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Original article

Paleoenvironmental and paleobiogeographic implications of Middle Miocene Ostracods from the Al Khums area, northwestern Libya

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Abstract

This paper studies the Middle Miocene ostracods from three different outcrops in the Al Khums area, northwestern Libya. Lithologically, these outcrops belong to the Al Khums Formation, and are considered synchronous due to the great similarity in their ostracod content. Twenty seven ostracod species, belonging to 22 genera and 13 families, were identified. Although the age of the Al Khums Formation cannot be precisely constrained based on its ostracod assemblage, the presence of the larger benthic foraminiferan subspecies *Borelis melo melo* allows to assign to the sequence a Middle Miocene age. The identified ostracods indicate that the depositional environment was shallow marine. This conclusion is also supported by the co-occurrence of algae, large oysters and corals. Multivariate analyses were applied to the present data to distinguish the paleobiogeographical provinces of the studied ostracod species. The results indicate that there are two distinguished bioprovinces: (1) The South Tethyan bioprovince (STP) including Algeria, Libya and Egypt, and (2) The North Tethyan bioprovince (NTP) including Spain, Italy, Malta, France, Turkey and Greece. Similarities between the ostracod assemblages of these bioprovinces suggest a good marine connection between both sides of the Mediterranean Sea during the Middle Miocene.

Keywords: Ostracods; Middle Miocene; Taxonomy; Paleobiogeography; Al Khums; Libya

1. Introduction

The ecological preference of ostracod species can be often traced in the fossil record based on the particular morphological traits expressed on their carapace; thus these small aquatic bivalve micro-crustaceans have a significant potential to establish paleoenvironmental reconstructions since the Paleozoic (e.g. Maillet et al., 2013; Casier et al., 2015); they are often used in paleoenvironmental reconstructions of Cretaceous and Tertiary sequences in northern African basins (e.g. Amami-Hamdi et al., 2016). Their paleobiogeographic patterns and presumed migration pathways are very important for understanding of past faunal exchanges, the chronology of faunal migrations and the dynamics in marine connections (Sarr, 2015; Trabelsi et al., 2015; Puckett et al., 2016).

Few studies have been published on the Miocene ostracods of Libya. Among the most important papers are those by Van Hinte et al. (1978), Szczechura (1980), Szczechura and Abd-Elshafy (1988), El-Waer (1988, 1992), Gammudi and Keen, 1993, Keen and Gammudi, 1996 and Gammudi (1996).

Van Hinte et al. (1978) identified different Late Micocene ostracod assemblages from Libya. El-Waer (1992) recorded similar ostracod faunas from Libya and assigned them also to the Late Miocene. Gammudi (1996) recorded similar ostracod assemblages from Libya and assigned them to the Late Miocene. Szczechura and Abd-Elshafy (1988) identified similar ostracod assemblages (with 70% common species) from Libya and Egypt and assigned them tentatively to the Middle Miocene age. The Libyan ostracod fauna differ from those recorded from central and northern Europe. However, their paleogeographic significance has not been evaluated as yet.

The main goals of this study are to:

- document the preserved diversity of the Middle Miocene ostracods from the Al Khums Formation;
- to analyse their paleoenvironmental significance in order to gain insights into the paleobathymetry of the basin in which accumulated the Al Khums Formation;

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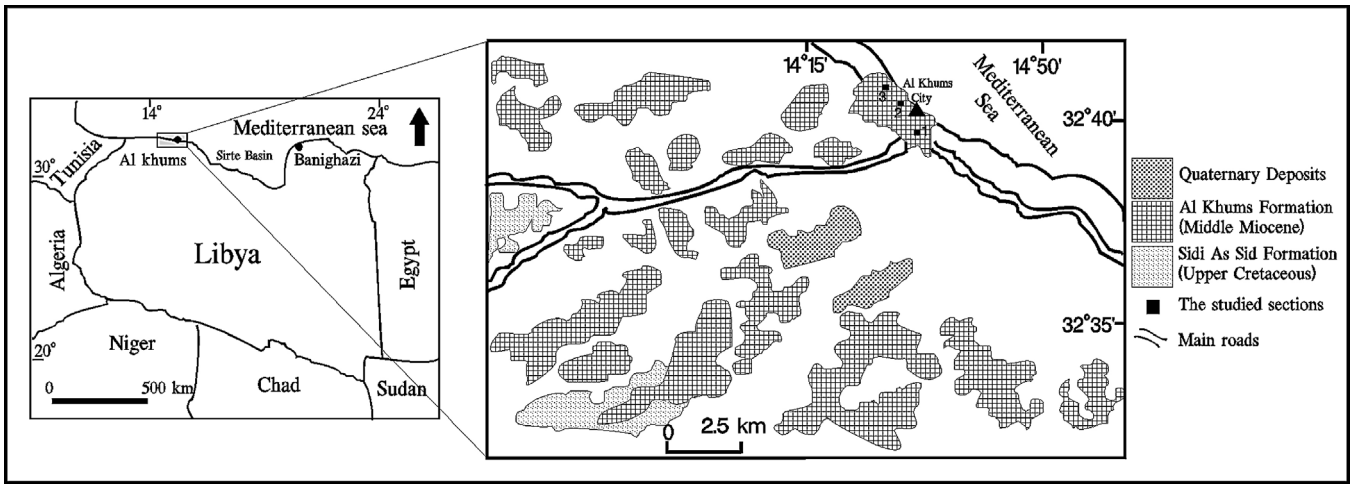

