10 April 2014
Received in revised form 4 March 2015
Accepted 5 March 2015
Available online 14 March 2015

Keywords:
Eocene–Oligocene-Siwa
Oasis-Larger
Foraminifera-Egypt

ABSTRACT

In the Eocene part of the Siwa Oasis, the larger foraminifera are represented by the genera *Nummulites*, *Arxina, Operculina, Sphaerogypsina, Asterocyclina, Grzybowskia, Silvestriella, Gaziryina* and *Discocyclina* in order of abundance. *Operculina* continues up to the early Oligocene as modern representatives in tropical regions, while the other genera became extinct. Nevertheless, the most common larger foraminiferal genus *Lepidocyclina* (*Nephrolepidina*) appears only in the lowermost Oligocene.

In spite of the Eocene–Oligocene (E/O) transition is thought to have been attended by major continental cooling at northern middle and high latitudes, we discover that at the Siwa Oasis, there is a clear warming trend from the late Eocene (extinction level of *Nummulites*, *Sphaerogypsina, Asterocyclina, Grzybowskia*, *Silvestriella* and *Discocyclina*) to the early Oligocene is observed due to the high abundance of *Operculina* and occurrence of kaolinite and gypsiferous shale deposits in both Qatrani and El Qara formations (Oligocene) at this transition. The El Qara Formation is a new rock unit proposed herein for the Oligocene (Rupelian age) in the first time.

Several episodes of volcanic activity occurred in Egypt during the Cenozoic. Mid Tertiary volcanicity was widespread and a number of successive volcanic pulses are starting in the late Eocene. The release of mantle CO_2 from this very active volcanic episode may have in fact directly caused the warm Eocene–Oligocene greenhouse climate effect.

1. Introduction

The Eocene–Oligocene climate transition (EOCT), is often cited as the most important interval of climate change during the Cenozoic because it heralds the switch from the warmer, equable, global greenhouse climates of the late Mesozoic and early Paleogene to the cooler, more seasonal, icehouse climates. Marine proxy data suggest significant cooling of mid- to high-latitude ocean temperatures (5–6 °C) over a short interval during the earliest Oligocene, beginning at about 33.7 Ma (Zachos et al., 2008; Liu et al., 2009; Miller et al., 2009). This cooling coincided with the onset of continental glaciation in Antarctica and with changes in patterns of ocean circulation. Changes in the marine realm had a profound effect on invertebrates, causing major faunal turnover (Dockery and Lozouet, 2003; Nesbitt, 2003; Pearson et al., 2008). In general there is a change from semi-humid, forested conditions in the latest Eocene to progressively more arid and more open conditions in the earliest Oligocene.

The palaeoclimatic event at the Eocene–Oligocene transition has attracted the attention of many paleontologists, palaeobotanists and researchers of palaeoenvironmental science (e.g., Molina et al., 1986; Collinson, 1992; Collinson et al., 2010; Kvaček, 2010 and Teodoridis et al., 2012). In general, the pronounced cooling in this time interval (e.g., Zanazzi et al., 2007; Hren et al., 2013) induced also changes in benthic foraminifera, although this event manifested variously in the mid-northern latitudes (Akhmetiev et al., 2009). During Late Eocene/Early Oligocene time, a global cooling caused biotic turnovers in many groups, both in oceanic and terrestrial domains (Coxall and Pearson, 2007).

Numerous studies have dealt with the climatic and biotic changes across the E/O transition (Pomerol and Premoli Silva, 1986; Premoli Silva et al., 1988; Prothero and Berggren, 1992; Molina et al., 1993, 2006; Thomas and Shackleton, 1996; Spezzaferri et al., 2002; Boukhary et al., 2012; Muftah and Boukhary, 2013) to elucidate the environmental effects of this crisis as well as to determine possible cause of climate change and extinctions (Keller, 1986; Keller et al., 1987; Montanari, 1990; Molina et al., 2004, 2006).

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http://dx.doi.org/10.1016/j.jafrearsci.2015.03.002
1464-343X/

The fundamental aims of this study are to investigate the possible causes of the Eocene/Oligocene (E/O) boundary turnover by analyzing patterns of benthic larger foraminiferal changes across the E/O of the Siwa Oasis (Western Desert, Egypt) to seek correlations between two sections namely; El Arag and El Qara (Fig. 1). This has been done to evaluate evidence for or against two rival hypotheses; (1) the meteorite impacts, and (2) possible climatic changes (warming/cooling).

1.1. Meteorite impacts

Molina et al. (1993) suggested that there were three late Eocene impact events within about 1 Ma (34.7–35.7 myr) in the middle Priabonian, and concluded that major species extinctions did not coincide with those impact events. Molina et al. (2004) discovered one major and two minor Ni-rich spinel anomalies at Fuente Caldera section, southern Spain, which are indicative of one or possibly several meteorite impacts and thus permit research into the possibility of a cause-effect relationship between late Eocene meteorite impacts and the extinction of foraminifera.

More impact evidence was discovered in upper Eocene sediments (Keller et al., 1987), including iridium anomalies (Montanari et al., 1993), shocked quartz (Glass and Wu, 1993; Clymer et al., 1996), and Ni-rich spinel (Pierrard et al., 1998; Molina et al., 2004). Moreover, three impact craters were found at Popigai (100 km), northern Siberia (Bottomley et al., 1993), Chesapeake Bay (90 km) and Toms Canyon (20 km) on the North American continental shelf (Koeberl et al., 1996; Poag and Pope, 1998).

