1. Introduction

The Paleocene–Eocene thermal maximum at 55 Ma was a transient period of global climatic warming leading to biotic turnover in marine microbenthos (e.g. Tjalsma and Lohmann, 1983; Speijer et al., 1997; Thomas, 1998, 2007), marine micro- and nannoplankton (e.g. Kelly et al., 1996; Aubry, 1998; Molina et al., 1998; Moncehi et al., 2000; Crouch et al., 2003; Tantawy, 2006), carbonate platform systems (Scheibner et al., 2005; Scheibner and Speijer, 2008) and terrestrial mammals (e.g. Gingerich, 2000, 2006). The global patterns of biotic change of these fossil groups are fairly well documented, indicating rapid extinction (benthic foraminifera) evolution (calcareous nannoplankton, planktic foraminifera) and migration (mammals, organic dinoflagellates, hermatypic corals). In contrast, the response of ostracoda to the climatic and paleoceanographic changes associated with the PETM is quite fragmentary and consists of rather disparate individual records. Some authors observe little change in ostracode communities (e.g. Honigstein and Rosenfeld, 1995; Guernet and Molina, 1997; Elewa, 2002), whereas others noted short-term response in a deep-sea locality (Steineck and Thomas, 1996) or intensification of a long-term turnover in Tethyan assemblages (Speijer and Morsi, 2002; Morsi and Speijer, 2003; Morsi and Scheibner, 2009).

The aim of this paper is to document the distribution of ostracodes in the Paleocene–Eocene (P/E) transition interval by studying two sections (Sidi Nasseur – NAS, Wadi Mezaz – MEZ) in northwest Tunisia (Figs. 1 and 2). These sections yield rich microfaunas, including ostracodes, and provide a unique marginal marine window into early Paleogene climatic and biotic change (Stassen et al., 2009). We address the biorstratigraphy, paleoenvironment and paleobiogeography across the P/E transition based on ostracodes.

The Paleocene–Eocene succession in the study area is represented by the topmost part of the Maastrichtian to Ypresian El Haria Formation, consisting of marls and shales (Burollet, 1956). It overlies Campanian–Maastrichtian limestones of the Abiod Formation and is overlain by Ypresian phosphatic marls (Chouabine Formation) and nummulitic limestones (El Garia Formation) of the Metlaoui Group (Zaier et al., 1998). Throughout the late Cretaceous and early Paleogene, the sediments of the El
Haria Formation unit were deposited in shelf to upper-slope settings (e.g. Aubert and Berggren, 1976; Donze et al., 1982; Guasti et al., 2005). Lateral facies and thickness variations are marked owing to structural controls along basement lineaments which gave rise to a number of small tectonically controlled basins (Zaier et al., 1998). The result is a latest Cretaceous–Paleocene paleogeography characterized by subsiding troughs in the northwest and northeast (NW Tunisian Trough and NE Tunisian Basin) and in the center of Tunisia (Gafsa Gulf), being separated by a large emerged zone (Kasserine Island; Fig. 1) (Aubert and Berggren, 1976; Zaier et al., 1998; Bensalem, 2002). During the early Paleogene, the Sidi Nasseur–Wadi Mezaz area near the town of Kalaat Senan was situated in the southern proximal part of the subsiding Tunisian Trough north of the emerged Kasserine Island. This region was characterized by prolonged marine sedimentation in a neritic setting with high subsidence rate and high sediment input. The Sidi Nasseur–Wadi Mezaz area (including Ain Settara) has recently come into focus for investigations on the Cretaceous/Paleogene boundary (e.g. Dupuis et al., 2001; Peryt et al., 2002; Hennebert and Dupuis, 2003), the Danian–Selandian boundary (e.g. Steurbaut et al., 2000; Guasti et al., 2006; Van Itterbeeck et al., 2007) and the Paleocene/Eocene boundary (Stassen et al., 2009). Previous low-resolution studies dealing with late Paleocene to early Eocene ostracodes by Said (1978), Donze et al. (1982), Peypouquet et al. (1986) and Said-Benzarti (1998) were performed in other sections in northwestern Tunisia (El Kef and Ellès) in a more distal position relative to Kasserine island.

In the present paper, the ostracode faunas retrieved are studied for their taxonomy, biostratigraphy, paleoecology and paleobiogeography. The publications dealing with ostracodes from the late Paleocene–early Eocene interval in Tunisia are limited and confined to the studies of Said (1978), Donze et al. (1982), Peypouquet et al. (1986) and Said-Benzarti (1998) were performed in other sections in northwestern Tunisia (El Kef and Ellès) in a more distal position relative to Kasserine island.

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![Fig. 1](image-url)
Fig. 2. Lithology and stratigraphy of El Haria Formation at the Sidi Nasseur (NAS) and Wadi Mezaz section (MEZ) with sample positions indicated. Planktic foraminiferal biostratigraphy is based on zonation criteria of Berggren and Pearson (2005), calcareous nannofossil biostratigraphy after Martini (1971) and Aubry (1999). The PETM interval is highlighted by the gray segment.
et al. (1986) and Said-Benzarti (1998). However, other papers on ostracodes from the Danian–Selandian (Esker, 1968; Van Itterbeeck et al., 2007) are also considered as they offer valuable information concerning many ostracode taxa which extend also in the Paleocene–early Eocene interval. The many publications available on late Paleocene–early Eocene ostracodes in other North African and Middle East areas are also indispensable since paleobiogeographically they all belonged to the South Tethyan Province of which Tunisia was a part having many taxa in common (Bassioniuni and Luger, 1990). Works on the coastal and internal basins of West Africa have also been considered since species migrations between these areas and the Southern Tethys are well documented (Bassioniuni and Luger, 1990; Morsi and Speijer, 2003).

2. Lithology and lithostratigraphic description

Both studied sections expose shales and marls of the El Hara Formation and the basal phosphatic part of the Metlaoui Group. The entire analyzed Sidi Nasseur (NAS: Nas’99 and Nas’06) sequence belongs to the top part of the El Hara Formation (upper Paleocene to lower Eocene). The lower part of the sequence consists of dark gray to brownish shales with occasional marly intervals. Intercalated within the basal 3 m, 50-cm-thick brownish layers of more indurated calcareous phosphatic beds with numerous coprolites occur. The CaCO$_3$ content gradually increases upwards, as can be observed in the field by the transition to pale marls. In the top of the marly unit, several thin discontinuous limestone layers are present. The upper thick limestone, rich in phosphatic coprolites at the base, belongs to the Eocene El Garia Formation (Metlaoui Group, NP11, see below) and the contact between the underlying marls and the phosphatic limestone is interpreted as an erosional surface (zone NP10 is completely missing).

The Wadi Mezaz section (MEZ: Mzh’06 and Mzg’06) sequence also spans the upper part of the El Hara Formation, abruptly changing into the basal phosphatic beds of the Chouabine Formation (Metlaoui Group). The lower part of the MEZ sequence consists of dark gray to brownish shales, very similar to the NAS shales, and these shales grade into marls, comparable with the increase in carbonate in the top of the NAS section. The 3.5-m-thick marly package below the most prominent phosphatic layer also contains several thin discontinuous limestone interbeds. The marls are cut off by the erosional base of the overlying 5-m-thick phosphatic bed: which is interpreted as an infilled channel system. The phosphatic bed is overlain by gray marls with alternating thin phosphatic horizons (Chouabine Formation). These gradually change into the limestones of the El Garia Formation. This transition is not seen in the Sidi Nasseur section where the El Garia limestones rest directly on top of the phosphatic bed.

3. Biostratigraphic framework

3.1. Calcareous nannoplankton

The shales of the Sidi Nasseur section, from base to 10.0 m, contain fairly well-preserved, moderately diversified nannofossil associations and span the top of calcareous nannofossil subzone NP9a (Stassen et al., 2009). The nannofossil associations from the upper shale unit of the Sidi Nasseur section, from 10.1 m upwards, are rather poor in species and number of specimens. Reworked Cretaceous taxa and Coccolithus pelagicus are dominating. Typical PETM taxa are present in the lowest part of these shales, although very rare: a few specimens of Discoaster araneus in sample NAS 10.1 m, 10.5 m and 10.85 m, but no record of Discoaster araneus. Assemblages of this unit refer to calcareous nannofossil subzone NP9b. The uppermost marly interval, ranging from NAS 14.5 to 17.5 m, contains very impoverished associations, in which an upward progressive decrease in nannofossils due to intensive weathering led to the preservation of only the most robust taxa. Among the few identifiable taxa recorded are Discoaster multiradiatus, Fasciculithus spp. and Braarudosphaera bigelowii. The composition of the nannofossil associations, although extremely biased, seems to indicate subzone NP9b right up to the top of the marly unit. The uppermost limestone level, overlaying a major phosphatic layer (from NAS 18.15 to 19.05 m) yields a poorly preserved, fairly diversified nannofossil association, although restricted in number of specimens. The underlying phosphatic layer is devoid of nannofossils. The presence of Tribirachiatus orthostylus, Ellipsolithus macellus, Discoster barbadiensis, Discoaster binodosus and Zygryphibolithus bijugatus nofiti, in association with the absence of Discoaster lodoenesis and any member of the family Helicosphaeraceae, point to the middle to upper part of Martini’s (1971) nannofossil zone NP11. According to the overall composition of the calcareous nannofossil associations, although biased by selective dissolution, the Paleocene–Eocene boundary is pinpointed between NAS 10 m (NP9a) and 10.1 m (NP9b) in the NAS section.

