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Biostratigraphic and Paleoenvironmental Implications of Eocene Ostracods from Wadi Tayiba-Wadi Nukhul area, West-Central Sinai, Egypt

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ABSTRACT
Investigation of the ostracod faunas recovered from two outcrop sections representing the Eocene succession at Wadi Tayiba and Wadi Nukhul in west central Sinai area yielded 47 species and subspecies belonging to 21 genera and 12 families. The ostracod faunal diversity and abundance are fairly high in the middle part of the two sections (Darat and Khaboba Formations), however dramatically decrease in the lower part of the two sections (Thebes Formation) as well as the upper part of the Wadi Tayiba section (Tanka Formation). Biostratigraphic evaluation of the recorded faunas revealed that the recorded assemblage is typically a Middle Eocene assemblage. The early Middle Eocene (Lutetian) and late Middle Eocene (Bartonian) intervals are distinguished by different ostracod species. The recorded ostracod faunas are entirely comprised of marine taxa. They implicate that the studied succession was deposited in marine environment, under inner to middle neritic environmental settings with transient intervals displaying a deeper outer neritic setting.

Keywords: *Ostracoda; Eocene; Biostratigraphy; Paleobathymetry; Egypt.*

1. Introduction

The Eocene rocks are widely exposed in vast areas of the Egyptian territories, covering about 21% of the surface area of Egypt (Said, 1990). They represent a wide variety of facies deposited in different environmental settings, from continental, to lagoonal, to different depths of marine environment. This wide variety is displayed in the Eocene successions outcropping in the area of west-central Sinai. In this region, the facies variation was not only controlled by eustatic sea-level changes, but was also influenced by tectonic movements that associated the opening of the Gulf of Suez. The area of west central Sinai incorporates one of the basins in the unstable shelf, Abu Zeneima Basin, where thicker than 400 m Paleogene sections are found (Said, 1990). Owing to the tectonic setting associated the rifting and economic importance of the Gulf of Suez region, especially with respect to hydrocarbon exploration, the well-developed Eocene succession was a significant part of the stratigraphic succession that attracted many authors for a long time, not only structural geologist, but equally stratigraphers, paleontologists as well as sedimenologists. Until the nineties of the last century, biostrtigraphic and paleoenvironmental studies were mostly based on foraminifera and calcareous nannoplankton. The study of ostracods in this area was initiated later when Shahin (2000) studied the ostracods from Paleogene-Neogene succession at Gebel Withr. The interest in ostracods from this region has significantly increased and later papers have been published (e.g. Shahin, 2005; Abd-Elshafy *et al*., 2007; Morsi *et al*., 2008). In the present study, we aim to add to the knowledge and understanding of the ostracod faunal composition during the Eocene in west central Sinai for their biostratigraphic and paleoenvironmental implications. For this purpose, the ostracod fauna extracted from two Eocene sections measured at Wadi Tayiba and Wadi Nukhul (Figs. 2, 3) has been investigated and evaluated.

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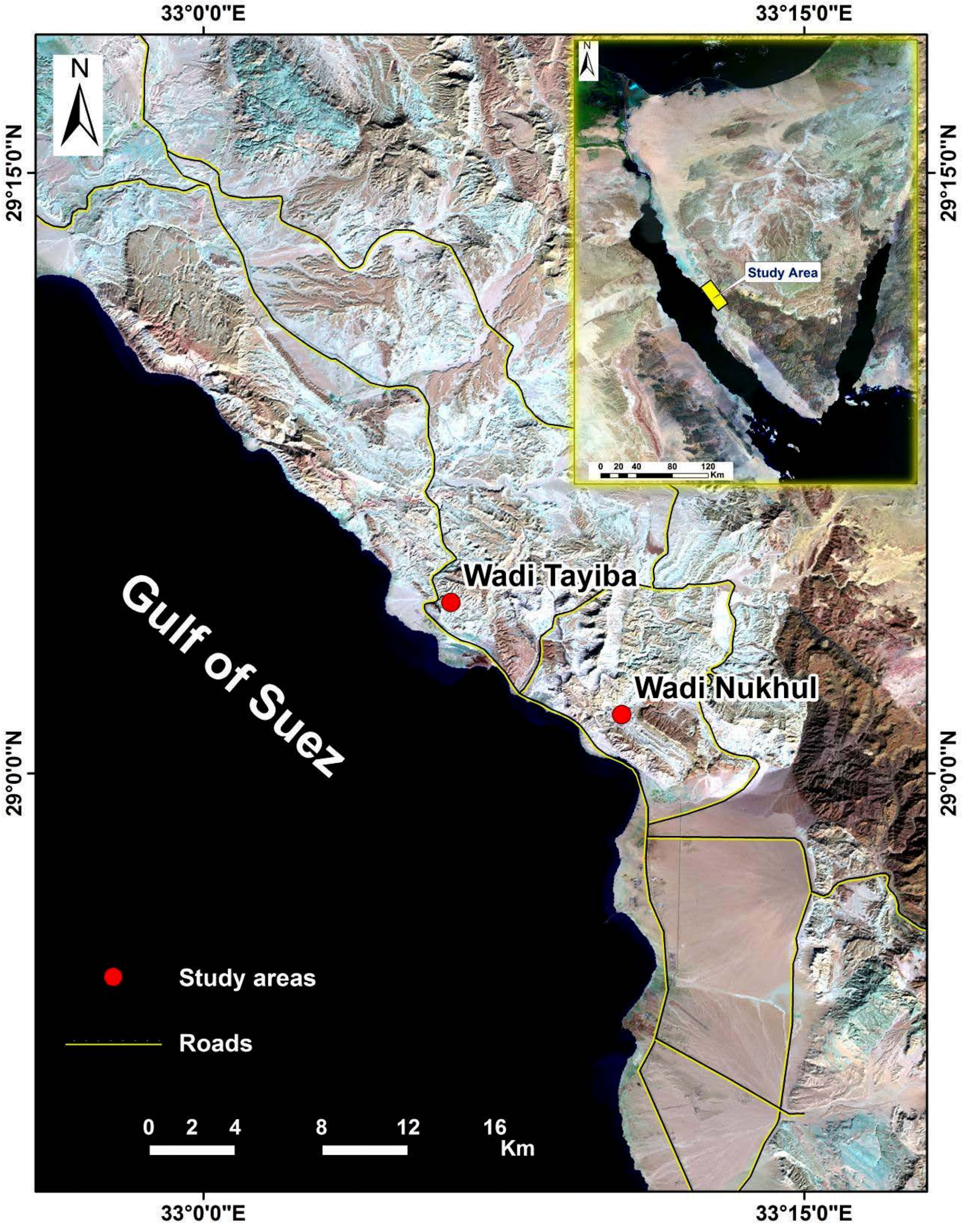

Fig. 1. Location map of the study area.

2. Lithostratigraphy

The studied successions are subdivided into four formations namely, from older to younger, the Thebes, Darat, Khaboba and Tanka Formations. Whereas the Wadi Tayiba section exposes the Thebes, Darat, Khaboba and Tanka Formations, in the Wadi Nukhul section, only the Thebes, Darat and Khaboba Formations are recorded. Age assignments used herein for the aforementioned units are following Abul-Nasr and Thunell (1987). According to theses authors, the Thebes Formation in west central Sinai is assigned as Early Eocene (Ypresian), the Darat Formation as early Middle Eocene (Lutetian), the Khaboba Formation as late Middle Eocene (Bartonian) and the Tanka Formation as Late Eocene (Priabonian). In the two sections, the Eocene rock units are unconformably followed on top by the Tayiba Formation. The Tayiba Formation represents red-colored clastic dominated lacustrine to paracontinental deposits assigned to the Oligocene (Said, 1990). Some authors, however, date this formation as Late Eocene (e.g. Refaat and Imam, 1999; Abul-Nasr, 2000; Abd-Elshafy *et al.*, 2007). Since no ostracods have been retrieved from the Tayiba Formation, it will be out of the scope of the present study.

The following is the detailed overview of the investigated Eocene rock units exposed in the studied area and important ostracod faunal content of each unit:

Thebes Formation:

This formation is composed mainly of yellowish white hard and massive chalky limestone with chert bands and concretions (Figs. 2, 3). The thickness of the Thebes Formation varies from 19 m at Nukhul section to 21 m at Wadi Tayiba section. The Thebes Formation conformably overlies the Esna Formation and underlies the Darat Formation in both Tayiba and Nukhul sections. The Formation is assigned to the Early Eocene (Ypresian).

Darat Formation:

This formation is composed mainly of yellowish brown soft marl intercalated with grayish orange moderately hard argillaceous limestone, pale green soft bedded shale, white hard chalky limestone, occasionally with few peleceypods. A flint band present in the middle of the section of Wadi Nukhul (Figs. 2, 3). The section attains 98.50 m thick in the type area. In the studied sections, the thickness of the Darat Formation varies from 24 meters in Wadi Tayiba section to 67 meters in Wadi Nukhul section. The formation conformably overlies and underlies the Thebes and Khaboba Formation respectively at Tayiba and Nukhul sections. The Darat Formation is assigned to the early Middle Eocene (Lutetian).

Khaboba Formation:

In the study area, the Khaboba Formation is composed mainly of yellow green, yellow brown soft papery shale intercalated with grayish white moderately hard argillaceous limestone, occasionally with few peleceypods (Figs. 2, 3). The section is 98.70 m thick at type area. In the studied sections the thickness of the Khaboba Formation varies from 6 m at Nukhul section to 7 m at Tayiba section. The Khaboba Formation conformably overlies and underlies the Darat Formation and underlies the Tanka Formation in Wadi Tayiba section, but It is conformably overlies the Darat Formation and unconformably underlies the Tayiba Formation (Oligocene) at Wadi Nukhul section. The Formation is assigned to the late Middle Eocene (Bartonian).

Tanka Formation:

In the study area, the Tanka Formation is composed mainly of grayish white hard limestone intercalated with yellowish brown soft papery shale (Fig. 2). The Tanka Formation is recorded only in Wadi Tayiba section where it reaches about 7 m thick. The Tanka Formation is recorded only in the Wadi Tayiba section. It conformably overlies the Khaboba Formation and underlies the Oligocene Tayiba Formation. the Tanka Formation assigned to the Late Eocene (Priabonian).

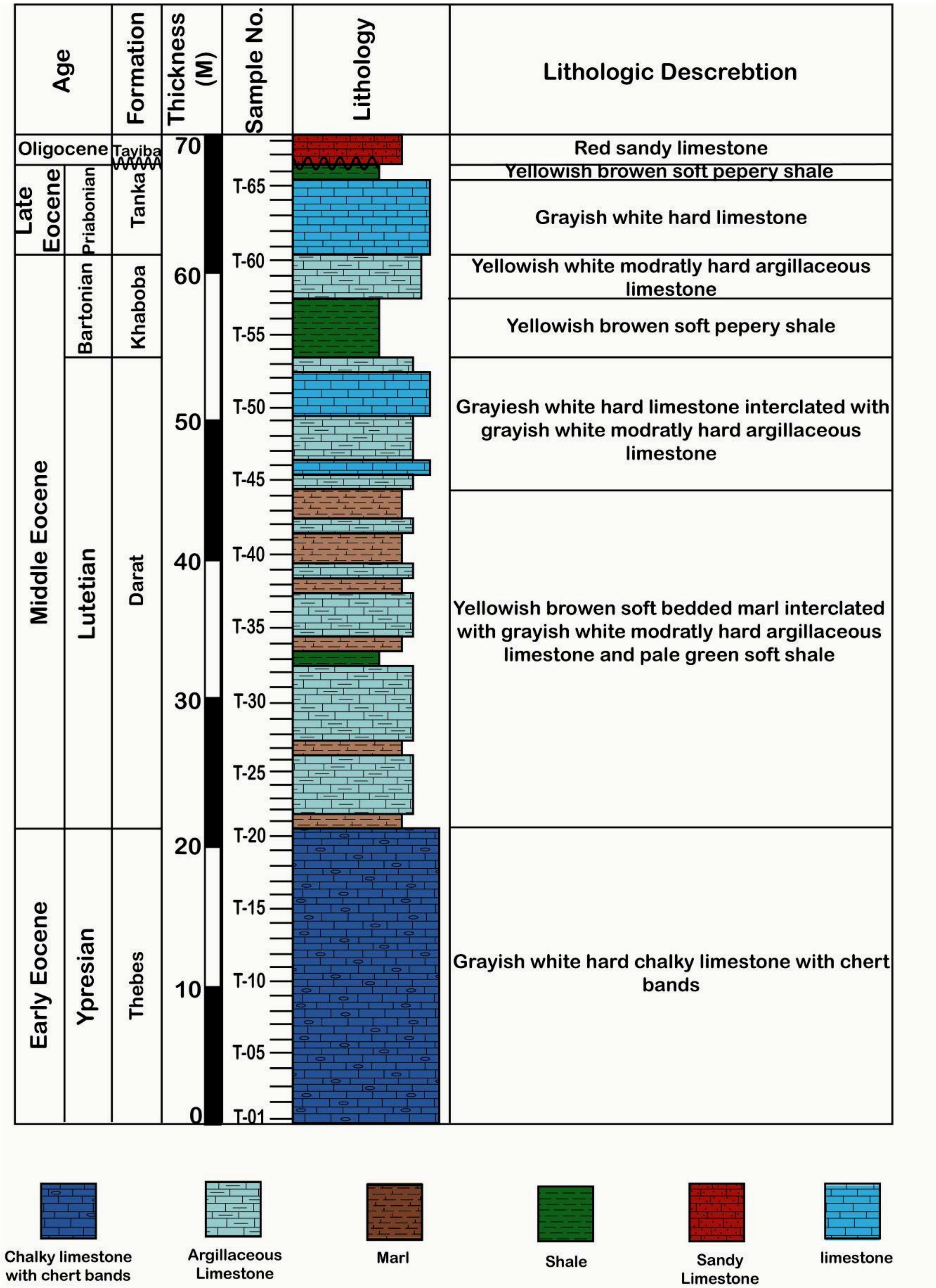

Fig. 2. Stratigraphic columnar section of Wadi Tayiba section.

