Journal of African Earth Sciences 124 (2016) 447–477

Contents lists available at ScienceDirect

Journal of African Earth Sciences

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

Paleontology, paleobiogeography and paleoecology of *Carolia*-bearing beds from the Late Eocene rocks at Nile-Fayum Divide, Egypt

Soheir H. El-Shazly*, Gouda I. Abdel-Gawad, Yasser F. Salama, Dina M. Sayed

Beni-Suef University, Egypt

ARTICLE INFO

Article history:
Received 9 August 2016
Received in revised form
25 September 2016
Accepted 26 September 2016
Available online 28 September 2016

Keywords:
Macro-invertebrate fauna
Paleogeography
Paleoecology
Eocene
Fayum
Egypt

ABSTRACT

The Paleontological study of the *Carolia*-bearing beds in (Qasr El-Sagha Formation) at Nile-Fayum Divide reveals the presences of thirteen species (three gastropods, six oysters and four Carolias). The paleobiogeography of these fauna indicates that genus *Carolia* Cantraine, 1838 was first recorded from the Lower Eocene of Egypt and Indian-Pakistani Region and spread out throughout the Tethyan province, West Africa and North and South America and its last occurrence was in the Early Miocene of North America. It shows also that, the first appearance of *Ostrea* (*T.*) *multicostata* (Deshayes, 1832) was in the Paleocene of Tunis and Algeria, and spread during the Eocene into India, northwestern Europe and the entire northern African regions. However, *Cubitostrea* (*Cubitostrea*) *cubitus* (Deshayes, 1832) was first reported in the Middle Eocene of France and spread to Texas in North America and North Africa. The statistical study on genus *Carolia* indicates that the distance between the byssal muscle scar and the retractor muscle scar increases with the increase of the left valve convexity. The paleoecological study of these faunal groups shows that, the predation and the parasitic elements as well as the stress environmental factors, caused the extinction of genus *Carolia* at the end of Late Eocene in Egypt.

1. Introduction

Fayum area is a circular depression located in the northern part of the Western Desert of Egypt. It lies between latitude 28° 60′ and 29° 45′ N and longitudes 30° 00′ and 31° 15′ E and occupies about 17,000 km^2 (Fig. 1). The exposed sedimentary rocks in this area belong exclusively to the Eocene and Oligocene epochs (Strougo et al., 2013).

The geology of the Fayum area attracted the attention of many geologists since the beginning of the last century. The earliest studies were carried out by Schweinfurth, 1886; Mayer-Eymar, 1892; Beadnell, 1905 and Cuvillier, 1930. However most of recent studies deal with either vertebrate fossils or planktonic foraminifera, calcareous nannofossils and larger foraminifera, which were used as biostratigraphic tools (eg. Bassiouni et al., 1984; Strougo and Haggag, 1984; Haggag, 1985; Bown and Kraus, 1988; Gingerich, 1992; Boukhary et al., 1993; Haggag and Bolli, 1995; Abdallah et al., 1997; Abdel Aziz and Abdel-Gaid, 2008; Strougo and Faris, 2008; Abdel Azeam, 2008; Abdelfattah et al., 2010; Strougo et al., 2013; Legler et al., 2013) and others. On the other hand, the paleoecologic, paleobiogeographic and the systematic studies of the macroinvertebrate fauna received little attention. Few studies discussed the paleoecology and the evolution of *Carolia* species (Abbass, 1961; Strougo, 1983). Other studies focused on the systematic of some macro-invertebrate groups (ex. Abbass, 1967, 1973 and Strougo, 1970, 1973, 1976, 1977). However, no recent work dealt with the paleobiogeography of the Eocene invertebrate fauna. In this work, a systematic study of bivalves and gastropod fauna from two sections at Nile-Fayum Divide is presented, their paleobiogeographic distribution and paleoecologic settings are discussed, and the cause of extinction of genus *Carolia* at the end of

* Corresponding author.
E-mail address: soheir14@gmail.com (S.H. El-Shazly).