The Wadi Mezaz section can be subdivided into comparable units on the basis of calcareous nannofossil characteristics. The nannofossil associations from the lower shaley to marly unit, ranging from MEZ 3.75 to 8.5 m, are rather poor in species and number of specimens and are also marked by high frequencies of reworked Cretaceous coccoliths and by Coccolithus pelagicus. Small Prinsiacea and a wide variety of Discoaster and Fasciculithus species are present in the best-preserved samples, whereas Discoster araneus, one of the few known PETM markers, is restricted to a single level (MEZ 4.75 m). This same influx was recognized in the NAS section, where it was found in association with the entry of PETM taxa. As a consequence, the nannofossil associations within interval MEZ 3.75–8.5 m are attributable to subzone NP9b. Samples from the main phosphatic layer, ranging from MEZ 8.5 to 11.5 m, are completely devoid of calcareous nannofossils. The subsequent assemblages, from MEZ 12 to 15 m, are marked by a substantial decrease in reworked Cretaceous material and by an increase in C. pelagicus. The assemblages from the upper phosphatic beds with alternating marls, ranging from MEZ 15.15 to 18.7 m, differ from those of the underlying units through the presence of Tribirachiatus bramlettei and Discoaster mahmoudii, the consistent occurrence of Pontosphaera spp. and Neococcolithus dubius and the decrease in C. pelagicus. The presence of T. bramlettei and the absence of T. orthostylus in the uppermost part of the section allow an attribution to NP10. The NP10–11 boundary is situated above the top of the uppermost phosphatic level at MEZ 19.5 m, on the basis of lithostratigraphic correlation with other nearby sections. This NP11 interval contains an impoverished nannofossil assemblage.

3.2. Planktic foraminifera

Planktic foraminifera are nearly absent in the upper Paleocene sediments of the Sidi Nasseur section. The rare presence of Morozovella velascoensis and the associated calcareous nannofossil NP9a assemblage, suggests that the studied interval comprises the top part of subzone P4c or zone P5 (sensu Berggren and Pearson, 2005; which is equivalent to the lower part of zone P5 sensu Berggren et al., 1995). Planktic foraminifera become more frequent in the foraminiferal residues from NAS 10.1 m onwards and consist to a large extent of Acarinina spp., including Acarinina sibayaensis and Acarinina multicamerata. Combined with occurrence of Morozovella africana, this planktic assemblage strongly resembles the well-known planktic excursion assemblage of the PETM worldwide (e.g. Kelly et al., 1996; Guasti and Speijer, 2008). The uppermost marly interval, ranging from NAS 13.5 to 17.6 m, has been strongly altered by weathering, hampering further stratigraphic
correlations. The lowermost shales and marls of the Wadi Mezaz section contain the same planktic PETM assemblage as the NAS section. Planktic foraminifera become less frequent above the base of the main phosphatic layer in the MEZ section and are also strongly affected by weathering. No extra stratigraphic information is obtained from the planktic foraminiferal record of the MEZ section.

3.3. Correlation between Sidi Nasseur and Wadi Mezaz

The lower part of the Sidi Nasseur section consists of uppermost Paleocene shales of the El Haria Formation (Stassen et al., 2009) and the P/E boundary can be pinpointed between NAS 10 and 10.1 m. The PETM interval in the NAS section corresponds with the overlying shales and marls up to the base of the uppermost phosphatic layer, followed by Eocene limestones. Correlation with nearby sections (e.g. Wadi Mezaz) suggests a substantial stratigraphic gap below the base of this limestone interval. The lower part of the Wadi Mezaz correlates with the PETM interval at NAS and is truncated at the top by the thick phosphatic bed. The subsequent marls and phosphatic beds are not encountered in the NAS section. Although the PETM interval in the MEZ section is also clearly truncated at the top and large parts seem to be eroded, it still contains a record of lower Eocene deposits missing in the NAS section and provides insights into the post-PETM recovery phase.

4. Material and methodology

The studied material is obtained from 116 rock samples (Fig. 2); of these, 36 samples (Nas’99) were collected in 1999 at a spacing of 50 cm from the Sidi Nasseur (NAS) section, 46 samples (Nas’06) represent a higher-resolution set from the NAS section, collected in 2006, with a spacing varying from 25 cm narrowing to 10 cm near the top of this limestone interval. 34 samples (Mzh’06 and Mzg’06) at spacing of 50 cm from the Sidi Nasseur (NAS) section, 46 samples (Nas’06) of these, 36 samples (Nas’99) were collected in 1999 at a spacing of 10 cm narrowing to 10 cm near the top by the thick phosphatic bed. The subsequent marls and phosphatic beds are not encountered in the NAS section. Although the PETM interval in the MEZ section is also clearly truncated at the top and large parts seem to be eroded, it still contains a record of lower Eocene deposits missing in the NAS section and provides insights into the post-PETM recovery phase.

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5. Systematic paleontology

The studied ostracode fauna is taxonomically classified into 26 species which are assigned to 18 genera. Three species are newly introduced. The classification used herein is that adopted in Horne et al. (2002). Morphologic and taxonomic remarks have been given to known species wherever necessary. Reference numbers (TPE01–TPE68) are given only to the illustrated specimens.

Class OSTRACODA Latrielle, 1806
Subclass PODOCOPA Müller, 1894
Order PLATycopida Sars, 1866
Suborder PLATycopina Sars, 1866
Superfamily Cytherelloidea Sars, 1866
Family Cythereillidae Sars, 1866
Genus Cytherrella Jones, 1849

Cytherella aff. farafraensis Bassiouni and Morsi, 2000
Plate 1, Figs. 1–3

Materials: 30 specimens.
Dimensions: L.: 0.86–0.96 mm, H.: 0.49–0.61 mm, W.: 0.37–0.41 mm.
Remarks: Cytherella farafraensis Bassiouni and Morsi, 2000 from the lower Eocene of Egypt closely resembles the present species. It deviates only slightly in having a rather compressed anterior end when seen in dorsal view, and the position of its greatest height more anteriorly shifted. Both Cytherella sp. 1 Andreu, 1996 from the Paleocene of Morocco and Cytherella cf. ligandula Marlière illustrated by Morsi (1999, 2000) from the Maastrichtian–Paleocene of Egypt and Van Itterbeeck et al. (2007) from the Danian–Selandian of Sidi Nasseur (Tunisia) differ from the present specimens in having almost straight and parallel longitudinal margins, whereas in the present species, the ventral margin is concave and the longitudinal margins are converging towards the anterior.

Occurrence: Upper Paleocene (Thanetian) at Sidi Nasseur.

Order Podocopida Müller, 1894
Suborder Bairdilocopina Sars, 1865
Superfamily Bairdidoidea Sars, 1865
Family Bairdidiidae Sars, 1888
Genus Bairdia McCoy, 1844

Bairdia aegyptiaca Bassiouni and Morsi, 2000
Plate 1, Fig. 4

1977. Bairdia gilberti Keij – Bassiouni et al., p. 1, Pl. 2, Fig. 10a–c. 2000. Bairdia aegyptiaca n. sp. – Bassiouni and Morsi, p. 32, Pl. 2, Figs. 1 and 2. 2009. Bairdia aegyptiaca Bassiouni and Morsi – Morsi and Scheinber, p. 156, Pl. 1, Fig. 15.

Materials: 22 specimens.
Dimensions: L: 1.29 mm; H: 0.80 mm; W: 0.68 mm.
Occurrence: (?) Upper Paleocene to lower Eocene of Egypt (Bassiouni et al., 1977; Bassiouni and Morsi, 2000; Morsi and Scheinber, 2009). It is found in the upper Paleocene (Thanetian) at Sidi Nasseur and Lower Eocene (Ypresian) at Wadi Mezaz.

Suborder Cypriooidea Jones, 1901
Superfamily Cypridoidea Baird, 1845
Family Candonidae Kaufmann, 1900
Genus Paracypris Sars, 1866

Paracypris eskeri Bassiouni and Morsi, 2000
Plate 1, Fig. 5

1968. Paracypris sp. A. – Esker, p. 322, Pl. 1, Fig. 9. 1982. Paracypris sp. A Esker – Donze et al., p. 282, Pl. 2, Fig. 8. 1990. “Paracypris”? sp. A – Bassiouni and Luger, p. 84, Pl. 2, Figs. 10 and 12.
2000. *Paracypris eskeri* n. sp. – Bassiouni and Morsi, p. 36, Pl. 2, Figs. 9–11.
2007. *Paracypris eskeri* Bassiouni and Morsi – Van Itterbeeck et al., p. 219, Pl. 2, Fig. 21.

**Material:** a single specimen.

**Dimensions:** L: 0.93 mm, H: 0.39 mm.

**Remarks:** When Bassiouni and Morsi (2000) erected the present species, they illustrated sexual dimorphs of which the males are identical to the specimen found in the present study. *Paracypris?* sp. A Bassiouni and Luger, 1990 is identical with the females and has therefore been placed in the synonymy.

**Occurrence:** Paleocene of Tunisia (Esker, 1968; Donze et al., 1982; Van Itterbeeck et al., 2007) and Paleocene–lower Eocene of Egypt (Bassiouni and Luger, 1990; Bassiouni and Morsi, 2000). It is found in the upper Paleocene (Thanetian) at Sidi Nasseur.

Paracypris aff. Jonesi Bonnema, 1941
Plate 1, Fig. 6


**Material:** four specimens.

**Dimensions:** L: 0.83 mm, H: 0.35 mm.

**Remarks:** *Paracypris Jonesi* was originally described from the Maastrichtian of the Netherlands (Bonnema, 1941). The present material recorded is similar to this species, but deviates slightly in being relatively higher.

**Occurrence:** Lower Eocene (Ypresian) at Wadi Mezaz.

Paracypris sp. B Esker, 1968
Plate 1, Fig. 7

1968. *Paracypris sp.* B – Esker, p. 323, Pl. 4, Fig. 5.
1998. *Paracypris sp.* B Esker – Said-BenZarti, Pl. 1, Fig. 7.