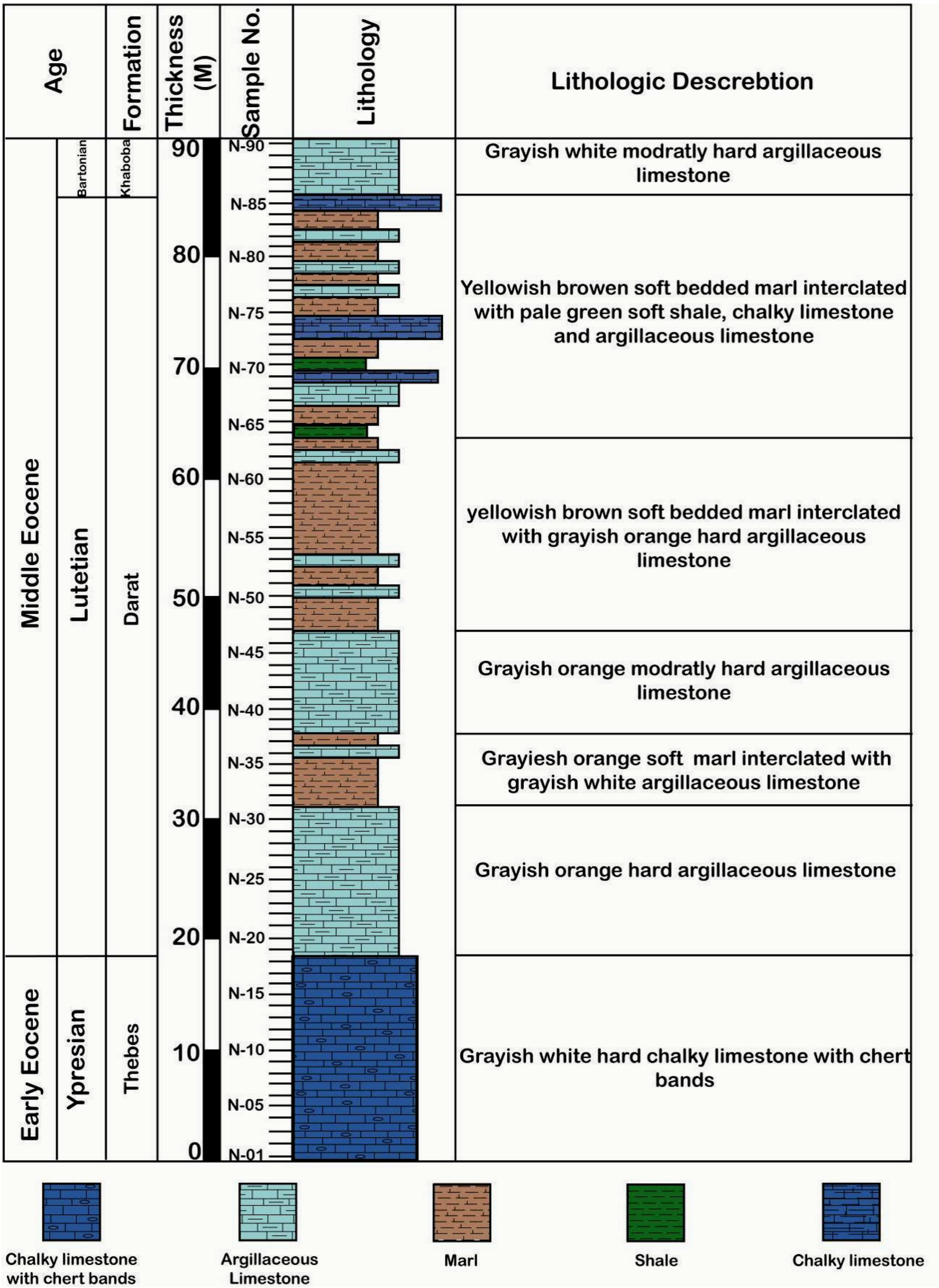

Fig. 3. Stratigraphic columnar section of Wadi Nukhul section.

3. Material and methods:

A sum of 158 rock samples were investigated for their ostracod contents from the studied two sections. From each sample, about 100 to 200 gram of dried rock was impregnated with hydrogen peroxide (15 %) and sodium bicarbonate and washed after several days over a 0.063 mm sieve. This process was repeated until the residues became clean. The residues were sieved and all ostracods were picked and quantified. The number of individuals of each species is the sum of adult carapaces and the largest number of either right or left adult valves. A binocular microscope with magnifications of 10, 20 and 40X was used for picking, investigating and identifying the ostracod assemblages. The identified fauna were mounted in micro slides for permanent record. All species have been photographed using the Scanning Electron Microscope (SEM) of the Egyptian General Authority of Mineral Wealth, Cairo, and are permanently stored at the Geology Department, Faculty of Science, Al-Azhar University (Cairo, Egypt).

4. Taxonomic list

The ostracod fauna recorded from the studied Eocene rocks are taxonomically classified into 47 species and subspecies belonging to 21 genera and 12 families. The classification of Horne *et al.* (2002) is adopted in the present study; genera are treated following Moore (1961) and later established genera are treated according to their authors. The ostracod material is deposited at the Geology Department, Faculty of Science, Al-Azhar University, Cairo, Egypt.

Class OSTRACODA Latrielle, 1806
Subclass PODOCOPA Müller, 1894
Order PODOCOPIDA Müller, 1894
Superfamily CYTHERELLOIDEA Sars, 1866
Family CYTHERELLIDAE Sars, 1866
Genus *Cytherella* Jones, 1849
    Cytherella tarabulusensis El-Waer, 1992; pl. 1, figs. 1-6
    Cytherella sp. 1; pl. 1, figs. 7-8
    Cytherella sp. 2, pl. 1, figs. 9-10

Order PODOCOPIDA Müller, 1894
Suborder BAIRDIOCOPINA Sars, 1865
Superfamily BAIRDIOIDEA Sars, 1865
Family BAIRDIIDAE Sars, 1888
    Genus *Bairdia* Mc'Coy, 1844
        Bairdia crolifai Morsi, Boukhary and Strougo, 2003, pl. 1, figs. 11-13
    Genus Oculobairdoppilata Van Itterbeeck, Morsi, Horne and Speijer, 2007
        Oculobairdoppilata sp., pl. 1, fig. 14

Family BYTHOCYPRIDIDAE Maddocks, 1969
    Genus *Bythocypris* Brady, 1880
        Bythocypris? cf. *mereirensis* Cronin and Khalifa, 1979, pl. 2, fig. 1

Family PONTOCYPRIDIDAE Müller, 1894
Subfamily PONTOCYPRIDINAE Müller, 1894
    Genus *Argilloecia* Sars, 1866
        Argilloecia sp., pl. 2, fig. 2

Superfamily CYTHEROIDEA Baird, 1850
Family KRITHIDAE Mandelstam, 1958
Subfamily KRITHINAE Mandelstam, 1958
    Genus *Parakrithe* Van Den Bold, 1958
        Parakrithe sp., pl. 2, figs. 3-6

Family CYTHERURIDAE Sars, 1866
Genus *Cytheropteron* Sars, 1866
Cytheropteron boukharyi Khalifa and Cronin, 1979, pl. 2, figs 7-9
Cytheropteron elongata El-Waer, 1992, pl. 2, figs. 10-11
Cytheropteron sp. 1, pl. 2, figs. 12-13
Cytheropteron sp. 2, pl. 2, fig. 14
Cytheropteron sp. 3, pl. 2, figs. 15-18
Cytheropteron sp. 4, pl. 2, figs. 19-21
Cytheropteron sp. 5, pl. 2, figs. 22-24

Family LOXOCONCHIDAE Sars, 1866
Genus *Loxoconcha* Sars, 1866
Loxoconcha mataiensis Khalifa and Cronin, 1979, pl. 3, fig. 1
Loxoconcha vetustopunctatella Bassiouni, Boukhary, Shama and Blondeau, 1984, pl. 3, figs. 2-6
Loxoconcha sp. 1, pl. 3, fig. 7
Loxoconcha sp. 2, pl. 3, fig. 8
Loxoconcha sp. 3, pl. 3, fig. 9
Genus *Nigeroloxoconcha* Reyment, 1963
Nigeroloxoconcha sp. 1, pl. 3, figs. 10-11
Nigeroloxoconcha sp. 2, pl. 3, fig. 12

Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948
Subfamily CAMPYLOCYTHERINAE Puri, 1960
Genus *Anticythereis* Van Den Bold, 1946
Anticythereis seylingi Cronin and Khalifa, 1979, pl. 3, figs. 13-17
Genus *Cativella* Coryell and Fields, 1937
Cativella qurnensis Bassiouni, 1969a, pl. 3, fig. 18
Genus *Echinocythereis* Puri, 1954
Echinocythereis bassiounii Boukhary, Toumarkine, Khalifa and Arif, 1982, pl. 4, figs. 1-4
Genus *Paracosta* Siddiqui, 1971
Paracosta ansaryi Bassiouni, 1969c, pl. 4, figs. 5-8
Paracosta crassireticulata crassireticulata Bassiouni, 1969a, pl. 4, figs. 9-10
Paracosta ducassae Bassiouni, Boukhary, Shama and Blondeau, 1984, pl. 4, figs. 11-14
Paracosta humboldti Bassiouni, 1969a, pl. 5, figs. 1-4
Paracosta mokattamensis praemokattamensis Bassiouni, 1969c, pl. 5, figs. 5-10
Paracosta praecrassireticulata Bassiouni, 1969c, pl. 5, figs. 11-16
Genus *Reticulina* Bassiouni, 1969a
Reticulina heluanensis Bassiouni, 1969a, pl. 6, figs. 1-4
Reticulina ismaili Bassiouni, Boukhary, Shama and Blondeau, 1984, pl. 6, figs. 5-7
Reticulina scitula Bassiouni, 1969a
Reticulina scitula scitula Bassiouni, 1969a, pl. 6, figs. 8-12
Reticulina sp., pl. 6, fig. 13
Genus *Reymenticosta* Bassiouni and Luger, 1990
Reymenticosta yarmukensis Bassiouni, 1969c, pl. 7, figs. 1-4
Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948
Subfamily Brachycytherinae Puri, 1954
Genus *Digmocythere* Mandelstam, 1958
Digmocythere ismaili Bassiouni, 1971, pl. 7, figs. 5-7
Digmocythere sp., pl. 7, figs. 8-12

Family CYTHERIDAE Baird,1850
Subfamily BUNTONIINAE Apostolescu, 1961

Genus *Asymmetricythere* Bassiouni, 1971
Asymmetricythere yousefi Bassiouni, 1971, pl. 7, fig. 13
Genus *Buntonia* Howe, 1935 (in Howe and Chambers, 1935)
Buntonia ramosa Bassiouni, 1969d, pl. 8, figs. 1-4
Buntonia sp. 1, pl. 8, figs. 5-12
Buntonia sp. 2, pl. 8, figs. 13-16
Genus *Soudanella* Apostolescu, 1961
Soudanella gracilicosta Bassiouni, 1969d, pl. 8, figs. 17-20

Family LEGUMINOCYTHEREIDIDAE Howe, 1961
Subfamily CAMPYLOCYTHERINAE Puri, 1960
Genus *Leguminocythereis* Howe, 1936
Leguminocythereis africana Bassiouni, 1969b, pl. 9, figs. 1-4
Leguminocythereis praesadeki Boukhary, Toumarkine, Khalifa and Arif, 1982, pl. 9, figs. 5-10

Family XESTOLEBERIDIDAE Sars, 1928
Genus *XESTOLEBERIS* Sars, 1866
Xestoleberis subglobosa Bosquet, 1852, pl. 9, figs. 11-14
Xestoleberis sp., pl. 9, figs. 15-16

5. Biostratigraphy

5.1 Biostratigraphic distribution

The investigated ostracod material is extracted from lithostratigraphic units ranging in age from the Early Eocene to the Late Eocene. They come from two sections at Wadi Tayiba and Wadi Nukhul in the area of west-central Sinai (Fig. 1). The studied sections yielded a well diversified ostracod fauna from most of the washed rock samples, some intervals are barren. The stratigraphic ranges of the species are clearly variable. The time ranges are deduced by matching with ages indicated for the studied sections by different authors, Abul-Nasr and Thunell (1987), based on other microfossil groups, mainly planktonic foraminifera.

5.1.1. Wadi Tayiba:

In this section, the Lower, Middle and Upper Eocene rocks are represented. From this section, 34 ostracod taxa have been retrieved (Fig. 4). Most of the taxa recorded in this section restricted to the Middle Eocene. Only two taxa, *Reticulina ismaili* and *Buntonia ramosa*, are found in the Lower Eocene (Ypresian), extending higher up into the Middle Eocene. Whereas sixteen species are restricted to the lower Middle Eocene (Lutetian) and six species are restricted to the upper Middle Eocene (Bartonian), ten species range throughout the Middle Eocene. In the Upper Eocene, only two taxa, *Cytherella tarabulusensis* and *Loxoconcha vetustopunctatella,* are found extending from the Middle Eocene.

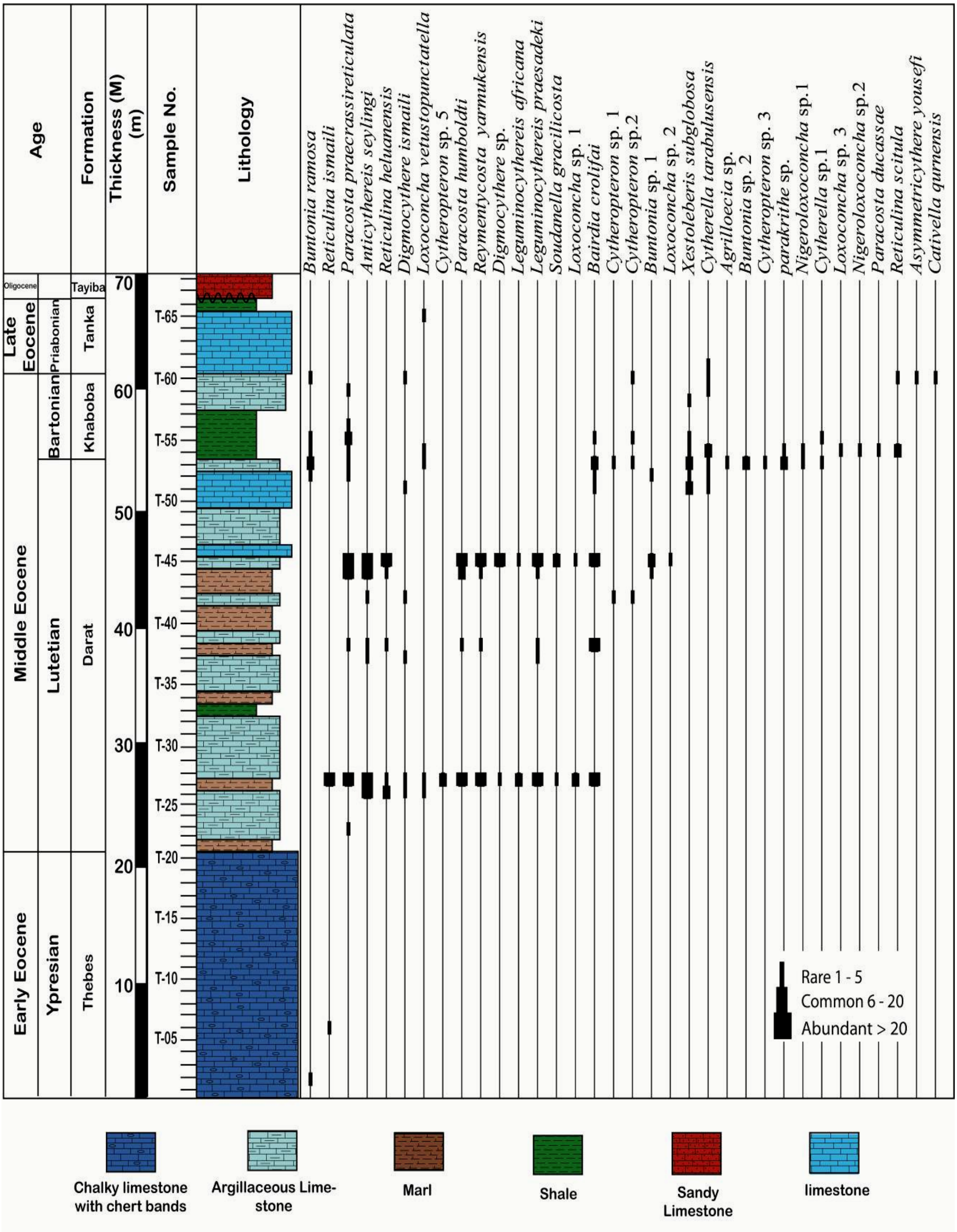

Figure 4. Stratigraphic distribution of the ostracod fauna in Wadi Tayiba section.