Fig. 1. Location and geologic map of the study area (modified after, Hamad, 2013).

- to investigate their paleobiogeographical affinities with other countries of the Mediterranean area.

In order to achieve our goals, three sections cropping out in the Al Khums area, northwestern Libya, were carefully studied (Fig. 1). Section Al Khums 1 was measured at the Wadi Kaam area, whereas Sections Al Khums 2 and 3 were measured to the west of the Al Khums city.

2. Stratigraphic setting

Lithostratigraphically, the studied sections are represented by the Al Khums Formation, described initially by Mann (1975) as a Middle Miocene sequence exposed in the vicinity of the city of Al Khums. The Formation is locally subdivided into two informal members: An Naggazah and Ras Al Mannubiyah (Salem and Spreng, 1980). In the present study, the An Naggazah Member consists mainly of reefal limestone at the base followed upwards by white, massive and fossiliferous limestone with bivalves, gastropods, bryozoan fragments, foraminifera, ostracods and algae. The upper part is represented by the Ras Al Mannubiyah Member, which consists of white creamy limestone with rare ostracods and foraminifera. The Naggazah Member reaches about 7 m in Section 1, 9 m in Section 2 and about 4 m in Section 3 (Figs. 2, 3 and 4). The Ras Al Mannubiyah Member attains a thickness of about 3.5 m in Section 1 and about 10 m in Section 2 (Figs. 2, 3).

3. Material and methods

Fifty samples were collected, mostly carbonate rocks, from the above-mentioned three sections cropping out in the Al Khums area. Approximately 100 g from each sample were soaked with 5% H_2O_2 solution, washed over a 63 μm mesh sieve and then dried and sieved into fractions greater than 250, 125 and 63 μm, respectively. About 30 g of washed residue from every sample were examined under a binocular microscope at 50 magnification. After that, the ostracods were picked and mounted on faunal slides. The identified ostracods were photographed by the Scanning Electron Microscope and illustrated with two plates. In order to reconstruct the structure of the recorded ostracod assemblages, several parameters were calculated including ostracod abundance (number of individuals per gram of dry sediment), species richness (S), and the frequency of the recorded families.

The paleobiogeographical reconstruction of the studied species was elaborated with the help of multivariate analyses using the PAST program (version 3.2). The countries that contain less than three species were omitted. The resulting matrix of 15 ostracod species from 9 countries (based on previous studies) was subjected to principal component analysis (PCA), based on the correlation coefficient of similarity using the UPGMA (Unweighted Pair Group Method with Algorithm) analysis, and Q-mode cluster analysis, based on Ward's method, to distinguish the paleogeographical provinces of the investigated countries.

4. Systematic paleontology

Detailed investigation of the ostracod content led to the recognition of 27 species belonging to 22 genera and 13 families. The systematic position of ostracods follows the classification of Hartmann and Puri (1974). The recorded species are illustrated in two plates and their occurrence throughout the studied sections is shown in Figs. 2, 3 and 4.

Subclass: Ostracoda Latreille, 1806
Order: Podocopida Miiller, 1894
Suborder: Platycopa Sars, 1866
Family: Cytherellidae Sars, 1866
Genus: ***Cytherella*** Jones, 1849
Cytherella libyaensis El-Waer, 1988
(Pl. 1, Fig. 1)

1988 *Cytherella libyaensis* El-Waer, p. 45, pl. 1, figs. 1–3.

1988 *Cytherella libyaensis* El-Waer - Szczechura and Abd-Elshafy, pl. 2, figs. 11, 14, 15.

1993 *Cytherella libyaensis* El-Waer - Gammudi and Keen, p. 126, fig. 2.a.

Material: 10 carapaces.

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