**Material:** a single specimen.

**Dimensions:** L: 0.92 mm, H: 0.42 mm.

**Occurrence:** Lower and lower upper Paleocene of Tunisia (Esker, 1968; Said-Benzarti, 1998; Van Itterbeeck et al., 2007). In the present section, it is found in the upper Paleocene (Thanetian) at Sidi Nasseur.

Superfamily CYTHEROIDEA Baird, 1850
Family KRITHIDAE Mandelstam, 1958
Subfamily KRITHINAE Mandelstam, 1958
Genus Parakrithe van Den Bold, 1958

Parakrithe crolifa Bassiouni and Luger, 1990
Plate 1, Figs. 8 and 9

1979. *Krithe* sp. – Cronin and Khalifa, p. 410, Pl. 1, Figs. 26 and 27.
1990. *Parakrithe crolifa* n. sp. – Bassiouni and Luger, p. 796, Pl. 6, Figs. 13–22.
1995. *Parakrithe? kalambainaensis* Reyment – Honigstein and Rosenfeld, p. 53, Pl. 1, Fig. 7.
1999. *Parakrithe crolifa* Bassiouni and Luger – Morsi, p. 38, Pl. 1, Fig. 16.
2000. *Parakrithe crolifa* Bassiouni and Luger – Bassiouni and Morsi, p. 44, Pl. 5, Fig. 4.
2002. *Parakrithe crolifa* Bassiouni and Luger – Honigstein et al., p. 372, Pl. 1, Fig. 12.

2005. *Parakrithe crolifa* Bassiouni and Luger – Shahin, p. 759, Pl. 2, Fig. 17.
2005. *Parakrithe crolifa* Bassiouni and Luger – Ismail and Ied, p. 131, Pl. 2, Fig. 16.

**Material:** five specimens.

**Dimensions:** L: 0.55–0.58 mm; H: 0.27–0.29 mm.

**Remark:** Based on size variation, Bassiouni and Luger (1990) distinguished two morphotypes, MTA and MTB, of which the latter one is relatively smaller. The material recorded in the present study fits into the morphotype-B.

**Occurrence:** The present species is found in the Paleocene–Eocene of Israel (Honigstein and Rosenfeld, 1995; Honigstein et al., 2002) and Maastrichtian to middle Eocene of Egypt (Cronin and Khalifa, 1979; Bassiouni and Luger, 1990; Morsi, 1999; Bassiouni and Morsi, 2000; Ismail and Ied, 2004. 2005. Shahin, 2005; Morsi and Scheibner, 2009). Of these records, morphotype-B is differentiated in Bassiouni and Luger (1990) and Morsi (1999) from the Paleocene of Egypt. In Tunisia, this morphotype is recorded in the lower to lower upper Paleocene (Danian–Selandian) at Sidi Nasseur (Van Itterbeeck et al., 2007) and in the present study in the upper Paleocene (Thanetian) of the same area.

Family CYTHERURIDAE Sars, 1866
Genus Cytheropteron Sars, 1866

Cytheropteron lugeri Bassiouni and Morsi, 2000
Plate 1, Fig. 10

1990. *Cytheropteron sp.* – Bassiouni and Luger, Pl. 7, Fig. 15.
2000. *Cytheropteron lugeri* n. sp. – Bassiouni and Morsi, p. 45, Pl. 5, Figs. 8 and 9.
2007. *Cytheropteron lugeri* Bassiouni and Morsi – Van Itterbeeck et al., p. 220, Pl. 3, Fig. 20.

**Material:** two specimens.

**Dimensions:** L: 0.50 mm; H: 0.30 mm.

**Occurrence:** Upper Paleocene and lower Eocene of Egypt (Bassiouni and Luger, 1990; Bassiouni and Morsi, 2000). In Tunisia, it is found at Sidi Nasseur in the lower upper Paleocene (Selandian) (Van Itterbeeck et al., 2007), upper upper Paleocene (Thanetian) and lower Eocene (Ypresian) (present study).

Genus Eucytherura Sars, 1866

Eucytherura aff. dentata (Lienenklaus, 1905)
Plate 1, Fig. 11


**Material:** a single specimen.

**Dimensions:** L: 0.31 mm; H: 0.17 mm.

**Occurrence:** Lower Eocene of Egypt (Bassiouni and Morsi, 2000). In the present study, it is found also in the lower Eocene (Ypresian) at Sidi Nasseur.

Family LOXOCONCHIDAE Sars, 1866
Genus Loxoconcha Sars, 1866

Loxoconcha saharaensis Bassiouni and Luger, 1990
Plate 1, Fig. 12
1982. *Loxoconcha* sp. – Mohamed, p. 262, Pl. 22, Fig. 11.
1990. *Loxoconcha saharaensis* n. sp. – Bassiouni and Luger, p. 809, Pl. 10, Figs. 12, 15–18.
Non 1994. *Loxoconcha saharaensis* Bassiouni and Luger – Eleva and Ishizaki, Pl. 1, Fig. 3.

**Material:** a single specimen.

**Dimensions:** L: 0.41 mm; H: 0.26 mm.

**Remarks:** The present species is known only from the upper Paleocene. The specimen figured as *Loxoconcha saharaensis* by Eleva and Ishizaki (1994, Pl. 1, Fig. 3) from the lower Eocene of Egypt has a more inflated mediodorsal surface compared to the present specimen as well as the illustrations of Bassiouni and Luger (1990, Pl. 10, Figs. 12, 15–18); this character relates it more to *Loxoconcha blanchenhorni* which was described by Bassiouni and Luger (1990) from the lower Eocene of Egypt.

**Occurrence:** Paleocene of Egypt (Bassiouni and Luger, 1990; Morsi and Speijer, 2003). Here, it is recorded in the upper Paleocene (Thanetian) at Sidi Nasseur.

Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948
Subfamily TRACHYLEBERIDINAE Sylvester-Bradley, 1948
Genus *Aegyptiana* Boukhary, Damotte and Mohamed, 1982

*Aegyptiana duwiensis* Morsi and Speijer, 2003
Plate 1, Figs. 13–18

2003. *Aegyptiana duwiensis* n.sp. – Morsi and Speijer, p. 74, Pl. 3, Figs. 31–33; Pl. 4, Figs. 34 and 35.

**Material:** 155 specimens.

**Dimensions:** Females: L: 0.75–0.78 mm, H: 0.42–0.48 mm, W: 0.39 mm; males: L: 0.81–0.91 mm, H: 0.42–0.46 mm, W: 0.37 mm.

**Remarks:** The present species is represented in the studied sections by two size variants, the smaller one is found in the upper Paleocene at Sidi Nasseur and the larger one is recorded in the upper Paleocene (Thanetian) at Sidi Nasseur.

**Occurrence:** Upper Paleocene of Tunisia (Benson, 1977; Donze et al., 1982; Said-Benzerarti, 1998) and upper Paleocene to lower Eocene of Egypt (Bassiouni and Luger, 1990; Morsi and Speijer, 2003; Shahin, 2005). In the present work, it is recorded in the upper Paleocene (Thanetian) at Sidi Nasseur.

Genus *Paracosta* Siddiqui, 1971

*Paracosta kefensis* (Benson, 1977)
Plate 1, Figs. 19 and 20; Plate 2, Figs. 1–4.

1977. *Paleocosta kefensis* n.sp. – Benson, p. 36, Pl. 1, Fig. 7, text-Figs. 4G and 7B.
1998 *Paleocosta kefensis* Benson – Said-Benzerarti, Pl. 3, Fig. 15.
Pars 2005. *Paracosta kefensis* (Benson) – Shahin, p. 763, Pl. 4, Fig. 2.

**Material:** 59 specimens.

**Dimensions:** Females: L: 1.00–1.02 mm, H: 0.56–0.60 mm, W: 0.52 mm; males: L: 1.10–1.12 mm, H: 0.55–0.57 mm, W: 0.51 mm.

**Remarks:** Two morphotypes of the present species were separated by Bassiouni and Luger (1990) in the upper Paleocene sediments of southern Egypt: morphotype-A (MTA), which is identical to the Tunisian material illustrated by Benson (1977), Donze et al. (1982) and Said-Benzerarti (1998), and morphotype-B (MTB), which deviates slightly in posterior outline and has a weaker marginal rib and less-developed eye tubercles. At Gebel Duwi in the Eastern Desert of Egypt, these two morphotypes were recorded, MTA at the PETM interval and MTB throughout the upper Paleocene to lower Eocene (Morsi and Speijer, 2003). In the present study, only MTA has been recorded in the upper Paleocene at Sidi Nasseur.

**Occurrence:** This species was recorded in the upper Paleocene of Tunisia (Benson, 1977; Donze et al., 1982; Said-Benzerarti, 1998) and upper Paleocene to lower Eocene of Egypt (Bassiouni and Luger, 1990; Morsi and Speijer, 2003; Shahin, 2005). In the present work, it is recorded in the upper Paleocene (Thanetian) at Sidi Nasseur.

*Paracosta aff. paleomokattamensis* Bassiouni and Luger, 1990
Plate 2, Figs. 5–7


**Material:** 124 specimens.

**Dimensions:** L: 1.06–1.08 mm, H: 0.56–0.57 mm, W: 0.44 mm.

**Discussion:** The present specimens closely resemble *Paracosta paleomokattamensis* Bassiouni and Luger, 1990 from the lower upper Paleocene of southern Egypt with respect to ornamentation. However, they deviate in having the ventral rib situated more distant from the ventral margin and the posterior end more rounded. *Paracosta mokattamensis* (Bassiouni, 1969a) from the upper Eocene of Egypt and *Paracosta praemokattamensis* (Bassiouni, 1969b) from the middle Eocene of Jordan are smaller in size, have a more acute posterior end and a different ornamentation.