5.1.2. Wadi Nukhul:

In this section, only the Lower and Middle Eocene rocks are represented; the Upper Eocene rocks are absent. From this section, we identified 31 ostracod taxa (Fig. 5). In the Lower Eocene (Ypresian), no species are found restricted to this interval; only one species, *Paracosta praecrassireticulata*, that appears in this interval and ranges higher up into the upper Middle Eocene (Bartonian) has been recorded. Eleven species are found to be restricted in the lower Middle Eocene (Lutetian). Two species, *Paracosta crassireticulata* and *Buntonia ramosa*, are found only in the upper Middle Eocene (Bartonian). Seventeen species first appear in the lower Middle Eocene (Lutetian) and persist higher in the upper Middle Eocene (Bartonian).

5.1.3. Comparison between Wadi Tayiba and Wadi Nukhul:

We found 47 different taxa in total of which 18 taxa were observed in common between the two sections, 16 taxa were recorded from Wadi Tayiba only and 13 taxa were recorded from Wadi Nukhul only. In the Lower Eocene part of two sections, three species that range higher up into the Middle Eocene have been found, two at Wadi Tayiba and one at Wadi Nukhul; no species confined to the Lower Eocene have been found in either sections. In the Middle Eocene, the assemblages recorded in the two sections are similar and are dominated by the occurrence of taxa such as *Anticythereis seylingi*, *Leguminocythereis praesadeki*, *Bairdia crolifai*, *Xestoleberis subglobosa* and *Cytherella tarabulusensis*. In the Upper Eocene, the taxa recorded come from the Tayiba section only.

5.2 Biostratigraphic Analysis:

For biostratigraphic analysis of the extracted ostracod fauna, a range chart has been made for the species based on their occurrence in the studied two sections (Table 1). Additionally, a table showing the stratigraphic intervals in which these species were previously recorded in other areas in and outside Egypt has been made (Table 2). Different biozonal schemes based on ostracods were suggested by different authors for different areas, and even sometimes different zones were suggested for same area by different authors (Table 3). As previously noted, none of the proposed schemes could be applied in longer distance correlations between vastly separated regions, possibly owing to the benthic mode throughout the entire ostracod life, which rendered many of the ostracod taxa more dependent on environment and their stratigraphic ranges as well as geographic distributions consequently more or less inconsistent and environmentally controlled. From the two sections, the recorded taxa can be categorized into the following kinds:

Lower-Middle Eocene Taxa:

It comprises the taxa found here in the Lower Eocene, extending higher to the upper Middle Eocene. It includes *Paracosta praecrassireticulata*, *Buntonia ramosa* and *Reticulina ismaili*.

Taxa restricted to the lower Middle Eocene (Lutetian):

This kind includes the taxa which are found here only in the lower Middle Eocene (Lutetian) part of the sections and have never been recorded in lower or higher intervals anywhere else. These taxa are *Anticythereis seylingi*, *Paracosta humboldti*, *Reymenticosta yarmukensis*, *Digmocythere* sp., *Loxoconcha* sp. 1, *Loxoconcha* sp. 2, *Reticulina heluanensis*, *Cytheropteron* sp. 1, *Agrilloecia* sp., *Buntonia* sp. 2, *Cytheropteron* sp. 3, *Bythocypris*? cf. *mereirensis*, *Loxoconcha mataiensis*, *Cytheropteron boukharyi*, *Echinocythereis bassiounii*, *Cytheropteron elongata*, *Paracosta mokattamensis praemokattamensis* and *Reticulina* sp. Among these taxa, *Anticythereis seylingi*, *Reymenticosta yarmukensis* and *Reticulina heluanensis* are in common between the two sections.

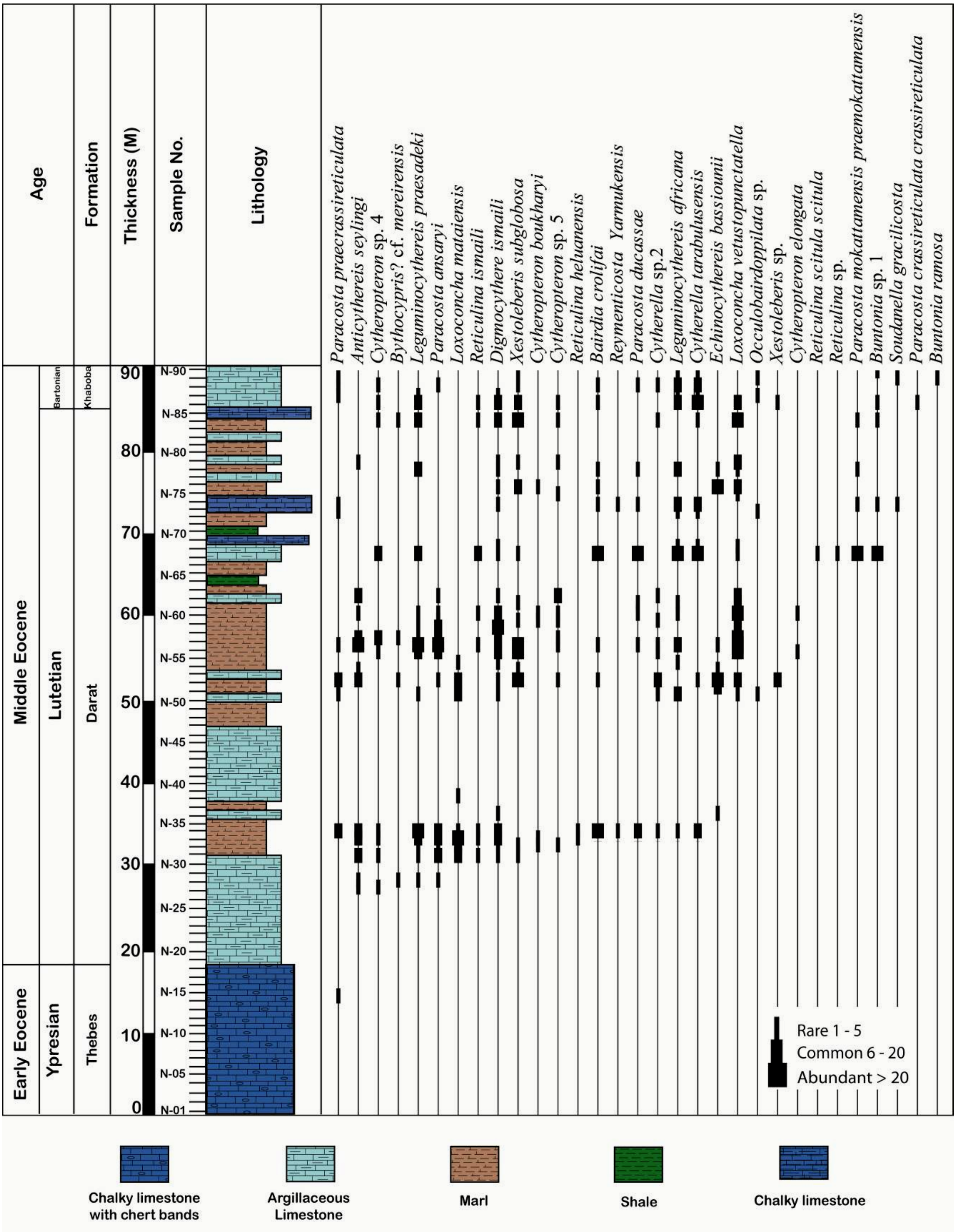

Figure 5. Stratigraphic distribution of the ostracod fauna in Wadi Nukhul section.

Taxa restricted to the upper Middle Eocene (Bartonian):

This kind includes the taxa which are found here only in the upper Middle Eocene part of the sections and have never been recorded in lower or higher intervals anywhere else. These taxa are *Loxoconcha* sp. 3, *Nigeroloxoconcha* sp. 2, *Asymmetricythere yousefi*, *Cativella qurnensis* and *Paracosta crassireticulata*. Whereas *Loxoconcha* sp. 3, *Nigeroloxoconcha* sp. 2, *Asymmetricythere yousefi* and *Cativella qurnensis* are found only at Wadi Tayiba, *Paracosta crassireticulata crassireticulata* is only present at Wadi Nukhul; no taxa are in common between the two sections.

Middle Eocene Taxa (Lutetian-Bartonian):

This group includes the taxa which first appear in the lower Middle Eocene and also extend higher into the upper Middle Eocene. These taxa are *Digmocythere ismaili*, *Cytheropteron* sp. 5, *Bairdia crolifai*, *Leguminocythereis africana*, *Leguminocythereis praesadeki*, *Soudanella gracilicosta*, *Cytheropteron* sp. 2, *Buntonia* sp. 1, *Xestoleberis subglobosa*, *Parakrithe* sp., *Nigeroloxoconcha* sp. 1, *Cytherella* sp. 1, *Paracosta ducassae*, *Reticulina scitula scitula*, *Cytheropteron* sp. 4, *Paracosta ansaryi*, *Cytherella* sp. 2, *Occulobairdoppilata* sp. and *Xestoleberis* sp. Of these, *Digmocythere ismaili*, *Bairdia crolifai*, *Leguminocythereis africana*, *Leguminocythereis praesadeki*, *Soudanella gracilicosta*, *Xestoleberis subglobosa*, *Paracosta ducassae*, and *Reticulina scitula scitula* are in common between the two sections.

Middle-Upper Eocene Taxa:

This kind includes the taxa which extend from the lower Middle Eocene to the Upper Eocene. They are represented only by three taxa found in the two sections, *Cytherella tarabulusensis*, *Loxoconcha vetustopunctatella* and *Paracosta praecrassireticulata*.

Table 1: Range chart of the identified ostracod fauna in the studied two sections.

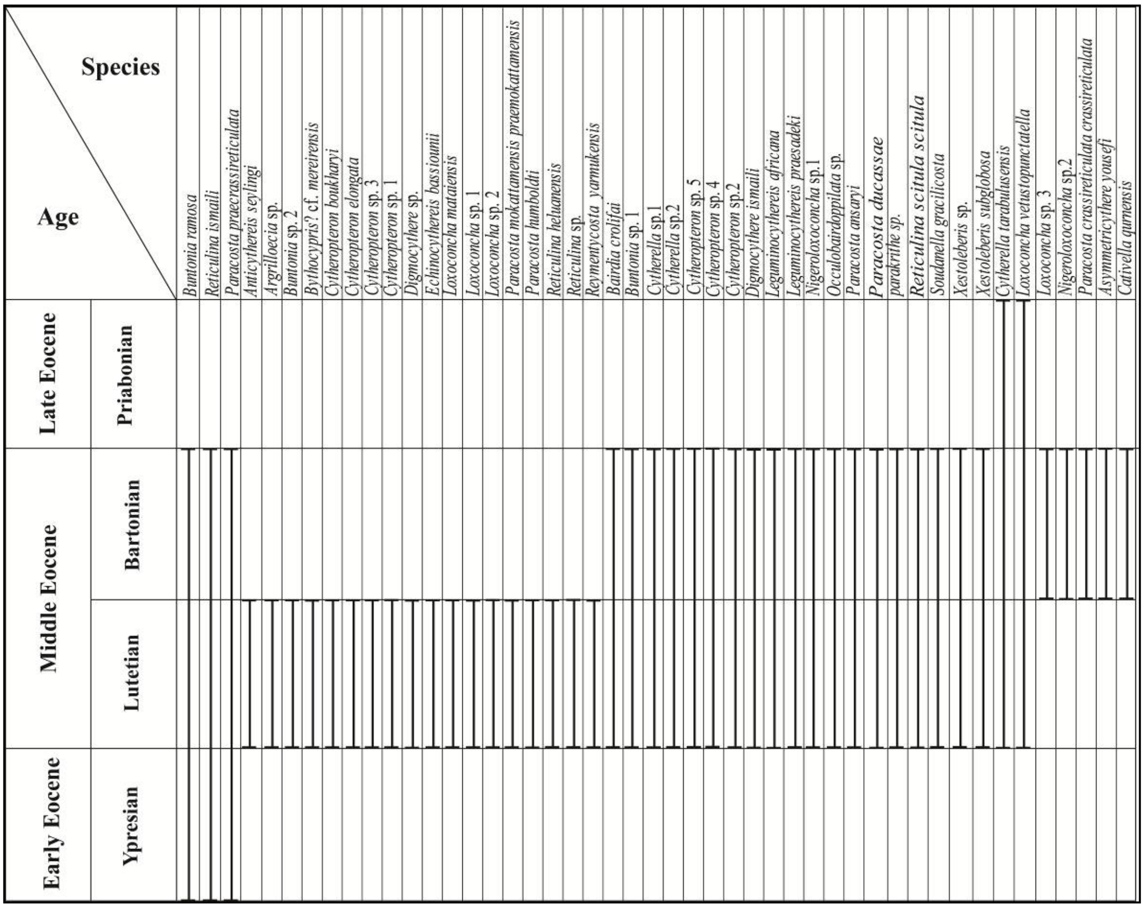

Table 2: Geographic and stratigraphic distributions of the recorded ostracod taxa inside and outside Egypt.