In contrast the catastrophic mass extinction event at the Cretaceous/Tertiary boundary, meteorite impact in the late Eocene did not cause the extinction of foraminifera, probably because the impact were relatively smaller, as suggested by the size of the coeval craters (Molina et al., 2006).

Molina et al. (2006) argued that at Fuente Caldera, southern Spain, the impact did not occur at a time of planktonic or benthic foraminiferal extinction event, and the Late Eocene meteorite impacts did thus not cause extinction of foraminifera. The most plausible cause of the Eocene/Oligocene boundary extinctions is the significant cooling, which generated glaciation in Antarctica and eliminated most of the warm and surface-dwelling foraminifera.

1.2. Possible climatic changes

1.2.1. Warming

At the onset of the Eocene, during a period of ca 100–150 kyr, the high latitudes and global deep waters experienced a 6–8 °C warming (Kennett and Stott, 1991). This warming event, referred to the Initial Eocene Thermal Maximum (IETM) is probably represents the warmest period on Earth during the Cenozoic. The warming coincides with global mass extinctions of 30–50% of the deep-sea benthic foraminiferal species (Ross, 1974; Tjalsma and Lohmann, 1983; Miller et al., 1987; Kennett and Stott, 1991; Thomas and Shackleton, 1996; Thomas et al., 2000). The prominent heating of the high latitudes has been explained in terms of an extreme green house event (Dickens et al., 1997), alternatively, as a shift in deep-water formation from high latitudes to the net evaporation zones at midlatitudes and increased poleward heat transport (Kennett and Stott, 1991; Thomas and Shackleton, 1996).

The transition from the global warmth of the early Eocene "greenhouse" climate to the glaciated state of the Oligocene is

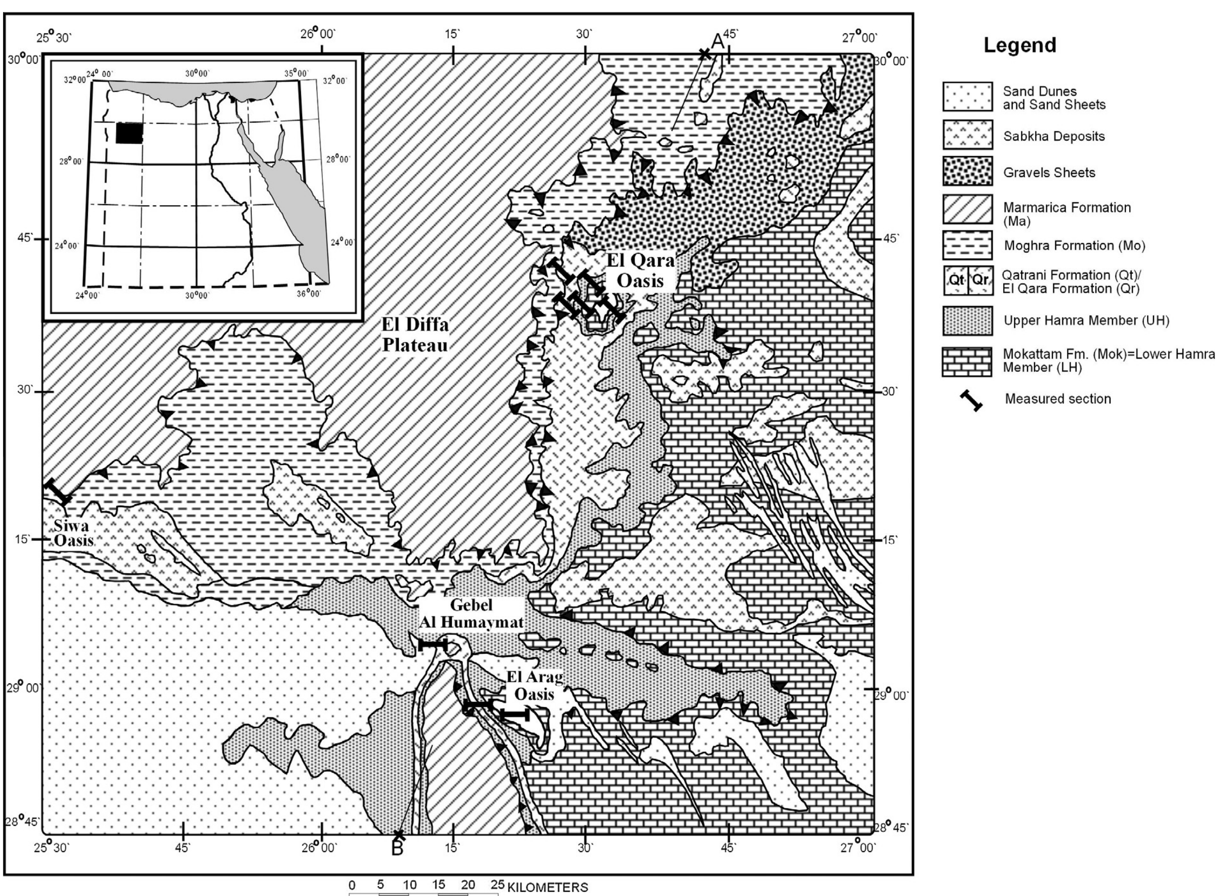

Fig. 1. Geological map of Siwa–El Qara stretch North Western Desert of Egypt.