**Occurrence:** Upper Paleocene (Thanetian) at El Kef Donze et al., 1982 and Sidi Nasseur (present study) in Tunisia.

Genus *Reticulina* Bassiouni, 1969a

*Reticulina lamellata* Bassiouni and Luger, 1990
Plate 2, Fig. 8

1982. *Reticulina aff. sangalkamensis* (Apostolescu) – Donze et al., p. 286, Pl. 5, Fig. 6.
1990. *Reticulina lamellata* n. sp. – Bassiouni and Luger, p. 837, Pl. 21, Figs. 1–6.
pars 2005. *Paracosta kefensis* (Benson) – Shahin, p. 763, Pl. 4, Fig. 3.
pars 2005. *Reticulina proteros* Bassiouni – Shahin, p. 763, Pl. 4, Fig. 7.

**Material:** 19 specimens.

**Dimensions:** L: 1.03 mm, H: 0.51 mm.

**Occurrence:** The species was previously recorded from the Paleocene of east Algeria (Damotte and Fleury, 1987) and upper Paleocene to lower Eocene of Tunisia (Donze et al., 1982; Said-Benzerarti, 1998) and upper Paleocene of Egypt (Bassiouni and Luger,
In the present work, it is found in the upper Paleocene (Thanetian) at Sidi Nasseur and lower Eocene (Ypresian) at Wadi Meazz.

Reticulina proteros Bassiouni, 1969a

Plate 2, Figs. 9, 10, and 19

Reticulina proteros Bassiouni, p. 95, Pl. 2, Figs. 17–19.


1991. Reticulina proteros Bassiouni – Honigstein et al., p. 104, Pl. 2, Fig. 7.


1998. Reticulina proteros Bassiouni – Said-Benzarti, Pl. 3, Fig. 18.

1999. Reticulina proteros Bassiouni – Morsi, p. 43, Pl. 3, Fig. 17.


2005. Reticulina proteros Bassiouni – Morsi and Speijer, p. 76, Pl. 3, Fig. 51.


2009. Reticulina proteros Bassiouni – Ismail and Ied, p. 140, Pl. 4, Fig. 5 and 6.

2009. Reticulina proteros Bassiouni – Morsi and Scheibner, p. 173, Pl. 5, Fig. 13.

Material: 115 specimens.

Dimensions: Females: L: 0.75–0.79 mm, H: 0.39–0.41 mm; male: L: 0.79 mm, H: 0.36 mm.

Occurrence: Paleocene of Senegal (Apostolescu, 1961; Sarr, 1998), Paleocene of Nigeria (Okosun, 1987) and upper Paleocene to lower Eocene of Egypt (Bassiouni and Luger, 1990; Morsi, 1999; Morsi and Speijer, 2003; Ismail and led, 2004, 2005; Morsi and Scheibner, 2009). In the present material, it is found in the upper Paleocene (Thanetian) at Sidi Nasseur.

Genus Reymenticosta Bassiouni and Luger, 1990

Reymenticosta bassiounii n. sp.

Plate 2, Figs. 12–18

Derivatio nominis: In honor of Prof. M. A. Bassiouni, Ain Shams University, Cairo, Egypt.

Holotype: Female carapace (Plate 2, Fig. 12, TPE33).

Paratypes: 189 specimens of which three female carapaces (Plate 2, Figs. 13–15, TPE34–36), and three male carapaces (Plate 2, Figs. 16–18, TPE37–39) are illustrated.

Locus typicus: Sidi Nasseur section.

Stratum typicum: A shale bed, upper Paleocene (Thanetian), zone P4–P5 (subzone NPP4a), sample NAS 7.90.

Diagnosis: A species of the genus Reymenticosta with two rows of reticules between dorsal and median ribs as well as median and ventral ribs, and coarse reticules at anterior and posterior regions.

Dimensions: Females: L: 0.85 mm, H.: 0.49 mm (holotype), L.: 0.85–0.86 mm, H.: 0.49–0.50, W.: 0.44 mm (paratypes); males: L.: 0.92–0.97 mm, H.: 0.46–0.49 mm (paratypes); W: 0.43 mm (paratypes).

Description: External features: Carapace relatively small-sized, oval in lateral view. Longitudinal margins converging posteriorly, more strongly in females; dorsal margin straight, overreached by longitudinal dorsal rib, ventral margin convex in females, almost straight in males. Anterior margin broadly rounded, dorsally oblique. Posterior margin narrowly rounded, very slightly pointed. Anterior and posterior margins finely denticulate. Eye-tubercle faintly developed, attached to anterior marginal rib. Surface sculpture composed of reticulation and three longitudinal ribs. Reticulation moderately coarse, regularly following the margins, aligned in two rows in intercostal areas. The three longitudinal ribs develop from the reticules behind the muscle region. Dorsal rib elevated, overreaches dorsal margin, being straight in the middle, bending obliquely anteriorly and posteriorly. Median rib rises gently behind the muscle region and disappears posteriorly in the reticulation at about three quarters of carapace length. Ventral rib broadly convex subparallel to ventral margin, joined anteriorly to reticulation muri that posteriorly bound the anterior reticulation alignment behind the marginal rib. Anterior marginal rib well-developed, being separated from anterior margin by a single row of reticules. Maximum length median, maximum height at eye-tubercle, at about one-fifth of length. Outline in dorsal view oval, with more or less homogenous lateral inflation and compressed ends.

Internal features: Not accessible.
**Sexual dimorphism:** Pronounced, males are more elongate than females.

**Discussion:** The new species resembles *Reymenticosta parabensoni* Bassiouni and Luger, 1990 in having the reticules in the intercostal areas aligned in two rows. However, *R. parabensoni* differs in having a narrower posterior end and finer reticules at anterior and posterior regions. Moreover, the longitudinal margins in the males of *R. parabensoni* are converging posteriorly, whereas in the present species they are subparallel. *Reymenticosta bensoni* (Donze and Said) (in Donze et al., 1982) is differentiated from both species by having the reticules in the intercostal areas further subdivided. *Reymenticosta zitteli Bassiouni and Luger, 1990* (=*Reymenticosta transaharaensis* Carbonnel et al., 1990) is similar to the present species with respect to outline and ornamentation at anterior and posterior marginal areas, but deviates in having the intercostal spaces of the median third of carapace occupied by a single row of high reticules. *Reymenticosta grekoffi* (Reyment, 1960) shows a similar outline and reticulation of intercostal areas to *R. bassiounii* n. sp., but has different reticulation anteriorly and posteriorly.

**Occurrence:** Upper Paleocene (Thanetian) at Sidi Nasseur.

*Reymenticosta nasseurensis* n. sp.
Plate 2, Figs. 20–22, Plate 3, Figs. 1–4

**Derivatio nominis:** From Sidi Nasseur area, the type locality of the species.

**Holotype:** Female carapace (Plate 3, Fig. 1, TPE43).

**Paratypes:** 316 specimens of which two female carapaces (Pl. 2, Figs. 20–21, TPE40–41), one female left valve (Plate 2, Fig. 22, TPE42) and three male carapaces (Plate 3, Figs. 2–4, TPE44–46) are illustrated.

**Locus typicus:** Sidi Nasseur section.

**Stratum typicum:** A shale bed, upper Paleocene (Thanetian), zone P4–P5 (subzone NP9a), sample NAS 7.90.

**Diagnosis:** A species of the genus *Reymenticosta* with indistinct reticulation and three elevated longitudinal ribs of which the ventral rib rises anteriorly upwards to support eye-tubercle from below.

**Dimensions:** Females: L: 0.95 mm, H.: 0.52 mm (holotype), L.: 0.95 mm, H.: 0.52, W.: 0.46 mm (paratypes); males: L: 1.01–1.02 mm, H: 0.50–0.52 mm (paratypes); W: 0.43 mm (paratypes).

**Description:** *External features:* Carapace medium-sized, oval in lateral view. Longitudinal margins converging posteriorly; dorsal marginal straight, modified by overreaching dorsal rib, joined to anterior and posterior margins through cardinal angles. Anterior cardinal angle protruding, posterior cardinal angle obtuse. Ventral margin broadly convex. Anterior margin broadly rounded, dorsally oblique, posterior margin narrow, upturned. Anterior and ventral–posterior margins finely denticulate. Eye-tubercle faintly developed, attached from below to joined anterior marginal rib and uprising extension of ventral rib. Ornamentation consists of three raised longitudinal ribs and faint reticulation. Dorsal rib very broadly arched, overreaching dorsal margin; anteriorly, it obtusely bends towards median rib, posteriorly, it slopes ending at a pore-cone shortly in front of posterior extremity. Median rib rises gently behind the muscle region and extends posteriorly at about three quarters of carapace length. Ventral rib broadly convex, subparalal to ventral margin, rises anteriorly upwards to join the well-developed anterior marginal rib at eye tubercle. Anterior marginal rib well-developed behind anterior margin; in front of it, a thinner rib is present along the upper two thirds of anterior margin. Reticulation indistinct, with rudimentary muri and pore-cones, better developed below ventral rib. The intercostal area displays longitudinal muri reflecting tendency to split the vague reticules into two rows. Maximum length above the middle, maximum height at eye-tubercle, at about one-fifth of length. Outline in dorsal view oval with gently tapering ends; maximum width behind the middle.

**Internal features:** Inner lamella of moderate width, building a narrow vestibule anteroventrally. Selvage subperipheral. Marginal pore-canals numerous, straight, normal pore-canalt distinct, widely spaced. Hinge amphidont, consisting in the left valve of an anterior socket closed from below by an elevate ridge, a postjacent knob-like tooth stepped anteriorly, a median, faintly crenulated furrow widening to extremities and a posterior socket closed from below by an elevated ridge. Right valve ventrally has an “Anschlagknopf”. Muscle scars not well-preserved.