Ostracod species	Greater Cairo 1	Nile Valley 2	Fayoum area 3	Sinai 4	Eastern desert 5	Jordan 6	Libya 7	Israel 8	study area
Cytherella tarabulusensis			u.M. - U. Eocene	u.M. Eocene			M. - U. Eocene		M. - U. Eocene
Cytherella sp. 1									M. Eocene
Cytherella sp. 2									M. Eocene
Bairdia crolifai	u.M. - U. Eocene	M. - U. Eocene	M. - U. Eocene	M. Eocene	u.M. - U. Eocene				M. Eocene
Occulobairdoppilata sp.									M. Eocene
Bythocypris ? cf. *mereirensis*									l.M. Eocene
Agrilloecia sp.									l.M. Eocene
Parakrithe tayibaensis .									l.M. Eocene
Cytheropteron biocostatum									M. Eocene
Cytheropteron boukharyi		M. Eocene	M. - U. Eocene	u.M. Eocene				L. - M. Eocene	l.M. Eocene
Cytheropteron elongata							L. Paleo.- M. Eocene		l.M. Eocene
Cytheropteron nukhulensis									l.M. Eocene
Cytheropteron speijeri									M. Eocene
Cytheropteron sp. 1									l.M. Eocene
Cytheropteron sp. 2									M. Eocene
Loxoconcha mataiensis		M. Eocene		l.M. Eocene					l.M. Eocene
Loxoconcha vetustopunctatella	u.M. Eocene		M. - U. Eocene		u.M. Eocene				M. - U. Eocene
Loxoconcha sp. 1									l.M. Eocene
Loxoconcha sp. 2									l.M. Eocene
Loxoconcha sp. 3									u.M. Eocene
Nigeroloxoconcha sp. 1									M. Eocene
Nigeroloxoconcha sp. 2									u.M. Eocene
Anticythereis seylingi		M. - U. Eocene		l.M. Eocene					l.M. Eocene
Cativella qurnensis	M. Eocene	M. - U. Eocene	u.M. - U. Eocene				U. Eocene		u.M. Eocene
Echinocythereis bassiounii		M. Eocene		u.M. Eocene					l.M. Eocene
Paracosta ansaryi		M. Eocene				M. Eocene			M. Eocene
Paracosta crassireticulata crassireticulata	l.M. Eocene	M. - U. Eocene		u.M. Eocene	M. Eocene				u.M. Eocene
Paracosta ducassae			u.M. - U. Eocene	l.M. Eocene	u.M. Eocene				M. Eocene
Paracosta humboldti	M. Eocene		u.M. Eocene	l.M. Eocene	u.M. Eocene				l.M. Eocene
Paracosta mokattamensis praemokattamensis	L. Eocene					L. Eocene			l.M. Eocene
Paracosta praecrassireticulata						M. Eocene			u.L. -M. Eocene
Reticulina heluanensis	M. - U. Eocene	l.M. - U. Eocene	U. Eocene	M. - U. Eocene					l.M. Eocene
Reticulina ismaili	M. Eocene		M. - U. Eocene	u.M. Eocene					M. Eocene
Reticulina scitula scitula				M. Eocene		L. Eocene	U. Eocene		M. Eocene
Reticulina sp.									l.M. Eocene
Reymenticosta yarmukensis				u.M. Eocene		M. Eocene		l.M. Eocene	l.M. Eocene
Digmocythere centrreticulata									l.M. Eocene
Digmocythere ismaili	M. - U. Eocene		M. - U. Eocene		u.M. Eocene			M. Eocene	M. Eocene
Asymmetricythere yousefi	M. - U. Eocene	U. Eocene	M. - U. Eocene	M. - U. Eocene					u.M. Eocene
Buntonia bassiounii									M. Eocene
Buntonia posteroacuta									l.M. Eocene
Buntonia ramosa				l.M. Eocene		M. - U. Eocene		L. - U. Eocene	L. - M. Eocene
Soudanella gracilicosta				L. Eocene		M. - U. Eocene		L. - U. Eocene	M. Eocene
Leguminocythereis africana	u.M. - U. Eocene	M. - U. Eocene	M. - U. Eocene	u.M. Eocene	u.M. Eocene		U. Eocene		M. Eocene
Leguminocythereis praesadeki		M. Eocene		l.M. Eocene					M. Eocene
Xestoleberis posterotruncata									M. Eocene
Xestoleberis subglobosa	M. Eocene	M. Eocene	M. - U. Eocene	u.M. Eocene	u.M. Eocene				M. Eocene

5.3 Biostratiraphic implications:

The present ostracod record in the studied Wadi Nukhul and Wadi Tayiba sections and the comparison with previous records of the identified ostracod taxa (Table 4.3) revealed that the assemblage recorded is typically a Middle Eocene assemblage. The early Middle Eocene (Lutetian) and late Middle Eocene (Bartonian) are distinguished by different ostracod species. Whereas *Anticythereis seylingi*, *Reymenticosta yarmukensis*, *Loxoconcha mataiensis*, *Cytheropteron boukharyi*, *Echinocythereis bassiounii*, *Cytheropteron elongata* and *Paracosta mokattamensis praemokattamensis* characterize the early Middle Eocene (Lutetian), *Asymmetricythere yousefi*, *Cativella qurnensis* and *Paracosta crassireticulata* are found only in the late Middle Eocene (Bartonian). Very rare fauna represented by *Paracosta praecrassireticulata*, *Reticulina ismaili* and *Buntonia ramosa* occur in the Early Eocene interval and similarly rare fauna represented by *Cytherella tarabulusensis* and *Loxoconcha vetustopunctatella* are found in the Late Eocene intervals; none of these species is respectively characteristic for these intervals as they are also commonly present in the Middle Eocene.

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Table 3: Correlation chart of the previous proposed Eocene ostracod biozones in Egypt.

Age	Authors & Areas	Bassiouni *et al.* (1984) Fayoum area	Bassiouni *et al.* (1994) northwestern Eastern Desert	Elewa and Ishizaki (1994) Eastern Desert	Elewa (1998) Nile Valley	Shahin (2000) southwestern Sinai	Bassiouni & Morsi (2000) Farafra Oasis	Abdallah *et al.* (2002) Fayoum area	Shahin (2005) northern Sinai	Abd El-Shafy *et al.* (2007) west central Sinai	Shahin *et al.* (2008) Qattamiya area
Late Eocene	Priabonian	unstudied	*Uromuellerina saidi*	unstudied	unstudied	*Legum. Africana / Buntonia faresi*	unstudied	*Legum.sadeki / Costa humboldti*	unstudied	*Uromuellerina saidi / Asymm. yousefi* (AZ)	unstudied
Middle Eocene	Bartonian		*Costa humboldti* *Ruggieria (Keijella) glabella*			*Asymm. Yousefi / Cytherella piacabucuensis*		Barren *Costa crassireticulata/ Costa ducassae*	*Martinicythereis samalutensis/ samalutensis*	*Cativella qurnensis Cytheropteron boukharyi* (AZ)	*Loxoc. Pseudopunctatella / Asymm. asymmetrella*
	Leutetian	*Trachyleberis nodosus nodosus* *Loxoc. vetustopunctatella*	unstudied	*Bairdoppilata cerebra / Legum. africana* *Krithe bartonensis / Xestol. ? Kenawyi* *Xesto.? Kenawyi* *Loxoc. Mataiensis / Xestol.? Kenawyi*	*Krithe bartonensis/ Xestol.? Kenawyi* *Trachyleberis nodosus nodosus*	*Reticulina saitoi / Trachyleberis nodosus*		*Brachycythere ismaili / Bairdia tarabulusensis* Barren		*Costa mokattamensis/ Digmocythere ismaili* (AZ)	*Loxoc. Vetustopunctatella / Trachyleberis nodosus nodosus* *Digmocythere ismaili / Uromuellerina saidi*
Early Eocene	Ypersian	unstudied		*Xestol. Keseibaensis / Loxoc. Saharaensis*	*Paracosta mokattamensis praemokattamensis* *Xestol keseibaensis / Loxoc. saharaensis* unstudied	*Legum. bopaensis / Legum. Bicostata*	*Phalcocythere cf. tranquilis / Horni. moosae* *Dahomeya alata anteroglabrata / Phalcocythere cf. tranquilis / Horni. moosae* *Dahomeya alata alata/ Dahomeya alata*	*Xesto. Kenawyi*	????? *Reticulina proteros*	*Reticulina proteros / Soudanella laciniosa triangulata* (AZ)	unstudied

Legum. = Leguminocythereis, Megom. = Megommatocythere, Loxoc. = Loxoconcha, Xesto. = Xestoleberis, Asymm. = Asymmetricythere.

6. Paleoenvironment:

A statistical attempt to use the triangle diagram published by Dingle (1981) for reconstructing a simple palaeobathymetric image for each section of the study area has been made in the present study (Tables 4, 5). This diagram seems to be more reliable for neritic and bathyal environmental settings. In this diagram, the heads of the triangle diagram are referred by Cytheracea, Cypridacea and Bairdiacea, and Cytherellidae. The marine water depths are shown in the seven fields of the diagram where fields 1-3 refer to a depth <100 m, 4a refers to a 100-200 m depth, 4b to a depth of about 200 m, 5a to a 200-300 m depth, 5b to a 300-500 m depth and 6-7 refer to a depth >500 m. (Fig. 6).

After plotting all samples in the Tayiba and Nukhul sections on the ternary diagram of Dingle (1981), we were able to estimate that the paleodepth of all samples in two sections lie between 0 to 100 m; this interval refers to an inner to middle neritic environment. Three samples only (N-73, Darat Formation, N-88, Khaboba Formation, in Nukhul section and T-38, Darat Formation, in Tayiba section) exceed on 100 m depth.

6.1.1 Wadi Tayiba section:

Thebes Formation: This formation is mainly composed of yellowish white massive chalky limestone with chert bands and concretions. It is characterized by low diversity and abundance of the ostracod faunal content (Fig. 5.4). The recorded ostracod species in this formation totally belong to cytheraceans (Table 5.2) that dominate in the inner to middle neritic settings (0-100 m depth). Supportingly, the ostracod species plot in the triangle diagram of Dingle (1981) falls in the field 1-3 (Fig. 5.2), which indicates a marine water depth less than 100 m.

Darat Formation: This formation is composed mainly of yellowish brown soft marl intercalated with grayish orange argillaceous limestone, pale green soft bedded shale and white massive chalky limestone. It is characterized by high diversity and abundance of the ostracod faunal content (Fig. 5.4). The cytheraceans are more dominate than the other groups (47-100 %), whereas the Cytherellidae constitute (0-17 %) and Cypridacea and Bairdiacea constitute (0-53%) (Table 5.2); this association reflects a shallow marine condition. The population has been plotted in the triangle diagram of Dingle (1981) and occur in the field 1-3 (Fig. 5.2), indicating a marine water depth less than 100 m.

Khaboba Formation: In the Wadi Tayiba section, this formation is composed mainly of yellow green, yellow brown soft papery shale intercalated with grayish white moderately hard argillaceous limestone. It is characterized by high ostracod diversity and moderate ostracod abundance (Fig. 5.4). The cytheracean ostracods dominate the other forms (50-100%) (Table 5.2), thus indicating the inner to middle neritic setting (0-100 m depth). This setting is moreover supported by the ostracod species plot in the triangle diagram of Dingle (1981) as they lie in the field 1-3 (Fig. 5.2) reflecting a marine water depth less than 100 m. However, one assemblage at sample T-54 (*Paracosta praecrassireticulata*, *Buntonia ramosa*, *Loxoconcha vetustopunctatella*, *Xestoleberis subglobosa*, *Cytherella tarabulusensis*, *Parakrithe tayibaensis*, *Nigeroloxoconcha* sp.1, *Nigeroloxoconcha* sp.2, *Loxoconcha* sp. 3, *Paracosta ducassae* and *Reticulina scitula scitula*) is plotted in the field 5a and very close to Cytheracean line, which may be deposited in the shallow part of the water depth interval of 200-300, i.e. in the outer neritic zone.

Tanka Formation: This formation is composed mainly of grayish white hard Limestone intercalated with yellowish brown soft papery shale. It is characterized by low diversity and abundance of the ostracod faunal content (Fig. 5.4). The recorded ostracod species in this formation belong to the Cytheracea only (Table 5.2); this refers to the inner to middle neritic (0-100 m depth). Also the ostracod species found in this formation and plotted in the triangle diagram of Dingle (1981) are found in the field 1-3 (Fig. 5.2) indicating a marine water depth less than 100 m.

6.1.2 Wadi Nukhul section:

Thebes Formation: This formation is composed mainly of yellowish white massive chalky limestone with chert bands and concretions. It is characterized by low diversity and abundance of the ostracod faunal content (Fig. 5.3). The recorded ostracod species in this formation belong to the Cytheracea only (Table 5.2); this implicates an inner to middle neritic environmental setting (0-100m depth). Moreover, the ostracod species recorded in this formation are plotted in the triangle diagram of Dingle (1981). They are plotted in the field 1-3 (Fig. 5.2), thus reflecting a marine water depth less than 100 m.

Darat Formation: This formation is composed mainly of yellowish brown soft marl intercalated with grayish orange argillaceous limestone, pale green soft bedded shale and white massive chalky limestone. It is characterized by high diversity and abundance of the ostracod faunal content (Fig. 5.3). In the investigated samples, the cytheraceans are more common than the other groups (33-100 %), whereas the Cytherellidae constitute (0-36 %) and the Cypridacea and Bairdiacea constitute (0-42 %) (Table 5.1); this association reflects a shallow marine condition. The population has been plotted in the triangle diagram of Dingle (1981) and has been found to occupy the field 1-3 (Fig. 5.2), thus indicating a marine water depth less than 100 m. However, one assemblage at sample N-73 (*Paracosta praecrassireticulata*, *Leguminocythereis africana*, *Cytherella tarabulusensis*, and *Occulobairdoppilata* sp.) is plotted below the cytheracean line in the field 4b, and the cypridacean and bairdiacean forms exceed the cytheracean one, which reflects a water depth approximate of 200 m in this sample.

Khaboba Formation: In Wadi Nukhul, this formation is composed of grayish white moderately hard argillaceous Limestone. It is characterized by high diversity and abundance of the ostracod faunal content (Fig. 5.3). The cytheraceans in the investigated samples are more common than the other groups (53-100 %), whereas representatives of the Cytherellidae constitute (0-36 %) and Cypridacea and Bairdiacea constitute (0-23 %) (Table 5.1); this association reflects a shallow marine condition. The population plotted in the triangle diagram of Dingle (1981) dominantly occurs in the field 1-3 (Fig. 5.2), indicating a marine water depth less than 100 m.

5.6 Paleoenvironmental implications:

The Eocene rocks of Wadi Nukhul and Wadi Tayiba sections in west central Sinai is characterized by changes in the ostracod diversity and faunal composition which increase in the middle part of the two sections (Darat and Khaboba Formations). This indicates suitable environmental conditions and nutrient supply. On the contrary, the ostracod diversity decreases dramatically in the upper part of the Wadi Tayiba section (Tanka Formation); this indicates inconvenient environmental conditions and insufficient nutrient supply (Fig. 5.3 and 5.4). Except for two assemblages plotted in the fields 4b and 5a of the ternary Dingle diagram (Fig. 5.2), indicating depths more than 100 m, the ostracod assemblages of the two sections is plotted in the field 1-3 of Dingle diagram (Fig. 5.2), indicating (0-100m depth). This implicates that the studied sections were generally deposited in inner to middle neritic environmental settings with some short episodes of relative deep of the sea level.

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Table 4. Percentage of the ostracod groups used in the palaeobathymetric reconstruction and the paleodepth resulted from Dingle diagram of the Wadi Tayiba section.