http://dx.doi.org/10.1016/j.jafrearsci.2016.09.033
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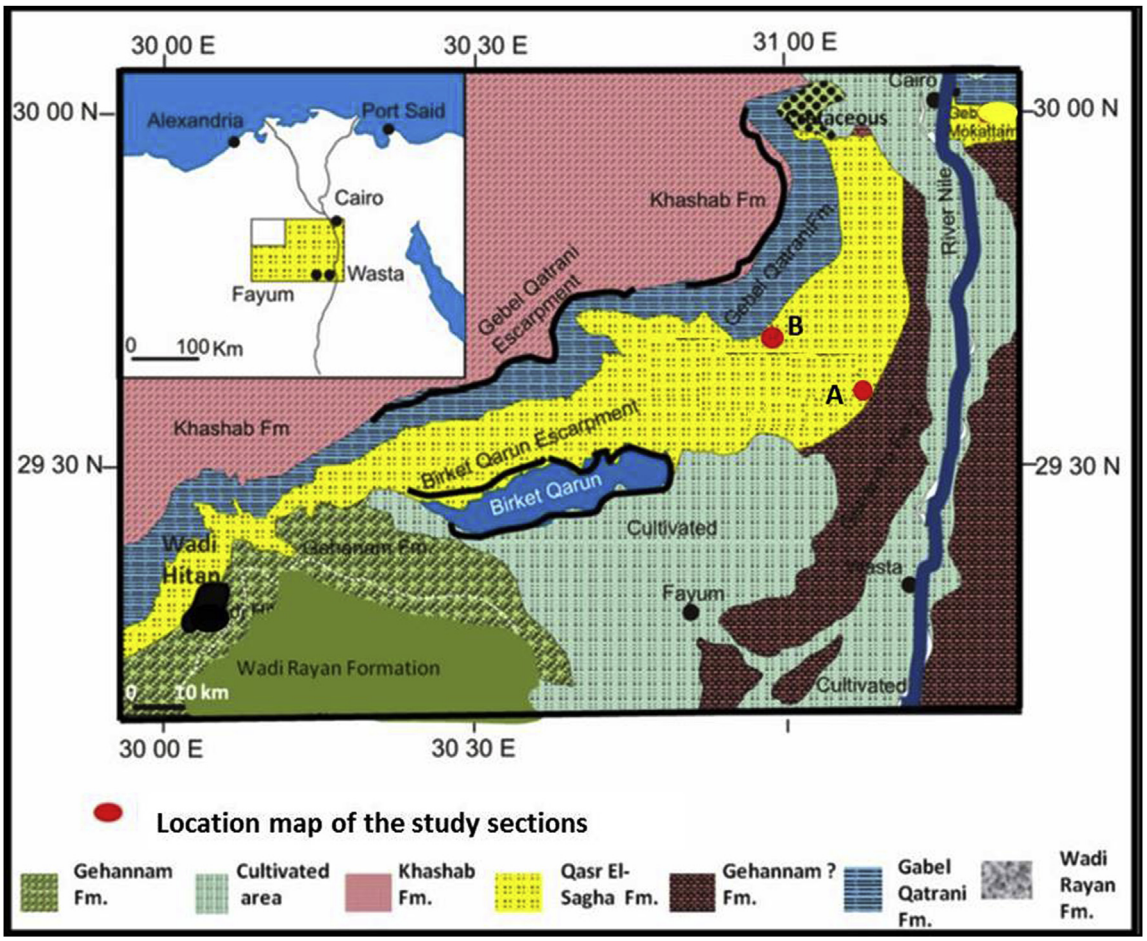

Fig. 1. Geological map of Fayum area showing the locations of the studied sections (modified after Anderson and Feldmann, 1995**).**

the Late Eocene of Egypt is also explained.

2. Stratigraphy

The Eocene rocks of the Fayum area were studied by Beadnell (1905), who divided them into four units from old to young as follows: Wadi Rayan series, Ravine beds (Middle Eocene), Birket Qarun series, and Qasr El-Sagha series (Upper Eocene). Said (1962) introduced Gehannam and Wadi El Rayan Formations to describe the Middle Eocene and Qasr El-Sagha and Birket Qarun Series for the Upper Eocene. Gingerich (1992) assigned Priabonian age for the Qasr El-Sagha Formation and divided it into four units (Umm Rigl, Harab, Temple and Dir Abu Lifa Members). However, the subdivision of the studied sections into Temple and Dir Abu Lifa members follows Bown and Kraus (1988) and Abdallah et al. (1997).

In the present work, two stratigraphic sections located in the western side of El-Ayiat City at the Nile-Fayum Divide (Fig. 1) have been sampled for stratigraphic and macropaleontological analysis. The exposed Eocene succession in this area represents Qasr El-Sagha Formation of Late Eocene age. The two sections attain a thickness of 166.5 m and are subdivided, from the base to the top, into Temple Member (Section A) (Fig. 2) and Dir Abu Lifa Members (Section B) (Fig. 3).

2.1. Section (A) Temple Member

The first Section (A) is located at the western entrance of El Masanda village of El-Ayiat town at latitude (29°35′ N) and longitude (31°10′ E). It represents the Temple Member of Qasr El-Sagha Formation (Fig. 2). It attains a thickness of about 90 m and consists of repeated cycles of fine marly sandstone, gypsiferous marl, sandy shale, and carbonaceous mudstone (Fig. 2).

The basal part of this section is made up of sandy shale and highly burrowed with *Ophiomorpha* and Thalassinoide trace fossils (Fig. 3a). The upper part contains large calcite cemented concretions, which form remarkable spheroidal shapes (Fig. 3b) characteristic of the Temple Member (Abdel-Wahab and McBride, 2001). The presence of root horizons and wide range of marine trace fossils in this member suggest an inshore, tide-influenced, or even tide-dominated depositional environment (Legler et al., 2013).

In this section, six *Carolia* horizons were delineated (Fig. 2) associated with small gastropod and oyster shells. In the first horizon *Carolia* (*C.*) *placunoides placunoides* appears at the base (A3) as disarticulated and fragmented shells in yellowish white fossiliferous marls. The second horizon (A 17) forms a scarp of yellowish grey sandy shale rich in *Carolia* (*C.*) *placunoides placunoides* and *Carolia* (*C.*) *placunoides foraminifera*. The *Carolia* bed forms wavy