**Sexual dimorphism:** Pronounced, males are longer and lower than females.

**Discussion:** *Reymenticosta parabensoni* Bassiouni and Luger, 1990 closely resembles *Reymenticosta nasseurensis* n. sp. in outline and shape of the longitudinal ribs. It differs however in having a very distinct surface reticulation and less-developed anterior marginal rib. Moreover, the anterior uprisng extension of the ventral rib found in the present new species is not displayed in *R. parabensoni*; it might be accentuated in the present species in favor of the absence of reticules. *Reymenticosta zitteli Bassiouni and Luger, 1990* (=*R. transaharaensis* Carbonnel et al., 1990) is similar to the present species with respect to the rib developments, but deviates in outline and in having a more distinct reticulation with the intercostal spaces of the median third of carapace occupied by a single row of high reticules; in *R. nasseurensis* n. sp. the reticulation is indistinct and the intercostal area displays longitudinal muri reflecting tendency to split the vague reticules into two rows.

**Occurrence:** Upper Paleocene (Thanetian) at Sidi Nasseur.

**Subfamily BRACHYCYTHERINAE Puri, 1954.
Genus Dahomeya Apostolescu, 1961

*Dahomeya alata alata* Apostolescu, 1961
Plate 3, Fig. 5

1963. *Dahomeya alata* Apostolescu – Barsotti, p. 1524, Pl. 1, Fig. 3.
1978. *Dahomeya alata* Apostolescu – Ducasse et al., p. 20, Pl. 2, Fig. 3.
1981. *Dahomeya alata* Apostolescu – Reyment, p. 57, Pl. 1, Figs. 11 and 12, Pl. 2, Fig. 3.
1986 *Dahomeya alata* Apostolescu – Carbonnel, p. 81, Pl. 5, Figs. 4–6.
1987. *Dahomeya alata* Apostolescu – Okosun, p. 84, Pl. 15, Fig. 5, Pl. 17, Figs. 9, 12 and 15.
1990. *Dahomeya alata alata* Apostolescu – Carbonnel et al., p. 679, Pl. 2, Fig. 7.
1991. *Dahomeya alata* Apostolescu – Damotte, p. 10, Pl. 2, Fig. 7.
1994. *Dahomeya alata* Apostolescu – Digbehi et al., p. 193, Pl. 2, Fig. 15.
1994. *Dahomeya alata* Apostolescu – Keen et al., Pl. 16.1, Fig. 8.
1995. *Dahomeya alata* Apostolescu – Carbonnel and Monciardi, p. 62, Pl. 6, Fig. 15.
1998. *Dahomeya alata alata* Apostolescu – Sarr, p. 160, Pl. 1, Fig. 13.
1998. *Dahomeya alata alata* Apostolescu – Colin et al., p. 304, Pl. 6, Fig. 14.  

**Material**: a single specimen.  
**Dimensions**: L.: 0.50 mm, H.: 0.30 mm.

**Occurrence**: The present subspecies is widely known in West and North Africa from the Paleocene of Ivory Coast (*Apostolescu, 1961; Digbehi et al., 1994*), Nigeria (*Reyment, 1981; Okosun, 1987*), Mali (*Damotte, 1991; Carbonnel and Monciardini, 1995; Colin et al., 1998*) and Niger (*Carbonnel et al., 1990; Carbonnel and Monciardini, 1995*), Paleocene to lower Eocene of Senegal (*Apostolescu, 1961; Ducasse et al., 1978; Carbonnel, 1986; Sarr, 1998*), and upper Paleocene to lower Eocene of Egypt (*Bassioni and Luger, 1990; Bassioni and Morsi, 2000*), Libya (*Barsotti, 1963; El-Waer, 1992; Whatley and Arias, 1993; Keen et al., 1994*) and Tunisia (*Donze et al., 1982*). In the present work, it is recorded from the lower Eocene at Sidi Nasseur.

**Subfamily BUNTONINAE** Apostolescu, 1961

Genus *Buntonia* Howe, 1935

*Buntonia fortunata* Apostolescu, 1961  
**Plate 3, Figs. 6–9**

1963. *Buntonia fortunata* Apostolescu – Reymant, p. 50, Pl. 17, Figs. 6 and 7, Pl. 18, Fig. 1.  
1978. *Buntonia fortunata* Apostolescu – Ducasse et al., p. 20, non 1983. *Buntonia fortunata* Apostolescu – Foster et al., p. 120, Pl. 3, Fig. 10, Pl. 7, Figs. 8 and 9.  
1995. *Buntonia fortunata* Apostolescu – Carbonnel and Monciardini, p. 50, Pl. 5, Fig. 12.

**Material**: 32 specimens.  
**Dimensions**: Females: L.: 0.47–0.50 mm, H.: 0.29–0.31 mm, W.: 0.22 mm; male: L.: 0.57, H.: 0.31 mm.

**Remarks**: In the present material, sexual dimorphism is observed; males are more elongate than females. When Apostolescu first described the present species he pointed out that it occasionally possesses an elevated rim at the anterior margin: “extrémité antérieure régulièrement arrondie et surmontée d’un rebord parfois assez saillant”. In present material this elevated anterior margin is merely finely punctate (Plate 3, Figs. 10 and 13). In the present material comes from.

**Derivatio nominis**: With reference to Tunisia, where the present material comes from.

**Holotype**: Female carapace (Pl. 3, Fig. 11, TPE54).

**Paratypes**: 61 specimens of which two female carapaces (Pl. 3, Figs. 10 and 12, TPE52 and TPE54), and one male carapace (Pl. 3, Fig. 13, TPE53) are illustrated.

**Locus typicus**: Sidi Nasseur area.

**Stratum typicum**: A shale bed, basal Eocene, sample NAS 10.75.

**Diagnosis**: A species questionably assigned to the genus *Buntonia* with a densely punctate lateral surface, thick anterior and posterior marginal ribs, broadly concave ventrolateral rib and a short, thin mediadorsal rib from which three, variably developed ribs extend downwards.

**Dimensions**: Females: L.: 0.50 mm, H.: 0.31 mm (holotype), L.: 0.49 mm, H.: 0.30, W.: 0.20 mm (paratypes); male: L.: 0.50 mm, H.: 0.26 mm (paratype).

**Description**: *External features*: Carapace small, suboval in lateral outline. Maximum length at mid-height, maximum height at anterior one-third of length. Anterior margin broadly rounded, smoothly joined to dorsal and ventral margins. Dorsal margin straight, ventral margin convex, with steeper anteroventral slope in females, straight in males. Posterior margin rounded with a weak concavity in the right valve above the middle. Ornamentation consists of a broadly concave ventrolateral rib, dense surface punctae, and marginal anterior, posterior and dorsal ribs. The anterior rib is thick, begins at eye-spot, runs parallel to the margin, and ends at anteroverntal corner. In front of this, two parallel ribs are present, one at half distance to the margin and the other occupies the anterior margin; the area between the rib and the fine ribs as well is coarsely punctate. In some specimens, the area behind the thick anterior rib displays a single alignment of adjoining coarse reticules. Posterior marginal rib moderately-thick, shortly separated from the marginal. Dorsal riblet fine, from it three variably developed ribs extend downwards. Small cones are occasionally present in the median part. Eye-spot developed. Carapace in dorsal view suboval with compressed ends; maximum width behind the middle, at posterior one-third of length.

**Internal features**: Not accessible.

**Sexual dimorphism**: Pronounced, males are longer and lower than females.

**Discussion**: The present new species is assigned to the genus *Buntonia* based on outline and similarity to *Buntonia compressa* Carbonnel, 1990 from the upper Paleocene of West Africa. However, the generic assignment is questionable since no open valves are available and the internal features could not be recognized. *Buntonia compressa* resembles the present species in the general aspects of ornamentation. It is differentiated by having a broader posterior margin and two anterior marginal ribs, one at the margin and the other behind it; in the present species the anterior marginal area is occupied by a thick rib parallel to the margin and two riblets in front of it of which one coincides with the margin. Moreover, *Buntonia compressa* lacks the dense punctation exhibited by our material and the illustration of its holotype (*Carbonnel, 1990: Pl. 1, Fig. 14*) shows a longitudinal median rib which is lacking in the present material. *Buntonia teiskotensis* Apostolescu, 1961 from the Paleocene of Mali has similarly ventrolateral and marginal ribs, but deviates clearly in lateral and dorsal outline and lacks the vertical mediadorsal ribs and surface punctation. Intraspecific variation is displayed in the material of *Buntonia? tunisiensis* n. sp.; in some specimens the area immediately behind the thick anterior rib exhibits a single alignment of adjoining coarse reticules in some specimens (Plate 3, Fig. 11), whereas in others, this area is merely finely punctate (Plate 3, Figs. 10 and 13).
Occurrence: Lower Eocene (Ypresian) at Sidi Nasseur and Wadi Mezzar.

Buntonia sp. 3 Donze et al., 1982
Plate 3, Figs. 14 and 15


Material: nine specimens.

Dimensions: Females: L: 0.67 mm, H.: 0.49 mm; male: L: 0.81 mm, H.: 0.43 mm.

Remarks: The present species is characterized by the presence of a large subocular depression and occasional irregular punctuation at posterior part of lateral surface. The specimens illustrated by Keen et al. (1994) as *Buntonia teiskotensis* Apostolescu from the Danian of Libya are very close, but exhibit an anteriomarginal rim, which is neither shown in our specimens nor in the illustrations of Donze et al. (1982). *B. teiskotensis* Apostolescu, 1961 from the Paleocene of Mali is remarkably higher, with a broader posterior margin and exhibits a high rim at anterior and posterior margins.

Occurrence: This species was previously recorded in the upper Paleocene of El Kef section in Tunisia (Donze et al., 1982). Closely similar specimens were recorded in the Danian of Libya (Keen et al., 1994). In the present study, this species is found in the upper Paleocene (Thanetian) at Sidi Nasseur.