Formation	Sample No.	Number of Ostracod individuals	Cytheracea		Cypridaea + Bairdiacea		Cytherellidae		Depth (m)
			No.	%	No.	%	No.	%	
Tanka	T-65	4	4	100	0	0	0	0	0-100
Khaboba	T-60	12	11	92	0	0	1	8	0-100
	T-59	4	3	75	0	0	1	25	0-100
	T-58	1	1	100	0	0	0	0	0-100
	T-56	1	1	100	0	0	0	0	0-100
	T-55	24	15	62	5	21	4	17	0-100
	T-54	42	21	50	4	10	17	40	200-300
Darat	T-53	85	50	59	31	36	4	5	0-100
	T-52	17	11	65	3	18	3	17	0-100
	T-51	17	13	76	2	12	2	12	0-100
	T-45	826	688	83	138	17	0	0	0-100
	T-44	79	79	100	0	0	0	0	0-100
	T-42	7	7	100	0	0	0	0	0-100
	T-38	43	20	47	23	53	0	0	0-100
	T-37	5	5	100	0	0	0	0	0-100
	T-27	316	291	92	25	8	0	0	0-100
	T-26	50	50	100	0	0	0	0	0-100
	T-23	1	1	100	0	0	0	0	0-100
Thebes	T-6	1	1	100	0	0	0	0	0-100
	T-2	1	1	100	0	0	0	0	0-100

Table 4. Percentage of the ostracod groups used in the palaeobathymetric reconstruction and the paleodepth resulted from Dingle diagram of the Wadi Nukhul section.

Formation	Sample No.	Number of Ostracod individuals	Cytheracea		Cypridaea + Bairdiacea		Cytherellidae		Depth (m)
			No.	%	No.	%	No.	%	
Khaboba	N-90	2	2	100	0	0	0	0	0-100
	N-89	13	8	62	3	23	2	15	0-100
	N-88	28	15	53	3	11	10	36	0-100
	N-87	14	9	64	2	15	3	21	0-100
	N-86	102	66	65	5	5	31	30	0-100
Darat	N-84	141	131	93	4	3	6	4	0-100
	N-79	24	24	100	0	0	0	0	0-100
	N-78	34	30	88	4	12	0	0	0-100
	N-76	69	68	99	1	1	0	0	0-100
	N-75	4	4	100	0	0	0	0	0-100
	N-74	32	21	66	4	12	7	22	0-100
	N-73	12	4	33	5	42	3	25	~200
	N-69	6	4	67	0	0	2	33	0-100
	N-68	289	193	67	42	14	54	19	0-100
	N-63	39	37	95	0	0	2	5	0-100
	N-62	10	10	100	0	0	0	0	0-100
	N-61	57	57	100	0	0	0	0	0-100
	N-60	18	17	94	0	0	1	6	0-100
	N-59	56	56	100	0	0	0	0	0-100
	N-58	137	136	99	1	1	0	0	0-100
	N-57	198	193	97	3	2	2	1	0-100
	N-56	127	125	98	0	0	2	2	0-100
	N-55	5	5	100	0	0	0	0	0-100
	N-54	4	4	100	0	0	0	0	0-100
	N-53	149	135	91	6	4	8	5	0-100
	N-52	14	9	64	0	0	5	36	0-100
	N-51	38	32	84	3	8	3	8	0-100
	N-39	3	3	100	0	0	0	0	0-100
	N-37	2	2	100	0	0	0	0	0-100
	N-35	131	100	76	20	15	11	9	0-100
	N-34	91	90	99	1	1	0	0	0-100
	N-33	32	32	100	0	0	0	0	0-100
	N-32	46	46	100	0	0	0	0	0-100
	N-29	11	10	91	1	9	0	0	0-100
	N-28	7	7	100	0	0	0	0	0-100
Thebes	N-15	3	3	100	0	0	0	0	0-100

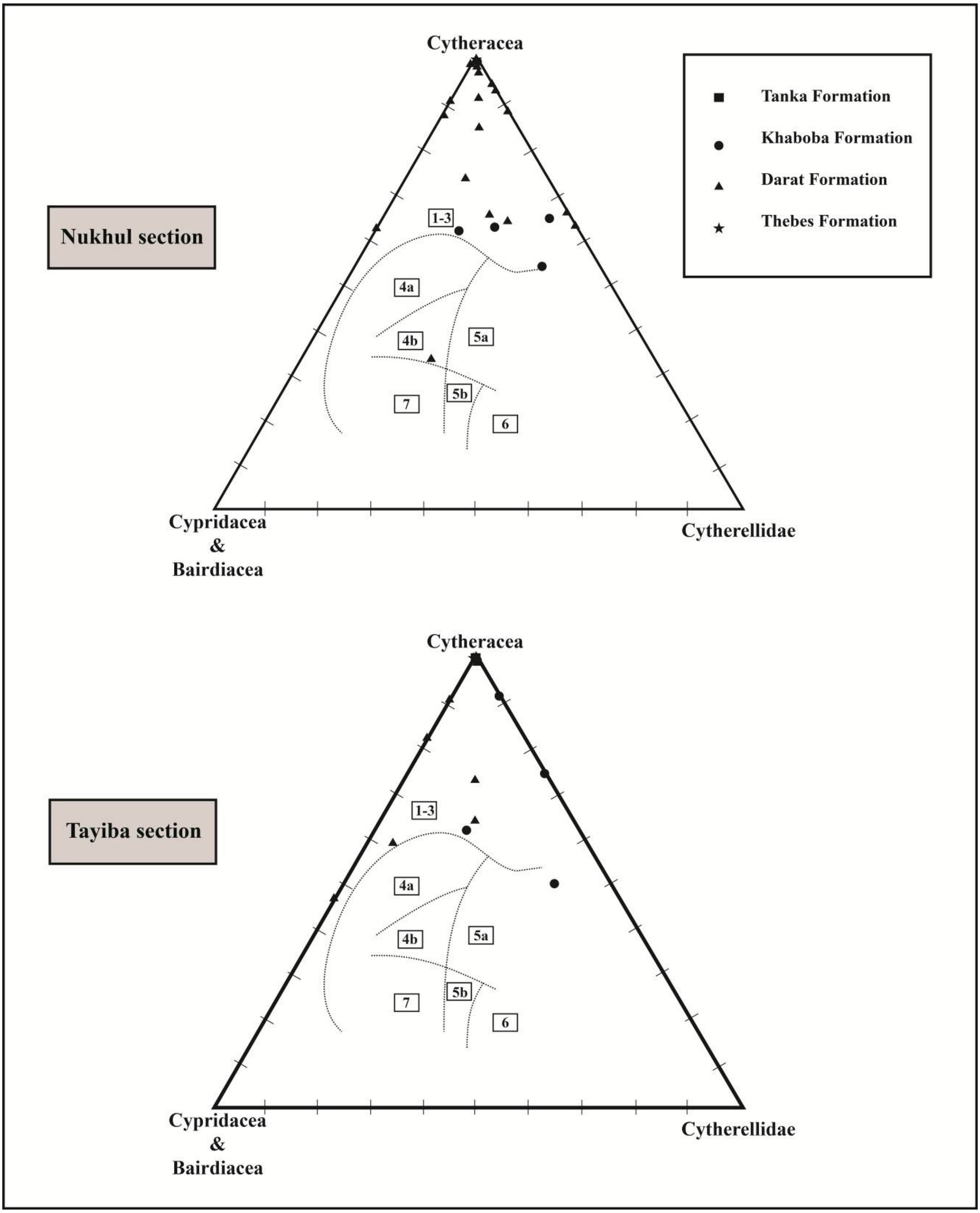

Figure 6. Ostracod plots on the ternary diagram of Dingle (1981) for paleobathymetric reconstruction of Wadi Tayiba and Wadi Nukhul sections.

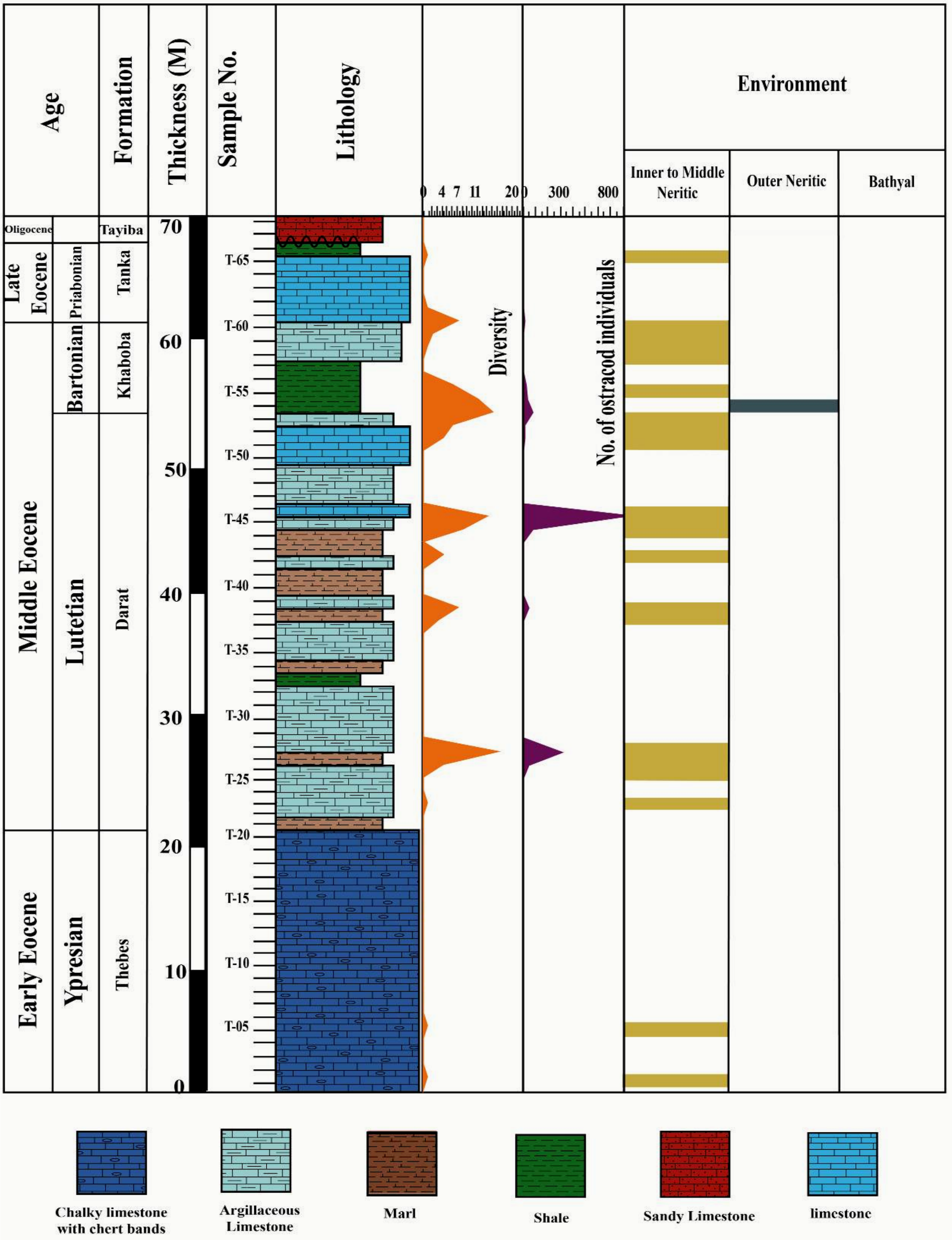

Figure 7. Stratigraphic succession at Wadi Tayiba section with ostracod diversity, abundance and paleoenvironment.

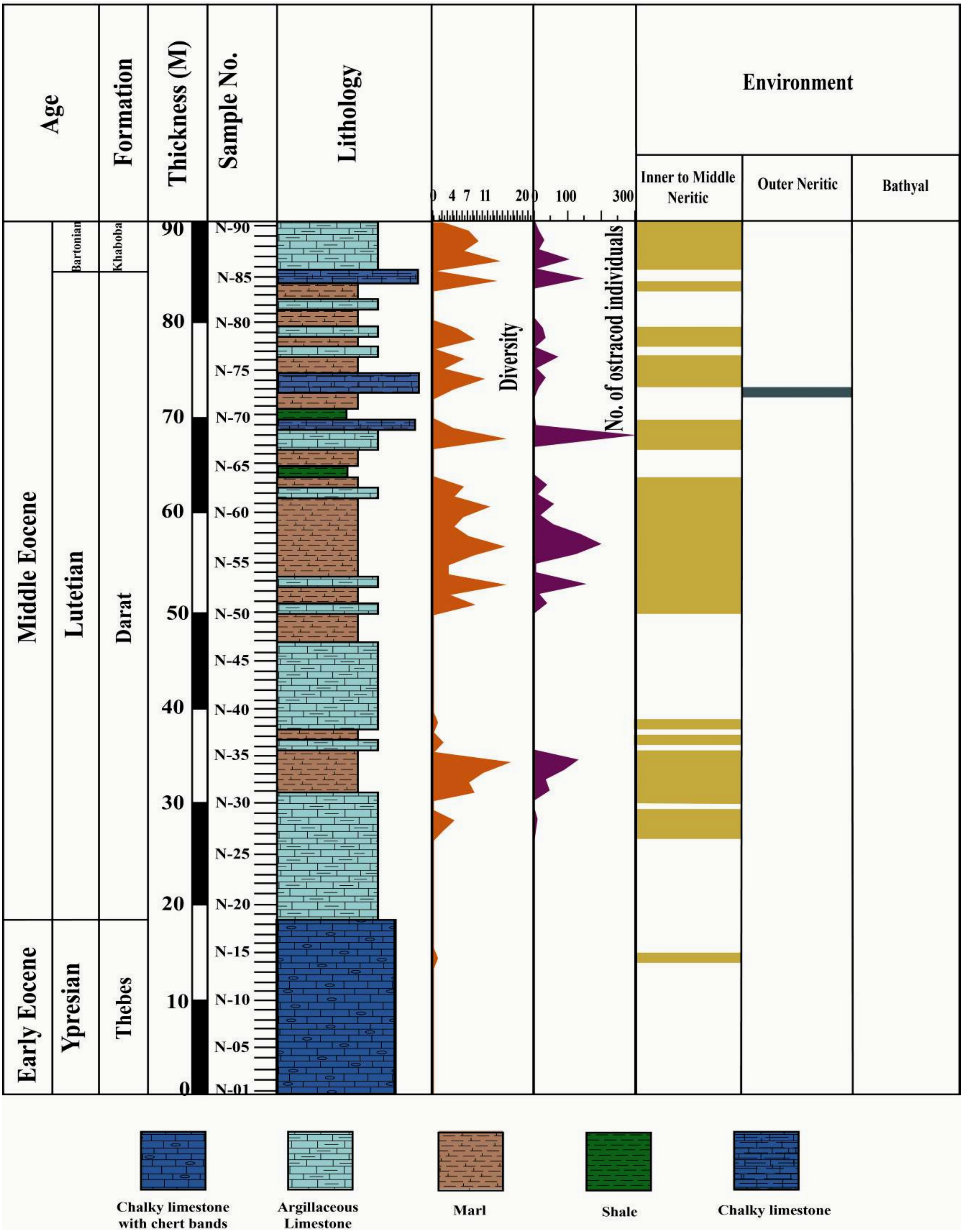

Figure 8. Stratigraphic succession at Wadi Nukhul section with ostracod diversity, abundance and paleoenvironment.

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Plate 1

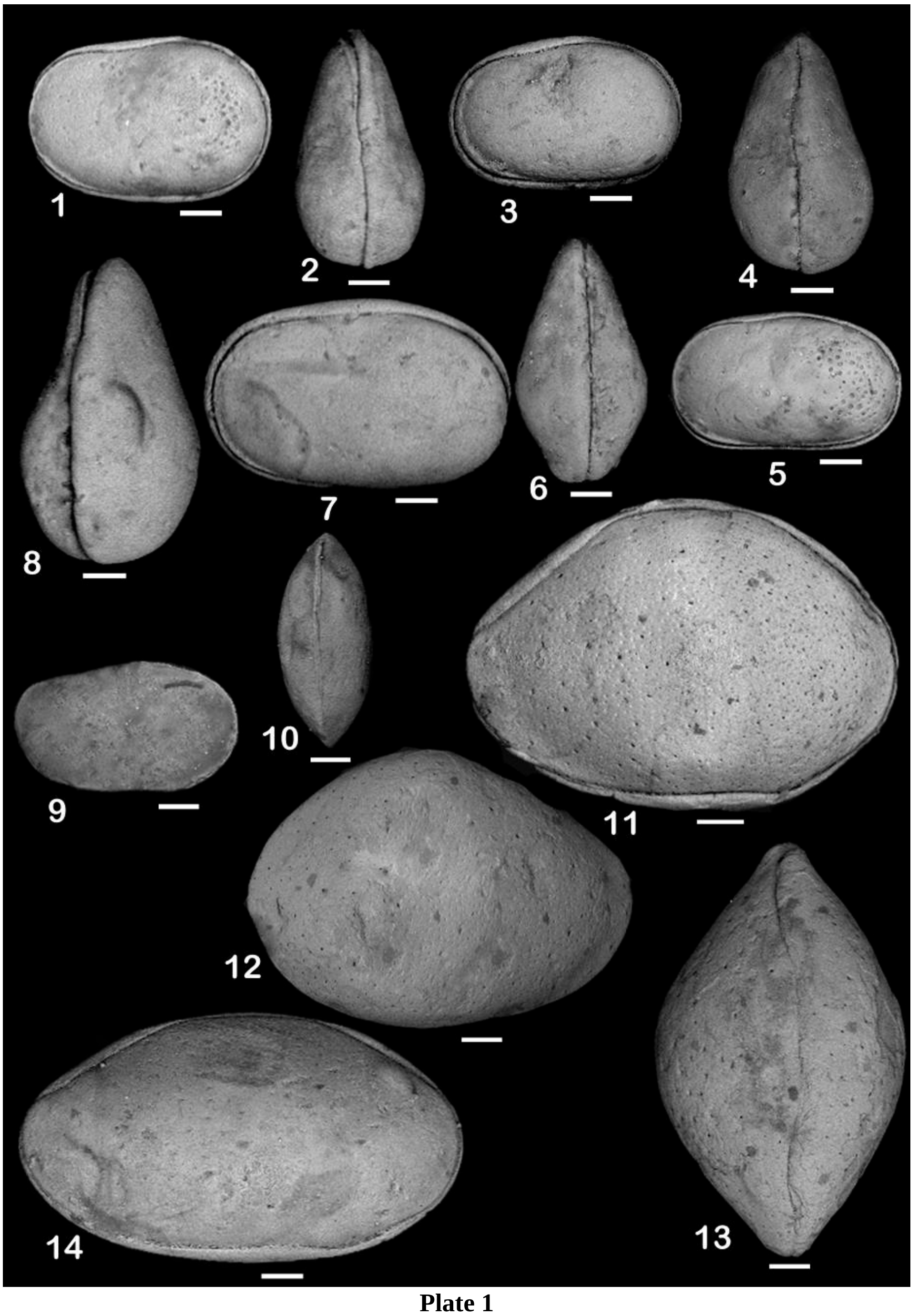

Plate 1

(Bar scale = 100 μm)

Figs. 1-6: *Cytherella tarabulusensis* El-Waer, 1992; 1, 2, 5, 6, Tayiba section, Khaboba Formation, sample T-54; 3, 4, Nukhul section, Darat Formation, sample N-73; 1-4, female carapaces, 1, 3 LVC, 2, 4 DVC; 5, 6, male carapace, 5 LVC, 6 DVC. Figs. 7-8: *Cytherella* sp. 1; Tayiba section, Khaboba Formation, sample T-54, female carapace, 7 LVC, 8 DVC. Figs. 9-10: *Cytherella* sp. 2; Nukhul section, Darat Formation, sample N-73, 9 LVC, 10 VVC. Figs. 11-13: *Bairdia crolifai* Morsi, Boukhary and Strougo, 2003; Tayiba section, Darat Formation, sample T-45, 11 RVC, 12 LVC, 13 DVC. Fig. 14: *Oculobairdoppilata* sp.; Nukhul section, Darat Formation, sample N-73, RVC.

Plate 2

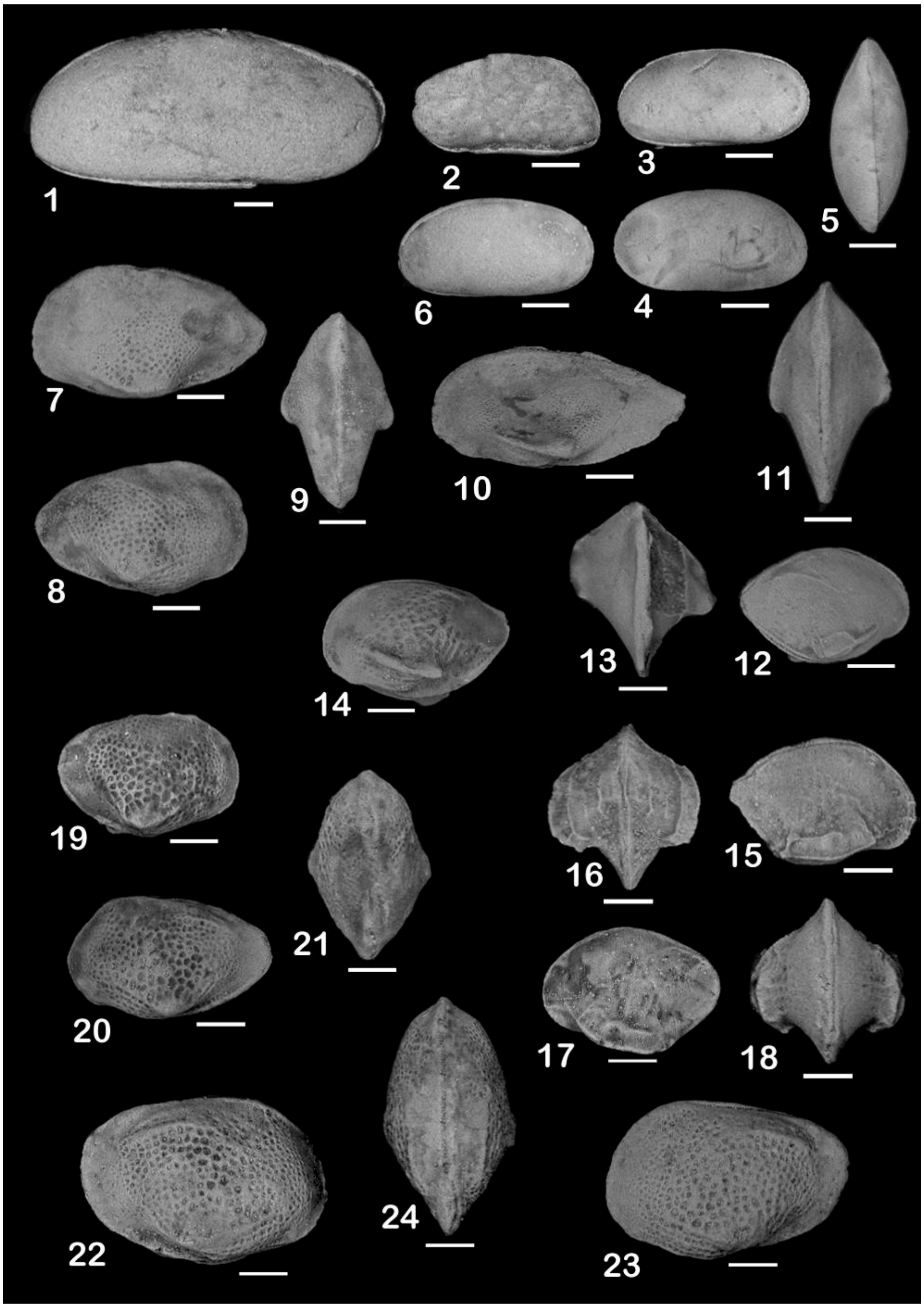

Plate 2
(Bar scale = 100 µm)

Fig. 1: *Bythocypris*? cf. *mereirensis* Cronin and Khalifa, 1979; Nukhul section, Darat Formation, sample N-53, RVC. Fig. 2: *Agrilloecia* sp.; Tayiba section, Darat Formation, sample T-53, LVC. Figs. 3-6: *Parakrithe* sp.; Wadi Tayiba section, sample T-53; 3 carapace, RVC, 4; carapace, RVC; 5, carapace, VVC; 6, carapace, RVC. Figs. 7-9: *Cytheropteron boukharyi* Khalifa and Cronin, 1979; Nukhul section, Darat Formation, 7, sample N-61, LVC, 8, sample N-34, RVC, 9, sample N-60, DVC. Figs. 10-11: *Cytheropteron elongata* El-Waer, 1992; Nukhul section, Darat Formation, sample N-61, 10 LVC, 11 DVC. Figs. 12-13: *Cytheropteron* sp. 1; Tayiba section, Darat Formation, sample T-53, 12 RVC, 13 DVC. Fig. 14: *Cytheropteron* sp. 2; Tayiba section, Darat Formation, sample T-53, LVC. Figs. 15-18: *Cytheropteron* sp. 3; Wadi Tayiba section, sample T-53; 15, carapace, RVC; 16, carapace, VVC; 17, carapace, LVC; 118, carapace, DVC. Figs. 19-21: *Cytheropteron* sp. 4; Wadi Nukhul section, sample N-58; 16, carapace, RVC; 17, carapace, LVC; 18, carapace, DVC. Figs. 22-24: *Cytheropteron* sp. 5; Wadi Nukhul section, sample N-61; 19, carapace, RVC; 20, carapace, LVC; 21, carapace, DVC.

Plate 3

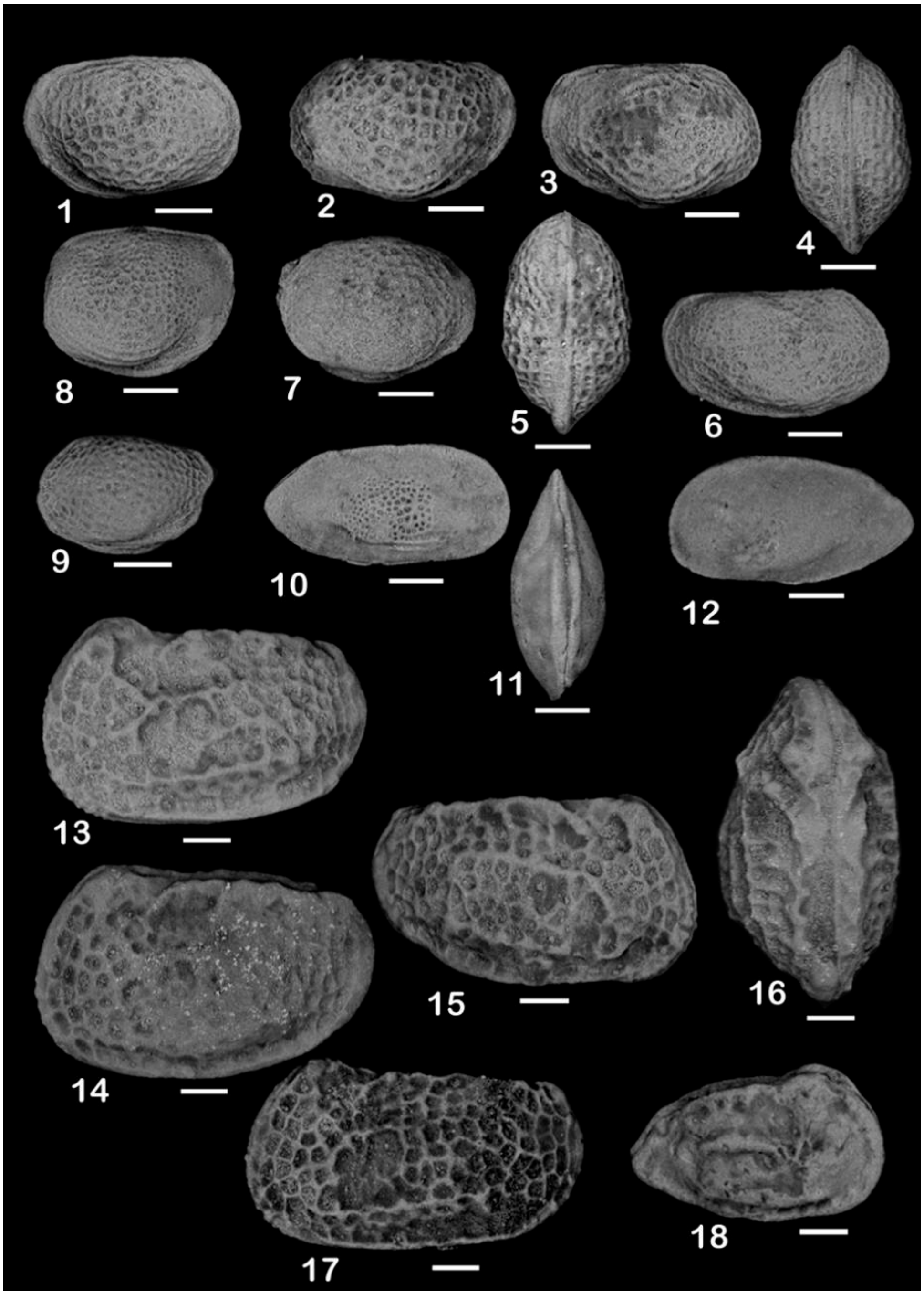

Plate 3

(Bar scale = 100 µm)

Fig. 1: *Loxoconcha mataiensis* Khalifa and Cronin, 1979; Nukhul section, Darat Formation, sample N-53, RVC. Figs. 2-6: *Loxoconcha vetustopunctatella* Bassiouni, Boukhary, Shama & Blondeau, 1984; Nukhul section, Darat Formation; 4, 6, sample N-53, 4, female carapace, VVC, 6, male carapace, LVC; 2, 3, 5, sample N-58; 2, 3, female carapaces, 2 LVC, 3 RVC, 5, male carapace, DVC. Fig. 7: *Loxoconcha* sp. 1k Tayiba section, Darat Formation, sample T-45, LVC. Fig. 8: *Loxoconcha* sp. 2; Tayiba section, Darat Formation, sample T-45, LVC. Fig. 9: *Loxoconcha* sp. 3; Tayiba section, Khaboba Formation, sample T-54, LVC. Figs. 10-11: *Nigeroloxoconcha* sp.1; Tayiba section; 10, Darat Formation, sample T-53, RVC, 11, Khaboba Formation, sample T-54, DVC. Fig. 12: *Nigeroloxoconcha* sp. 2; Tayiba section, Darat Formation, sample T-53, LVC. Figs. 13-17: *Anticythereis seylingi* Cronin and Khalifa, 1979; Tayiba section, Darat Formation, sample T-45; 13-16, female carapaces; 13, 14 LVC, 15 RVC, 16 DVC; 17, male carapace, LVC. Fig. 12: *Cativella qurnensis* Bassiouni, 1969a; Tayiba section, Khaboba Formation, sample T-60, RVC.