Genus Isobuntonia Apostolescu, 1961

Isobuntonia sp.
Plate 3, Figs. 16 and 17

Material: eight specimens.

Dimensions: L: 1.00–1.03 mm, H.: 0.50–0.53 mm.

Occurrence: Upper Paleocene, Sidi Nasseur section.

Protobuntonia Grékoff, 1954

Protobuntonia nakkadii Bassiouni, 1970

Plate 3, Fig. 18


1994. *Protobuntonia nakkadii* Bassiouni – Keen et al., Pl. 16.2, Fig. 12.

1998. *Protobuntonia nakkadii* Bassiouni – Said-Benzarti, Pl. 2, Fig. 2.

2000. *Protobuntonia nakkadii* Bassiouni – Morsi, p. 63, Pl. 3, Fig. 12.

Material: 10 specimens.

Dimensions: L: 1.26 mm, H.: 0.70 mm, W.: 0.50 mm.

Occurrence: The species was previously recorded from the Maastrichtian–lower upper Paleocene of Egypt (Bassiouni and Luger, 1990; Morsi, 2000), upper Maastrichtian–upper Paleocene of Tunisia (Donze et al., 1982; Said-Benzarti, 1998) and Algeria (Damotte and Fleury, 1987), lower Paleocene of Libya (Keen et al., 1994) and upper Paleocene of Jordan (Bassiouni, 1970). Here, it is found in the upper Paleocene at Sidi Nasseur.

Subfamily CAMPYLOCYTHERINAE Puri, 1960

Genus Alocopocythere Siddiqui, 1971

Alocopocythere attitogonensis (Apostolescu, 1961)
Plate 3, Figs. 19–24


1988. *Anticythereis attitogonensis* Apostolescu – Carbonnel, p. 149, Pl. 2, Fig. 6.


Material: 993 specimens.

Dimensions: Females: L: 0.61–0.63 mm, H.: 0.34–0.37 mm, W.: 0.31 mm; males: L: 0.67–0.68 mm, H.: 0.34–0.37 mm, W.: 0.31 mm.

Description: External features: Carapace subrectangular in lateral outline. Dorsal margin straight, slightly modified by overreaching dorsolateral surface, joined to anterior and posterior margins through cardinal angles. Anterior cardinal angle protruding, posterior cardinal angle less developed. Ventral margin almost straight, joined to anterior margin with slight concavity, rises at its posterior end to smoothly join posterior margin. Anterior margin broadly rounded, posterodorsal margin very slightly concave, particularly in the right valve, posteroventral margin rounded. Left valve slightly overreaches right valve, most clearly at posterodorsal margin. Eye-tubercle distinct and smooth. Surface reticulate; reticules medium-sized, homogenous, concentrically arranged at anterior region, more or less longitudinally at the posterior two thirds. Anterodorsal furrow small, also reticulate. Muscle region not tuberculate, however accentuated by concentric arrangement of reticules and a depression just behind the muscle area. Small spines decorate central–anterior, ventral anterior and ventral–posterior margins. Maximum length almost central, maximum height at eye tubercle, at about one-fourth of length in females and one-fifth of length in males. In dorsal view, carapace oval–elongate, more slightly thickened behind middle.

Internal features: Not accessible.

Sexual dimorphism: Pronounced, males are longer and thinner than females.

Remarks: *Alocopocythere attitogonensis* (Apostolescu, 1961) shows resemblance to *Alocopocythere schmitzi Morsi and Speijer, 2003* from the upper Paleocene of Egypt. It is differentiated, however, by its narrower posterior margin, smaller furrow behind the eye tubercle, thicker muri and less angular reticules.

Occurrence: The species was previously recorded in the Paleocene–middle Eocene of Togo (Apostolescu, 1961; Carbonnel and Johnson, 1989) and the offshore of Mauritania (Carbonnel, 1988). In the present study, it occurs in the lower Eocene at Wadi Mezzar and Sidi Nasseur.

Genus Leguminocythereis Howe, 1936

Leguminocythereis lokossaensis Apostolescu, 1961
Plate 3, Fig. 25


1963. *Leguminocythereis lokossaensis* Apostolescu – Barsotti, p. 1527, Pl. 2, Fig. 10.


1982. *Leguminocythereis lokossaensis* Apostolescu – Mohamed, p. 264, Pl. 23, Fig. 11.


1989. *Leguminocythereis lokossaensis* Apostolescu – Carbonnel and Johnson, p. 419, Pl. 3, Fig. 9.

2003. Leguminocythereis lokossaensis Apostolescu – Morsi and Speijer, p. 72, Pl. 3, Figs. 22 and 23.

Material: a single specimen.
Dimensions: L: 0.70 mm, H: 0.37 mm.
Occurrence: Paleocene–lower Eocene of Togo (Apostolescu, 1961; Carbonnel and Johnson, 1989), upper Paleocene–lower Eocene of Libya (Barsotti, 1963; Salahi, 1966) and Egypt (Mohamed, 1982; Bassiouni and Luger, 1990; Bassiouni and Morsi, 2000; Morsi and Speijer, 2003). The present specimen was found in the lower Eocene (Ypreian) at Sidi Nasseur.

Family XESTOLEBERIDIDAE Sars, 1928
Genus Xestoleberis Sars, 1866
Xestoleberis tunisiensis Esker, 1968 Plate 3, Fig. 26

1968. Xestoleberis tunisiensis n. sp. – Esker, p. 332, Pl.2, Figs. 13 and 14, Pl. 4, Fig. 2.
1982. Xestoleberis tunisiensis Esker – Donze et al., p. 282, Pl. 2, Fig. 9.
1992. Xestoleberis tunisiensis Esker – Ismail, p. 51, Pl. 2, Fig. 8.
1996. Xestoleberis tunisiensis Esker – Bassiouni and Luger, p. 73, Pl. 24, Figs. 14 and 17.
1998. Xestoleberis tunisiensis Esker – Said-Benzarti, Pl. 3, Fig. 21.
2000. Xestoleberis tunisiensis Esker – Bassiouni and Morsi, p. 68, Pl. 12, Figs. 11–14.
2003. Xestoleberis tunisiensis Esker – Morsi and Speijer, p. 78, Pl. 5, Fig. 57.
non 2005. Xestoleberis tunisiensis Esker – Shahin, p. 765, Pl. 4, Fig. 18.
2009. Xestoleberis tunisiensis Esker – Morsi and Scheibner, p. 175, Pl. 5, Fig. 20.

Material: a single specimen.
Dimensions: L: 0.43 mm, H: 0.29 mm.
Occurrence: Upper Campanian to lower Paleocene of Tunisia (Esker, 1968; Said, 1978; Donze et al., 1982; Said-Benziarti, 1998), Maastrichtian of Algeria (Damotte and Fleury, 1987), Maastrichtian to lower Eocene of Egypt (Bassiouni and Luger, 1990; Ismail, 1992; Bassiouni and Morsi, 2000; Morsi and Speijer, 2003; Morsi and Scheibner, 2009) and Eocene of Somalia (Bassiouni and Luger, 1996). Here, it is found in the upper Paleocene (Thanetian) at Sidi Nasseur.

6. Ostracode biostratigraphy

6.1. Sidi Nasseur

We counted 1603 specimens belonging to 22 different taxa extracted from two sample sets taken from the Sidi Nasseur section (NAS: Nas’99 and Nas’06). An almost continuous record was found in the upper Paleocene and lower Eocene parts of the section (Tables 1 and 2, Fig. 3). In the upper Paleocene, we counted 918 specimens assigned to 17 species. In the lower Eocene, 682 specimens belonging to seven species have been retrieved. The PETM interval is characterized by a marked ostracode faunal turnover. The associations recorded below and above the P/E boundary are almost completely different as only one species, Cytheropteron lugeri, is in common. The assemblage recorded in the upper Paleocene is highly diverse. It is characterized by the dominant occurrence of Reymenticosta bassiouni, R. nasseurensis, Paracosta kefensis and P. aff. paleomokattamensis, associated with a less common to rare presence of Cythereella aff. farafraensis, Bairdia aegyptiaca, Paracypris sp. B Esker, Parakraithe croafa (MTB, Bassiouni and Luger, 1990), Cytheropteron lugeri, Loxoconcha saharaisensis, Aegyptiana duwiensis, Reticulina lamellata, R. proteros, R. sangalkamensis, Puntonia sp. 3 Donze et al., Isobuntonia sp., Protobuntonia nakkadi and Xestoleberis tunisiensis (Tables 1 and 2). During the PETM, this assemblage is completely replaced by a different, poorly diverse ostracode fauna. In the basal ~1 m of the lower Eocene, this fauna is characterized by a monospecific occurrence of Alocopocythere attigotonensis. Higher up the assemblage consists of highly dominant A. attigotonensis, with less common occurrences of Puntonia? tunisiensis and Puntonia fortunata and rare representatives of Cytheropteron lugeri, Eucytherura aff. dentata, Leguminocythereis lokossaensis and Dahomeyana alata alata.

6.2. Wadi Mezzaz

The Wadi Mezzaz section yielded 579 ostracode specimens representing seven species (Table 3, Fig. 4). Of these, Paracypris aff. jonesi is not recorded at Sidi Nasseur. The lowermost 80 cm of the section (Mzg’06) yielded a rare fauna exclusively comprised of Alocopocythere attigotonensis. Up-section, it is characterized by dominant occurrence of A. attigotonensis with less common occurrence of Puntonia? tunisiensis and rare occurrence of Puntonia fortunata. The upper part of the section (topmost part of Mzg’06 and Mzh’06) is characterized by dominant occurrences of A. attigotonensis and Aegyptiana duwiensis, with occasional presence of Paracypris aff. jonesi, Bairdia aegyptiaca and Reticulina lamellata (Table 3). Of these taxa, B. aegyptiaca, A. duwiensis and R. lamellata are also present among the upper Paleocene assemblage from Sidi Nasseur.