Plate 4

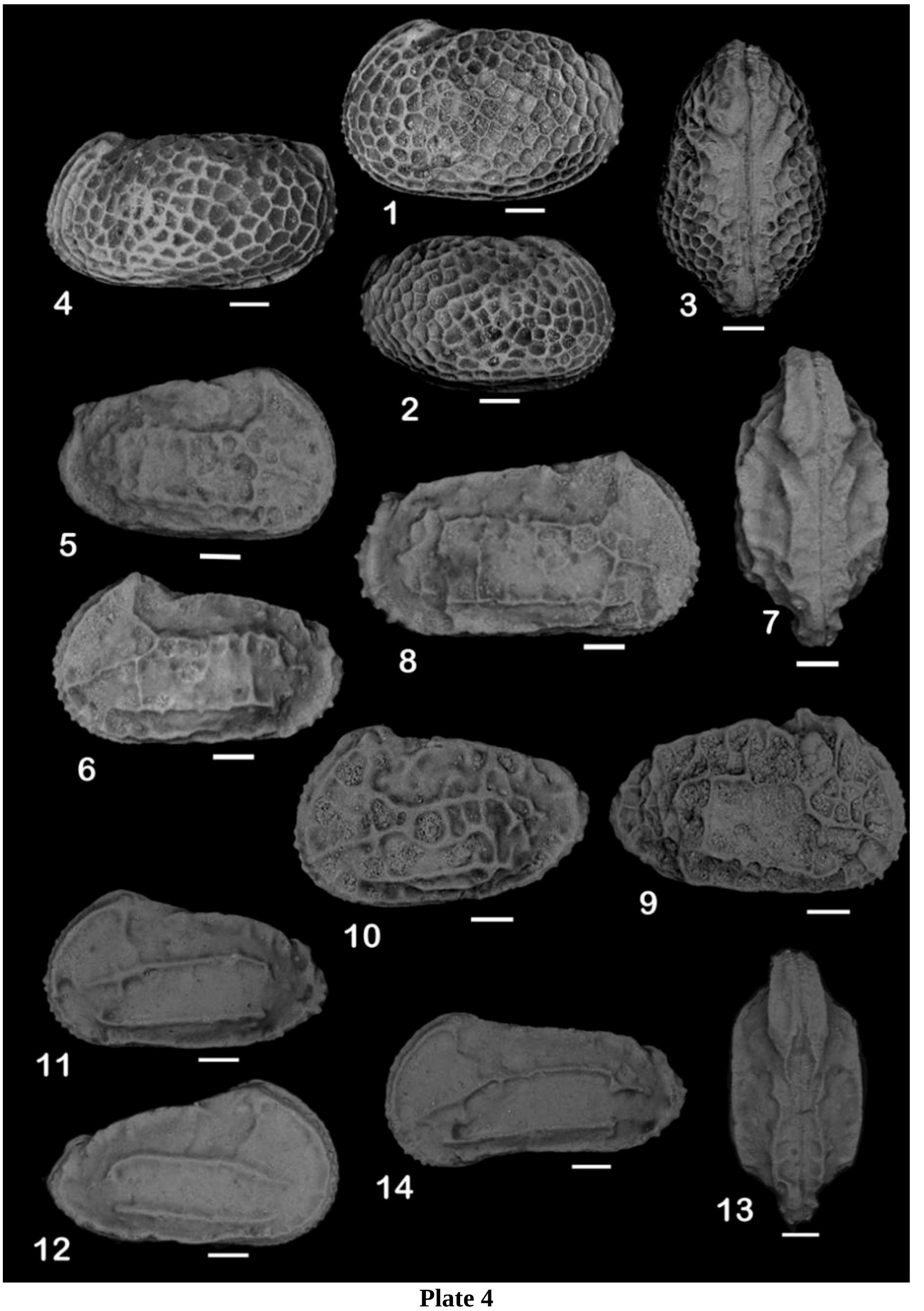

Plate 4

(Bar scale = 100 µm)

Figs. 1-4: *Echinocythereis Bassiounii* Boukhary, Toumarkine, Khalifa and Arif, 1982; Nukhul section, Darat Formation, sample N-76; 1-3 female carapaces, 1 LVC, 2 RVC, 3 DVC; 4, male carapace, LVC. Figs. 5-8: *Paracosta ansaryi* Bassiouni, 1969c; Nukhul section, Darat Formation, sample N-57; 5-7, female carapaces, 5 RVC, 6 LVC, 7 DVC; 8, male carapace, RVC. Figs. 9-10: *Paracosta crassireticulata* Bassiouni, 1969a; Nukhul section, Khaboba Formation, sample N-86, female carapace, 9 RVC, 10 LVC. Figs. 11-14: *Paracosta ducassae* Bassiouni, Boukhary, Shama and Blondeau, 1984; Nukhul section, Darat Formation, sample N-68; 11-13, female carapaces, 11 LVC, 12 RVC, 13 DVC; 14, male carapace, LVC.

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Plate 5

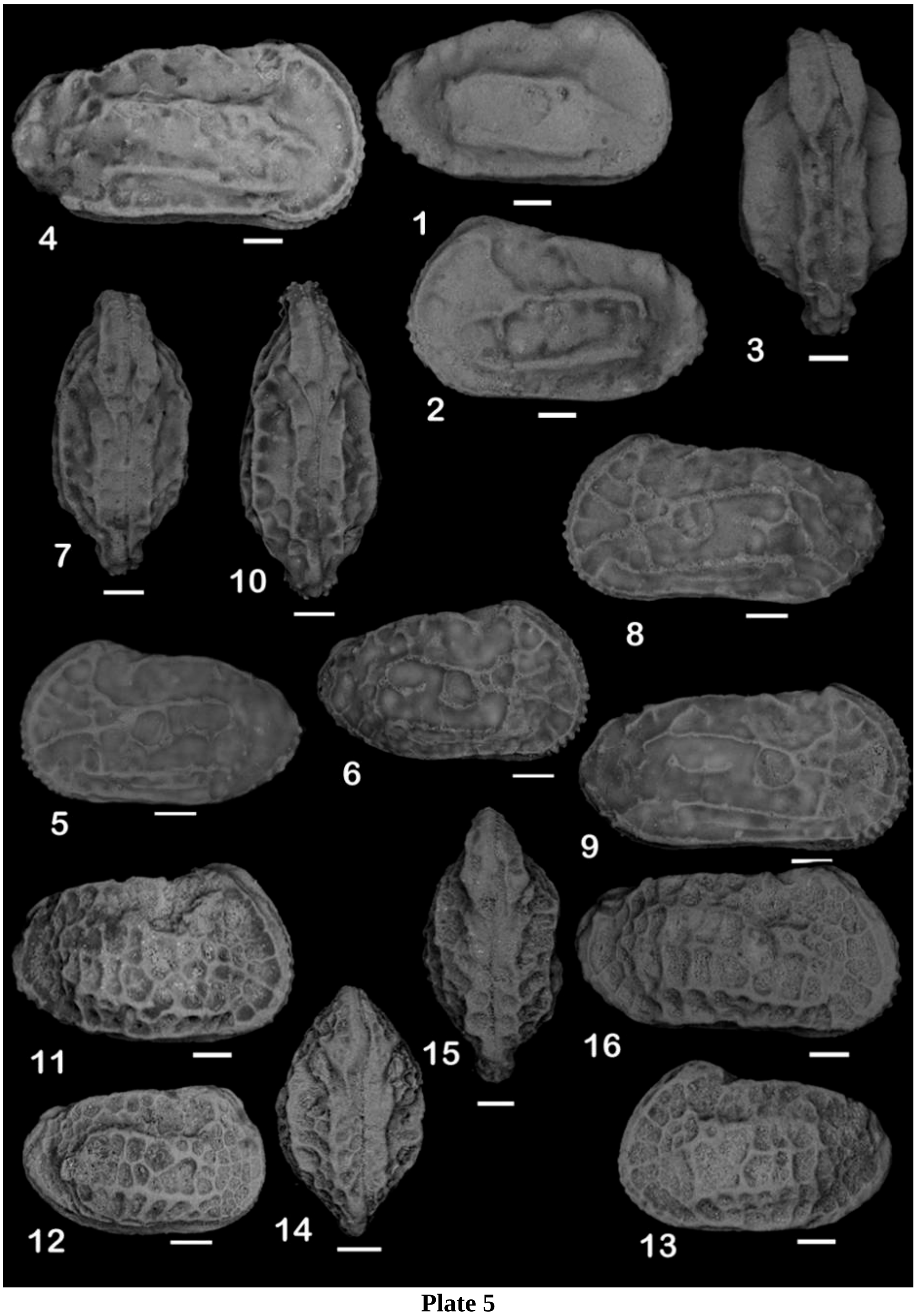

Plate 5

(Bar scale = 100 µm)

Figs. 1-4: *Paracosta humboldti* Bassiouni, 1969a; Tayiba section, Darat Formation, sample T-45; 1-3, female carapaces, 1 RVC, 2 LVC, 3 DVC; 4, male carapace, RVC. Figs. 5-10: *Paracosta mokattamensis praemokattamensis* Bassiouni, 1969c; Nukhul section, Darat Formation, sample N-68; 5-7, female carapaces, 5 LVC, 6 RVC, 7 DVC; 8-10, male carapaces, 8 LVC, 9 RVC, 10 DVC. Figs. 11-16: *Paracosta praecrassireticulata* Bassiouni, 1969c; Tayiba section, Darat Formation; 11,13,15,16, sample T-45; 12, 14, sample T-27; 11-14, female carapaces; 11, 12, RVC, 13 LVC, 14 DVC; 15, 16 , male carapaces, 15 DVC, 16 RVC.

Plate 6

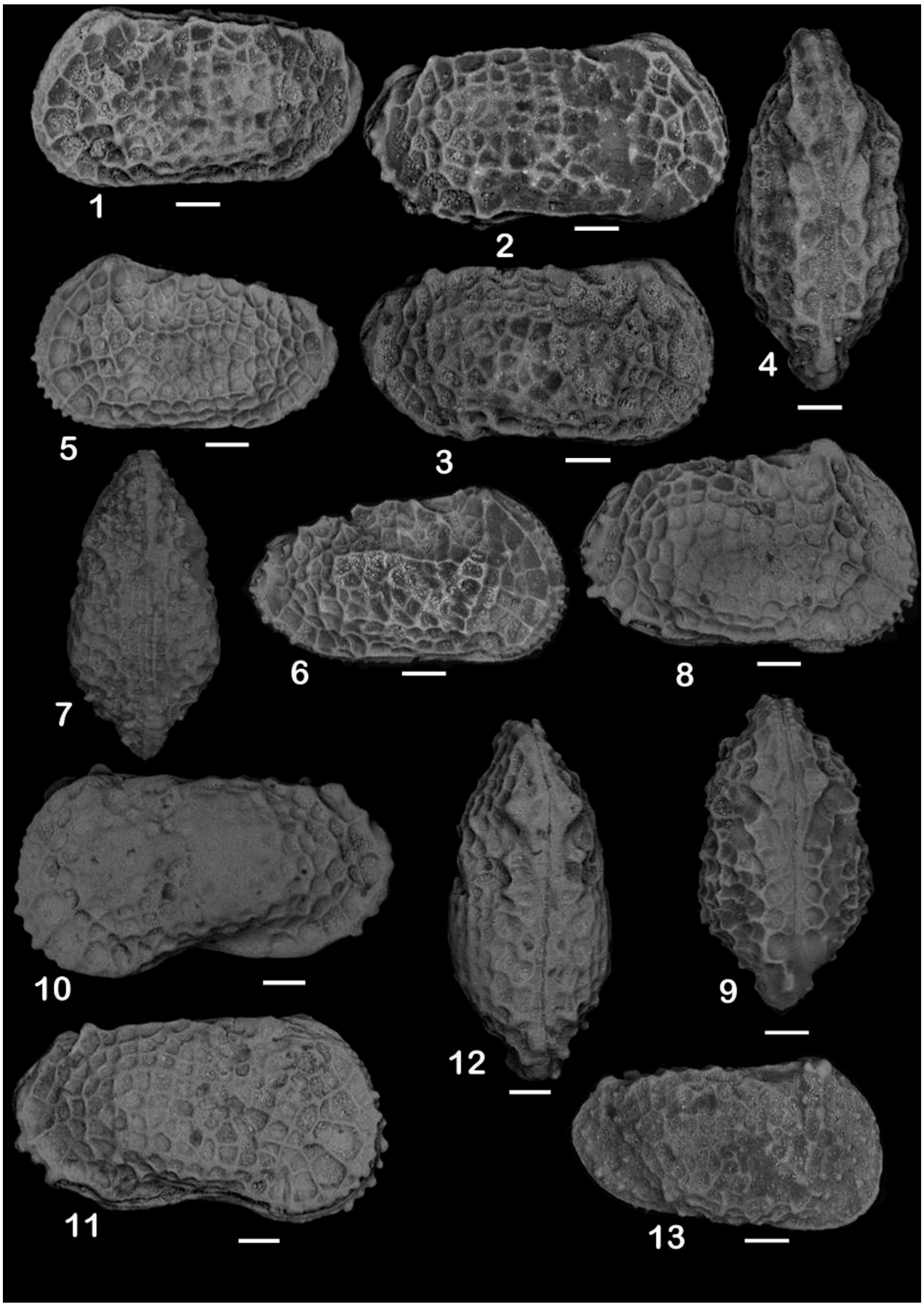

Plate 6
(Bar scale = 100 µm)

Figs. 1-4: *Reticulina heluanensis* Bassiouni, 1969a*;* Tayiba section, Darat Formation, sample T-45; 1, female carapace, LVC; 2-4, male carapaces, 2, 3 RVC, 4 DVC. Figs. 5-7: *Reticulina ismaili* Bassiouni, Boukhary, Shama & Blondeau, 1984*;* Nukhul section, Darat Formation, sample N-68; 5 LVC, 6 RVC, 7 DVC. Figs. 8-12: *Reticulina scitula scitula* Bassiouni, 1969a*;* 8, 9, Nukhul section, Darat Formation, sample N-68, female carapaces, 8 RVC, 9 DVC; 10-12, Tayiba section, Khaboba Formation, sample T-54, male carapaces, 10 LVC, 11 RVC, 12 DVC. Fig. 13: *Reticulina* sp.*;* Nukhul section, Darat Formation, sample N-68,RVC.

Plate 7

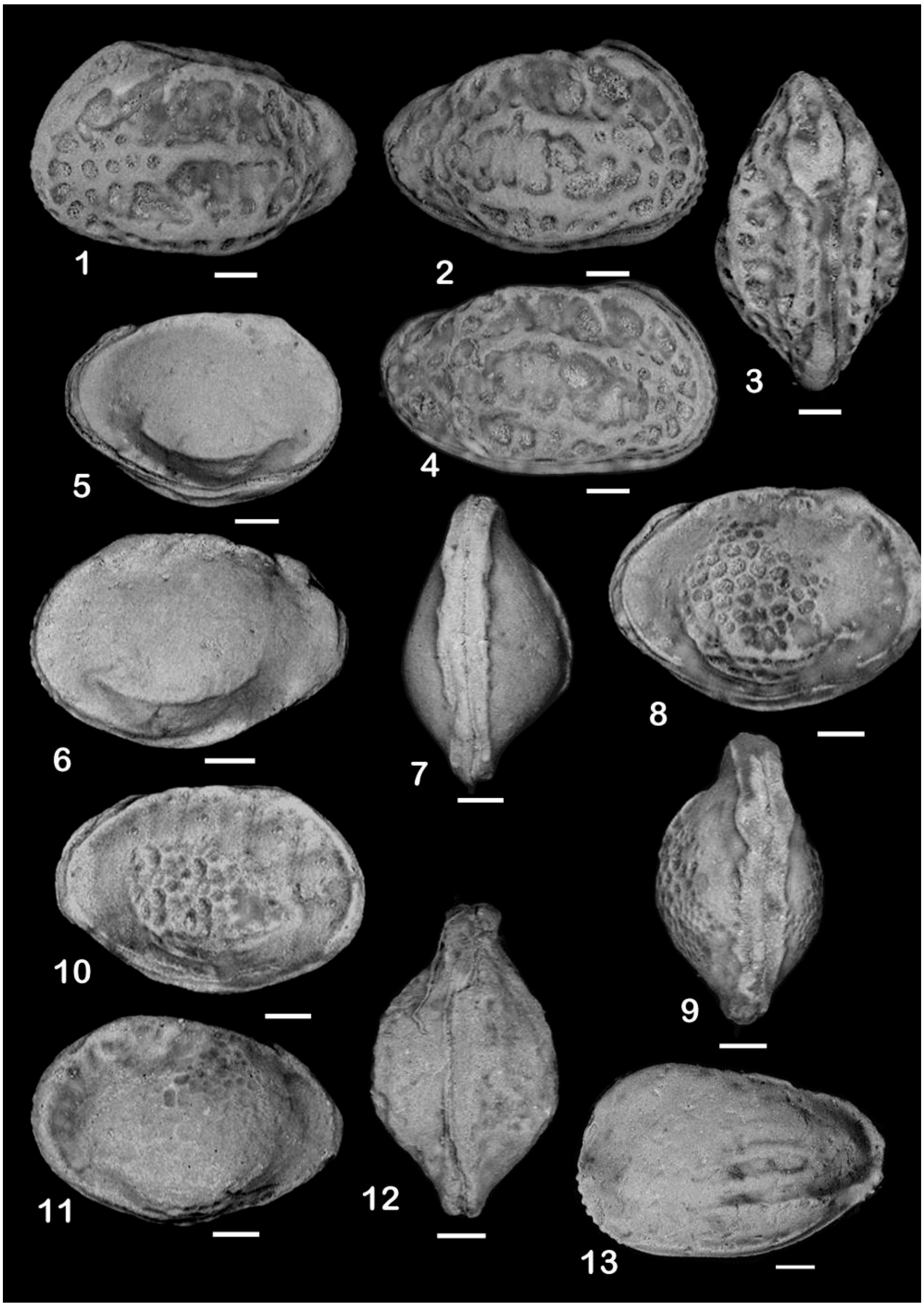

Plate 7
(Bar scale = 100 µm)

Figs. 1-4: *Reymenticosta yarmukensis* Bassiouni, 1969c*;* Tayiba section, Darat Formation, sample T-45; 1-3, female carapaces, 1 LVC, 2 RVC, 3 DVC; 4, male carapace, RVC. Figs. 5-7: *Digmocythere ismaili* Bassiouni, 1971; Nukhul section, Khaboba Formation, sample N-86, 5 RVC, 6 LVC, 7 DVC. Figs. 8-12: *Digmocythere* sp.; Wadi Tayiba section, sample T-45; 8, carapace, RVC; 9, carapace, DVC; 10, carapace, RVC; 11, carapace, LVC; 12, carapace, VVC. Fig. 13: *Asymmetricythere yousefi* Bassiouni, 1971; Tayiba section, Khaboba Formation, sample T-60, LVC.

Plate 8

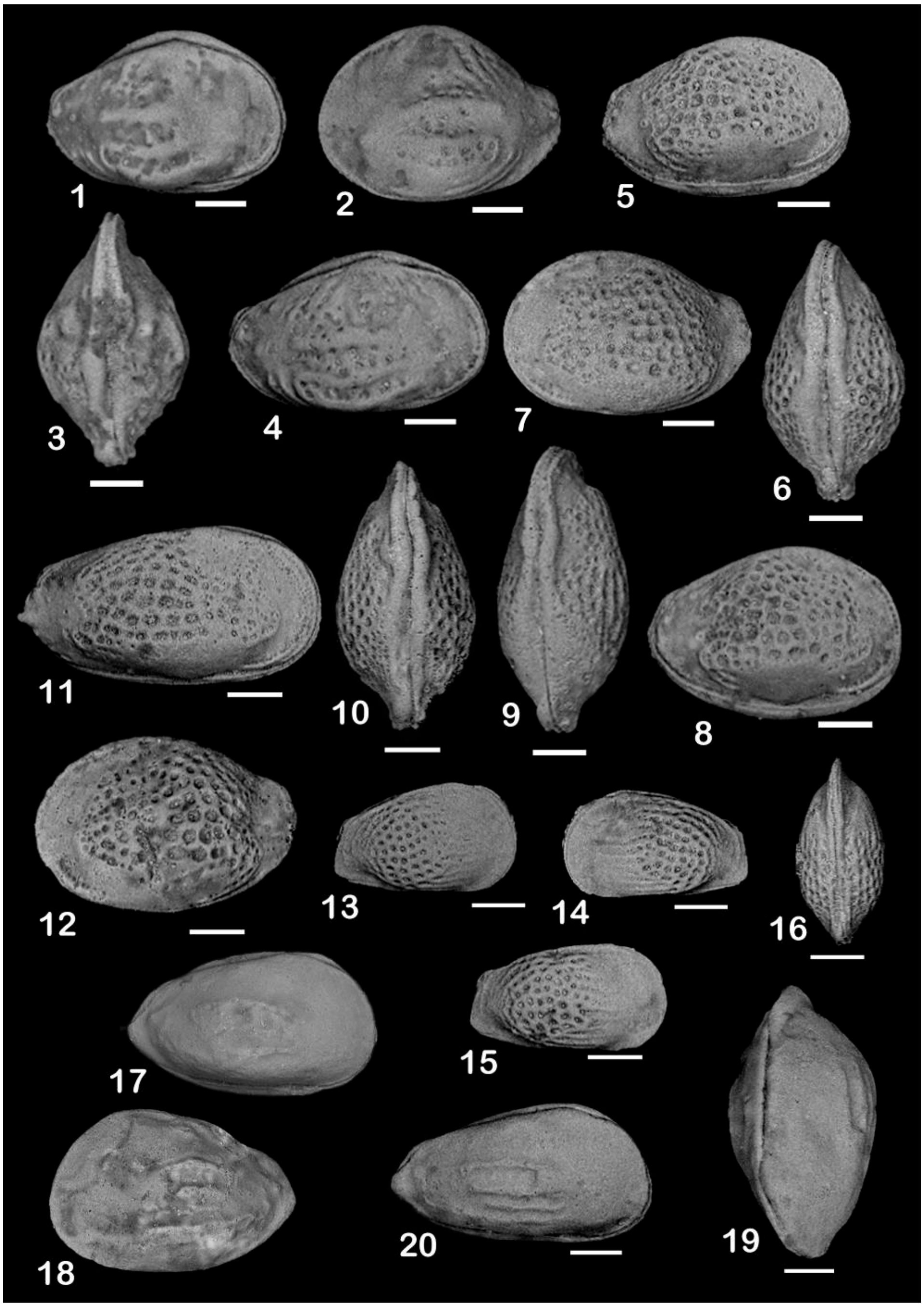

Plate 8

(Bar scale = 100 µm)

Figs. 1-4: *Buntonia ramosa* Bassiouni 1969d; Tayiba section, Darat Formation, sample T-53; 1-3, female carapaces, 1 RVC, 2 LVC, 3 DVC; 4, male carapace, RVC. Figs. 5-12: *Buntonia* sp. 1; Wadi Nukhul section, sample T-68: 5, female carapace, RVC; 6, female carapace, DVC, 7, female carapace, LVC, 8, female carapace, RVC, 9, male carapace, DVC, 10, female carapace, DVC, 11, male carapace, RVC, 12, female carapace, LVC. Figs. 13-16: *Buntonia* sp. 2; Wadi Tayiba section, sample T-53; 13, female carapace, RVC; 14, female carapace, LVC; 15, male carapace, RVC; 16, carapace, DVC. Figs. 17-20: *Soudanella gracilicosta* Bassiouni 1969d; Tayiba section, Darat Formation, sample T-45; 17, 18, female carapaces, 17 RVC, 18 LVC; 19, 20, male carapaces, 19 DVC, 20 RVC.

Plate 9

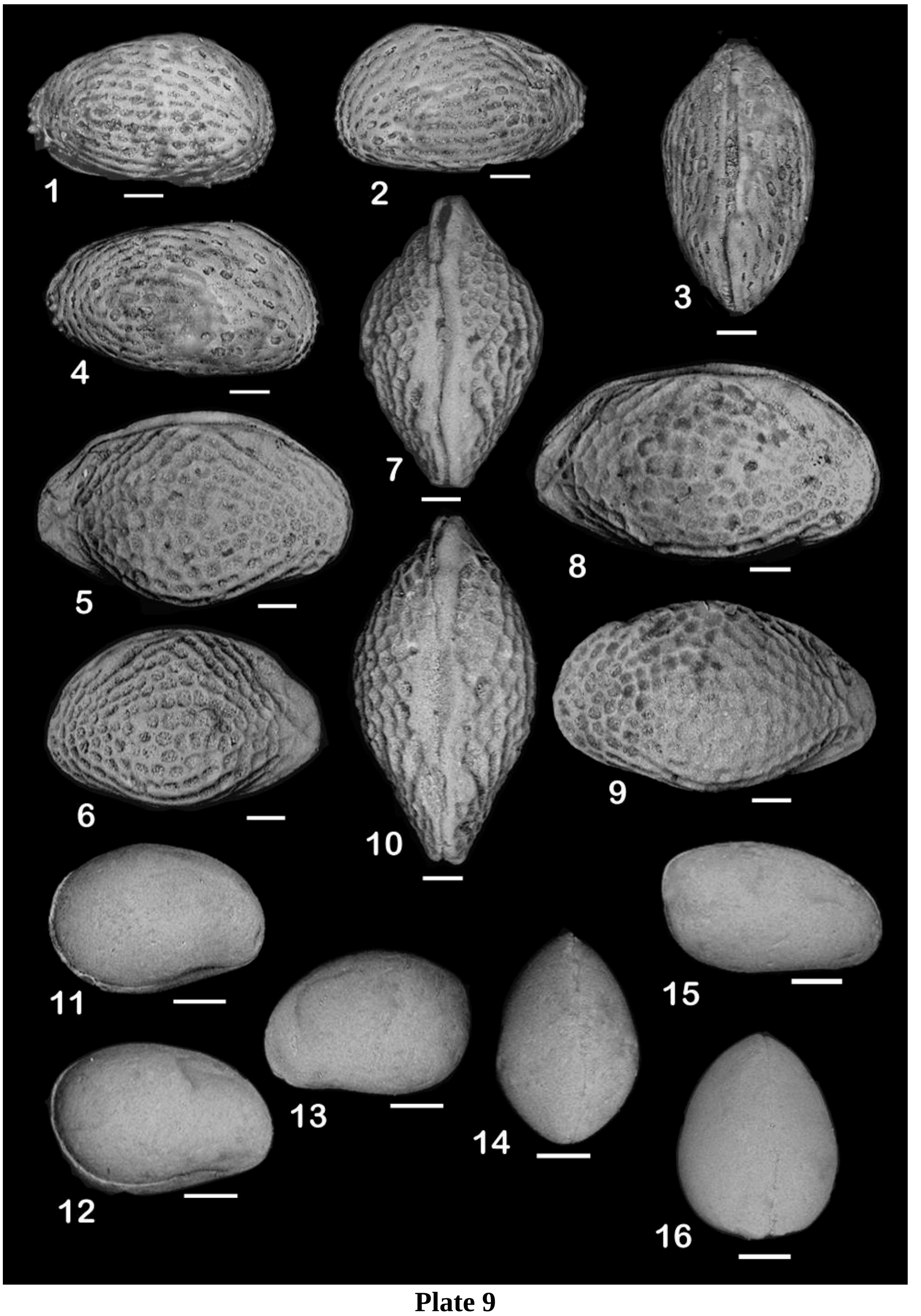

Plate 9

(Bar scale = 100 µm)

Figs. 1-4: *Leguminocythereis africana* Bssiouni, 1969b; Nukhul section, Darat Formation, sample N-68; 1, 2, female carapaces, 1 RVC, 2 LVC; 3, 4, male carapaces, 3 DVC, 4 RVC. Figs. 5-10: *Leguminocythereis praesadeki* Boukhary, Toumarkine, Khalifa & Arif, 1982; Tayiba section, Darat Formation, sample T-45; 5-7, female carapaces, 5 RVC, 6 LVC, 7 DVC; 8-10, male carapaces, 8 RVC, 9 LVC, 10 DVC. Figs. 11-14: *Xestoleberis subglobosa* Bosquet, 1852; Nukhul section, Darat Formation, sample N-53; 11,12 LVC, 13 RVC, 14 DVC. Figs. 15-16: *Xestoleberis* sp.; Wadi Nukhul section, sample N-53; 15, carapace, RVC; 16, carapace, DVC.