6.3. Biostratigraphic implications

We found a total of 2182 specimens representing 26 different ostracode species in the studied late Paleocene–early Eocene sections in the Sidi Nasseur–Wadi Mezzaz area. Of these, 15 taxa (~57.7%) have been found only in the late Paleocene, seven taxa (~26.9%) in the early Eocene, and four taxa (~15.4%) in both intervals. Most of the recorded taxa are known from the Paleocene and early Eocene in the Middle East and North and West Africa (Table 4). The ostracode data show a distinct turnover at the Paleocene/Eocene boundary (Figs. 3–6). Two different assemblages are clearly differentiated for the late Paleocene and early Eocene respectively (Figs. 3–5). In the late Paleocene, the ostracode assemblage is dominated by Reymenticosta bassiouni, R. nasseurensis, Paracosta kefensis (MTA) and P. aff. paleomokattamensis, which are found restricted to this interval (Paleocene assemblage: Fig. 5). Of these taxa, Reymenticosta bassiouni and R. nasseurensis are newly described herein. Paracosta kefensis (MTA) and P. aff. paleomokattamensis were previously recorded in Tunisia at El Kef (Donze et al., 1982) and Ellès (Said, 1978; Said-Benziarti, 1998) in the same stratigraphic interval. Paracosta kefensis was also recorded in Egypt in two morphotypes, MTA, to which the Tunisian material belongs, occurring only in the late Paleocene and MTB, which deviates mainly in posterior outline, spanning the late Paleocene–early Eocene (Bassiouni and Luger, 1990; Morsi and Speijer, 2003). The late Paleocene assemblage also includes less common to rare representatives of Cythereella aff. farafraensis and Isobuntonia sp. which have not been observed elsewhere, Bairdia aegyptiaca, Cytheropteron lugeri, Aegyptiana duwiensis, Reticulina
Table 1
Distribution of ostracode taxa at Sidi Nasseur (NAS), section Nas'99.

|---------------|-------------------------|--------------------------|-------------------------|------------------------|-----------------------------|-----------------------------|---------------------------------|-----------------------------|----------------|----------------|-----------------------------|----------------|----------------|--------------------|-----------------------------|----------------|----------------|----------------|-----------------
| 17.50         | 17.50                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 17.50             |
| 16.50         | 16.50                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 16.50             |
| 15.50         | 15.50                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 15.50             |
| 15.00         | 15.00                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 15.00             |
| 14.50         | 14.50                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 14.50             |
| 14.00         | 14.00                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 14.00             |
| 13.50         | 13.50                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 13.50             |
| 13.00         | 13.00                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 13.00             |
| 12.50         | 12.50                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 12.50             |
| 12.00         | 12.00                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 12.00             |
| 11.50         | 11.50                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 11.50             |
| 11.00         | 11.00                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 11.00             |
| 10.50         | 10.50                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 10.50             |
| 10.00         | 10.00                   |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 10.00             |
| 9.50          | 9.50                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 9.50              |
| 9.00          | 9.00                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 9.00              |
| 8.50          | 8.50                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 8.50              |
| 8.00          | 8.00                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 8.00              |
| 7.50          | 7.50                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 7.50              |
| 7.00          | 7.00                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 7.00              |
| 6.50          | 6.50                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 6.50              |
| 6.00          | 6.00                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 6.00              |
| 5.50          | 5.50                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 5.50              |
| 5.00          | 5.00                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 5.00              |
| 4.50          | 4.50                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 4.50              |
| 4.00          | 4.00                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 4.00              |
| 3.50          | 3.50                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 3.50              |
| 3.00          | 3.00                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 3.00              |
| 2.50          | 2.50                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 2.50              |
| 2.00          | 2.00                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 2.00              |
| 1.50          | 1.50                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 1.50              |
| 1.00          | 1.00                    |                           |                         |                        |                             |                             |                                 |                             |               |                |                             |               |                |                    |                             |               |                |               | 1.00              |
| Sample number | Sidi Nasseur height (m) | 6.50 | 6.40 | 6.30 | 6.20 | 6.10 | 6.00 | 5.90 | 5.80 | 5.70 | 5.60 | 5.50 | 5.40 | 5.30 | 5.20 | 5.10 | 5.00 | 4.90 | 4.80 | 4.70 | 4.60 | 4.50 | 4.40 | 4.30 | 4.20 | 4.10 | 4.00 | 3.90 | 3.80 | 3.70 | 3.60 | 3.50 | 3.40 | 3.30 | 3.20 | 3.10 | 3.00 | 2.90 | 2.80 | 2.70 | 2.60 | 2.50 | 2.40 | 2.30 | 2.20 | 2.10 | 2.00 | 1.90 | 1.80 | 1.70 | 1.60 | 1.50 | 1.40 | 1.30 | 1.20 | 1.10 | 1.00 | 0.90 | 0.80 | 0.70 | 0.60 | 0.50 | 0.40 | 0.30 | 0.20 | 0.10 | 0.00 |
|-------------|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 11.75       | 5.140                   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
Fig. 3. Ostracode distribution and frequency patterns (relative abundance) of the most important ostracode taxa (>2.5% in at least one sample) at Sidi Nasseur. Note that in order to reduce bias toward the high-resolution interval and to increase the number of specimens per interval, census data from individual sample sets are combined into 1 m intervals.
Table 3
Distribution of ostracode taxa in Wadi Mezaz section (MEZ).

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<th>Sample number</th>
<th>Wadi Mezaz height (m)</th>
<th>Alocopocythere attitogonensis</th>
<th>Buntonia? fortunea</th>
<th>Buntonia? tunisiensis</th>
<th>Aegyptiana duwiensis</th>
<th>Paracypris aff. jonesi</th>
<th>Bairdia aegyptiaca</th>
<th>Reticulina lamellata</th>
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Lamellata, R. proteros, R. sangalkamensis and Xestoleberis tunisiensis, which are known from the Paleocene and early Eocene in Tunisia and elsewhere, and Paracypris sp. B Esker, Parakrithe crolifa (MTB), Loxoconcha saharaensis, Buntonia sp. 3 Donze et al. and Protobuntonia nakkadii, which appear restricted to the Paleocene in Tunisia and elsewhere (Table 4). In the basal Eocene the majority of the abovementioned taxa disappeared, being replaced by a new assemblage, starting at the onset of the PETM, initially exclusively consisting of Alocopocythere attitogonensis, and higher up by strongly dominant A. attitogonensis with less common occurrences of Buntonia fortunea and Buntonia? tunisiensis, and rare presence of Cytheropteron lugeri, Eucytherura aff. dentata, Leguminocythereis lokossaensis and Dahomeya alata alata (PETM assemblage: Fig. 5). Above the PETM interval, the assemblage is characterized by the frequent occurrence of A. attitogonensis and Aegyptiana duwiensis, with less common representatives of Paracypris aff. jonesi, Bairdia aegyptiaca and Reticulina lamellata (Eocene assemblage: Fig. 5). Among these taxa, Aegyptiana duwiensis and Reticulina lamellata were previously recorded in the early Eocene in Tunisia, at El Kef (Donze et al., 1982) and Ellès (Said-Benzarti, 1998). Alocopocythere attitogonensis, the most dominant species in the entire early Eocene assemblage, was previously recorded in the Paleocene–middle Eocene of the West African basins (Table 4). Of the associated taxa, Eucytherura aff. dentata also occurs in the early Eocene in Egypt (Bassiouni and Morsi, 2000). Although Leguminocythereis lokossaensis was recorded in the Paleocene and early Eocene in West Africa, its occurrence in North Africa is much more common in the early Eocene than in the late Paleocene. The remaining early Eocene species were previously observed in the Paleocene and early Eocene in various areas (Table 4). The ostracode faunal turnover represented by the substitution of most of the late Paleocene assemblage by a different early Eocene assemblage in the present area are most likely related to changes in the environmental conditions that took place at the Paleocene/Eocene boundary (Fig. 6).

7. Paleoecology

The paleoenvironmental developments in the study area during the Paleocene–Eocene transition are interpreted by combining various paleoenvironmental indicators. Associated foraminifera and comparison of our ostracode data with bathymetric distribution patterns in Tunisia, Egypt and elsewhere in North Africa and the Middle East (Table 4) indicate that deposition took place in inner neritic to coastal environmental settings. Two different ostracode assemblages are revealed in the studied upper Paleocene to lower Eocene sequence. In the upper Paleocene (Sidi Nasseur), the ostracode assemblage is comprised of taxa known only in the Southern Tethys (Paleocene assemblage: Fig. 5), being dominated by Paracosta kefensis (MTA), P. aff. paleomokattamensis and Reticulina proters, which are found in North Africa, with Reymenticosta bassiounii and R. nasseurenis known from the present study area only. The assemblage additionally includes less common to rare occurrences of Cytherella aff. farrafaensis, Bairdia aegyptiaca, Paracypris sp. B Esker, Parakrithe crolifa (MTB), Cytheropteron lugeri, Loxoconcha saharaensis, Aegyptiana duwiensis, Reticulina lamellata, R. sangalkamensis, Buntonia sp. 3 Donze et al., Isobuntonia sp., Protobuntonia nakkadii and Xestoleberis tunisiensis (Fig. 3). This association is assignable to the South Tethyan Type (OTT) of Bassiouni and Luger.
Fig. 4. Ostracode distribution and frequency patterns (relative abundance) of the most important ostracode taxa (>2.5% in at least one sample) at Wadi Mezaz. Note that in order to reduce bias toward the high-resolution interval and to increase the number of specimens per interval, census data from individual sample sets are combined into 1 m intervals.
genera, Paracosta with the present fauna. Except for the taxa belonging to the costine genera, Buntonia sp. 3 Donze et al., and Paracosta kefensis B. Esker, 1990, which were previously recorded in the upper Paleocene at El Kef (Donze et al., 1997) and dinoflagellates (Guasti et al., 2005) from the Ellès section, Protobuntonia nakkadii sp. late Paleocene, Isobuntonia aff. proteros, Reticulina lamellata and becomes substituted by a fauna dominated by Alocopocythere attitogonensis, and to a lesser extent Buntonia? tunisiensis and Buntonia fortunata, with minor representatives of Cytheropteron lugeri, Eucytherura aff. dentata, Leguminocythereis lokossaensis and Dahomeya alata alata (PETM assemblage: Fig. 5). In the basal ~1 m-thick interval above the P/E boundary, the assemblage is monospecific yielding only Alocopocythere attitogonensis (Figs. 3 and 4). At the

Table 4
Geographic and stratigraphic distribution of ostracode taxa in different regions.

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<th>Species</th>
<th>West Africa (1)</th>
<th>Algeria (2)</th>
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In the early Eocene (PETM interval, Sidi Nasseur–Wadi Mezz), most of the late Paleocene South Tethyan assemblage disappears and becomes substituted by a fauna dominated by Alocopocythere attitogonensis, and to a lesser extent Buntonia? tunisiensis and Buntonia fortunata, with minor representatives of Cytheropteron lugeri, Eucytherura aff. dentata, Leguminocythereis lokossaensis and Dahomeya alata alata (PETM assemblage: Fig. 5). In the basal ~1 m-thick interval above the P/E boundary, the assemblage is monospecific yielding only Alocopocythere attitogonensis (Figs. 3 and 4). At the

[Image 324x64 to 550x304]

Fig. 5. R-mode clustering (PAST software, paired group clustering using Pearson correlation) with three distinctive stratigraphic ostracode groups.
very base, up until ~30 cm above the P/E boundary, marked post-mortem dissolution is observed. Except for *Buntonia? tunicensis*, which is first recorded herein, this fauna is known from the West African basins and is similar to the Afro-Tethyan faunal type (ATT) which Bassiouni and Luger (1990) proposed for the shallow inner neritic suite of taxa present in both northern and West African localities. Benthic foraminiferal assemblages in the PETM interval are more diverse, consist mostly of infaunal species, and are also marked by very low foraminiferal numbers, indicating a deterioration of environmental conditions. The influx of deeper middle neritic infaunal benthic foraminiferal species indicates an increase in water depth with more or less constantly low oxygen levels (Fig. 6). Benthic foraminiferal assemblages gradually recovered during the PETM interval and the species encountered (dominance by *Stainforthia* spp.) higher up, above the thick phosphatic bed in the Wadi Mezaz section, are indicative of eutrophic shallow lagoonal to coastal conditions with better oxygenation compared to the PETM interval (Fig. 6). In this interval, the ostracode faunal composition witnesses the reappearance of *Bairdia aegyptiaca, Aegyptiana duwiensis* and *Reticulina lamellata* in the assemblage (Eocene assemblage: Fig. 5), probably in response to enhanced oxygen levels. *Aegyptiana duwiensis* similarly appears in the early Eocene at El Kef and Ellès, and *R. lamellata* at Ellès (see Donze et al., 1982; Said-Benzarti, 1998). The persistence and dominance of *Alococythere attitogonensis* throughout the entire early Eocene during and after the PETM indicates the tolerance of this species to changes in environmental conditions, which enabled it to live and develop under the environmental stress exerted by the shallow conditions and decrease in oxygenation associated with the PETM.

8. Paleobiogeography

During the Paleocene–early Eocene, Tunisia was a part of the well-documented South Tethyan bioprovince which incorporated North Africa and the Middle East. Numerous papers outlining and discussing the distribution and paleobiogeographic synthesis of ostracode faunas of this biogeographic province during this interval are available (e.g. Reyment and Reyment, 1980; Donze et al., 1982; Damotte and Fleury, 1987; Bassiouni and Luger, 1990; Damotte, 1993, 1995; Keen et al., 1994; Said-Benzarti, 1998; Morsi, 1999; Bassiouni and Morsi, 2000; Elewa, 2002; Luger, 2003; Morsi and Speijer, 2003; Shahin, 2005; Morsi and Scheibner, 2009).

8.1. Paleobiogeographic distribution

Many ostracode species recorded in the present study are known from different regions within the South Tethyan province, from Jordan in the east to eastern Algeria in the west. Several
species are also in common with the basins of West Africa indicating faunal exchange with the North African basins. Among the ostracode fauna found in the present study area, 17 species were also previously reported in other North African and Middle East countries (Table 4). The majority of these taxa, 15 species, were also recorded from different areas in Egypt. These species are Bairdia aegyptiaca, Paracypris eskeri, Parakrithe crolifa, Cytheropteron lugeri, Eucytherura aff. dentata, Loxoconcha saharaensis, Aegyptiana duwiensis, Paracosta kefensis, Reticulina lamellata, R. proteros, R. sangalkamensis, Dahomeya alata alata, Protobuntonia nakkadii, Leguminocythereis lokossaensis and Xestoleberis tunisiensis. Five species represented by Loxoconcha saharaensis, Dahomeya alata alata, Buntonia fortunata, Protobuntonia nakkadii and Leguminocythereis lokossaensis in the present material are also recorded from Libya. In Algeria, four ostracode taxa described by Damotte and Fleury (1987) have been recorded herein: Reticulina lamellata, R. proteros, Protobuntonia nakkadii and Xestoleberis tunisiensis. In Jordan, only Reticulina proteros and Protobuntonia nakkadii among the many ostracode taxa Bassiouni (1970) described are in common with the present material. In Israel, a large number of ostracode species was recorded by Honigstein et al. (1991, 2002) and Honigstein and Rosenfeld (1995) of which only Parakrithe crolifa and Reticulina proteros have been found in the present study. From West Africa, two species recorded in the present study area were recorded in the internal basins in Mali, Niger and NW Nigeria (Dahomeya alata alata, Buntonia fortunata) and five were recorded in coastal basins in Mauritania, Senegal, Ghana, Ivory Coast, Togo, Benin and SW Nigeria (Dahomeya alata alata, Reticulina sangalkamensis, Buntonia fortunata, Alocopocythere attitogonensis, Leguminocythereis lokossaensis). These taxa have their oldest records in the Paleocene of West Africa, whereas in North Africa and the Middle East they appear higher in the uppermost Paleocene or lower Eocene. In the present area, most taxa having paleobiogeographic distributions confined to North African and Middle East areas make up the major part of the fauna recorded herein in the upper Paleocene. On the other hand, the taxa in common with West Africa are found in the lower Eocene, mostly with high frequencies. The only exception is Reticulina sangalkamensis which has occurrences with low frequencies confined to the upper Paleocene.

8.2. Paleobiogeographic implications and conclusions

The paleobiogeographic distribution of the studied ostracode fauna confirms established paleobiogeographic patterns and provides new insights into late Paleocene–early Eocene ostracode distribution changes:

1. During the late Paleocene–early Eocene, Tunisia was a part of the South Tethyan bioprovince which extended along the southern shores of the Tethys in North Africa and the Middle East with no significant geographic barriers hindering east–west migrations.

2. The presence of taxa in common with the basins of West Africa indicates marine connections that allowed faunal exchange with the North African basins.

3. The taxa in common with the West African basins are predominant in the early Eocene, belonging to the shallow, inner shelf Afro-Tethyan Type (ATT) of Bassiouni and Luger (1990). Their earlier appearance in West African basins than in North Africa implicates that they originated in West Africa, then migrated northwards to the southern borders of the Tethys through the shallow Trans-Saharan seaway (Barsotti, 1963; Reyment and Reyment, 1980; Bassiouni and Luger, 1990; Carbonnel et al., 1990; Keen et al., 1994; Carbonnel and Monciardini, 1995; Morsi, 1999; Bassiouni and Morsi, 2000; Morsi and Speijer, 2003) (Fig. 7). The northward migration around western Africa was suggested as a possible route for deeper benthic ostracodes which were not able to reproduce in shallow marine environments of the Trans-Saharan Seaway (Bassiouni and Luger, 1990; Morsi and Speijer, 2003).

4. The predominance of immigrant taxa from West Africa in the early Eocene at the expense of the South Tethyan fauna that prevailed in the late Paleocene characterizes the local Paleocene/Eocene transition.

![Fig. 7. Paleogeographic map showing possible ostracode migration routes from central West African basins to northeast African basins (after Morsi and Speijer, 2003).](image-url)
5. Speijer and Morsi (2002) proposed that paleoceanographic changes during the PETM stimulated ostracode turnover in central and southern Egypt where the South Tethyan fauna was replaced by the regionally more restricted Ensa-type fauna. Yet this faunal transition was not abrupt, but rather progressed by sudden immigration associated with the PETM followed by more gradual replacement. Similar observations were noted for deep-to-shallow hemipelagic deposits fringing an isolated carbonate platform in northern Egypt (Morsi and Scheibner, 2009). Our observations in the Sidi Nasseur–Wadi Mezaz area confirm the view that tropical West African taxa flourished during and after the PETM at the expense of South Tethyan taxa. The local turnover may in part be caused by local biofacial shifts that resulted from sea-level change and a decrease in oxygenation; a similar response was elicited by ostracode faunal turnover at the P/E transition in the Jaisalmer Basin in India (Bhandari, 2008).

6. The recorded fauna is different from the fauna known in the northern Tethys. The dissimilarity between the northern and southern sides of the Tethys was already elucidated by many authors (e.g. Keen et al., 1994; Morsi, 1999; Speijer and Speijer, 2003; Morsi and Scheibner, 2009), and attributed to depth as a barrier to benthic ostracode faunal exchange between the two sides of the Tethys (Babinot and Colin, 1988; Keen et al., 1994).

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References


