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Miocene Calcareous Nannofossils from the Mut Basin, southern Turkey

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ABSTRACT – A detailed study of Miocene calcareous nannofossils using light and scanning electron microscope techniques has been undertaken on sections from the Cifciler, Mut and Silifke regions of the Mut Basin, southern Turkey. Age determinations are based upon a combination of previously published zonal schemes. Forty-one species are recorded; a new combination, *Pontosphaera segmenta* is also introduced.

GEOLOGICAL SETTING OF THE MUT BASIN

The Mut Basin is a sedimentary basin located in southern Turkey and comprises a sequence of sediments of Miocene age overlying an irregular surface of Palaeozoic and Mesozoic basement rocks. The occurrence of over 1000 m of Miocene algal limestones at the basin margins indicates the effect of a relative marine transgression. The strata are generally undisturbed and dip towards the centre of the basin at an angle of 5°, reflecting the probably results of local subsidence and differential compaction.

Three formations are recognised in the Mut region and comprise the Ortakoy Formation, the Mut Marl Formation and the Mut Limestone Formation, which are characterised by sandstone and mudstone, marls and reefal limestone respectively. The Mut Marl and Mut Limestone Formations display an interdigitating contact which has been documented by Özer *et al.* (1974), Sezer (1975) and also observed during field work by the author. Fig. 1 illustrates Sezer's (1975) observation of this relationship. As the Mut Limestone Formation was not, however, examined for calcareous nannofossils, no confirmation of the facies change can be made in this study.

In the Silifke region, the Silifke Formation crops out, in which the argillaceous limestone Medetsiz Member stratigraphically overlies both the Mut Marl Formation and Mut Limestone Formation. The present study confirms the stratigraphic position of the Medetsiz Member (*Cyclicargolithus floridanus* Zone) above the Mut Limestone Formation (*Helicosphaera carteri* Zone (*pars*) to *Sphenolithus heteromorphus* Zone (*pars*)).

The present study is concentrated on calcareous nannofossil analysis of the Mut Marl Formation and the Medetsiz Member of the Silifke Formation. The Medetsiz Member was not developed in the Mut area, possibly because of the presence of a topographic high between the two regions within the basin.

PREVIOUS WORK

The Mut Marl Formation has been studied previously for its foraminifera by different workers. Akarsu (1960) studied the geology of the Mut Basin and identified rocks ranging in age from Palaeozoic to Quaternary. He paid particular attention to the Miocene strata, which cover 90% of the basin. The limestone sequence was assigned an Early Miocene age on the presence of the foraminiferal species *Archais malabaricus* (Carter) while the laterally equivalent marls were regarded as Middle Miocene on macrofossil evidence. It is noteworthy that Adams (1970) has subsequently assigned a Middle Miocene age, Letter Stage Lower Tf (for *Taberina ("Archais") malabaricus* (Carter). Further contributions to the knowledge of the biostratigraphy and micropalaeontology of Tertiary basins in southern Turkey, including the Mut Basin, were made by Bizon *et al* (1974). On the basis of foraminifera, these workers suggested an Early-Middle Miocene (Upper Burdigalian -Lower Langhian) age for the Mut Marl Formation. In 1975, Sezer defined three formations in the Mut Basin and described the lateral facies changes between the Ortakoy Formation, Mut Marl Formation and Mut Limestone Formation. He divided the rocks into the following four zones based on planktonic foraminifera: *Orbulina universa* zone, *Orbulina suturalis* zone, *Praeorbulina* zone, and *Globigerinoides sicanus* zone, which indicate an Early-Middle Miocene age.

The Medetsiz Member of the Silifke Formation was studied by Bizon *et al.* (1974) and Gökten (1976). Bizon *et al.* (1974) suggested a late Middle Miocene (Serravalian) age for this member on the basis of the presence of *Globorotalia mayeri* Cushman & Ellis and *Globorotalia praemenardii* (Cushmann & Ellis). The former has a range of N9-N13 and the latter N9-N12 which would indicate that the formation has an age within the N9-N12 zones of Blow (1969, 1979), Langhian and not Serravallian as quoted by Bizon *et al.* (1974). Gökten (1976) dated the Medetsiz Member as Middle Miocene

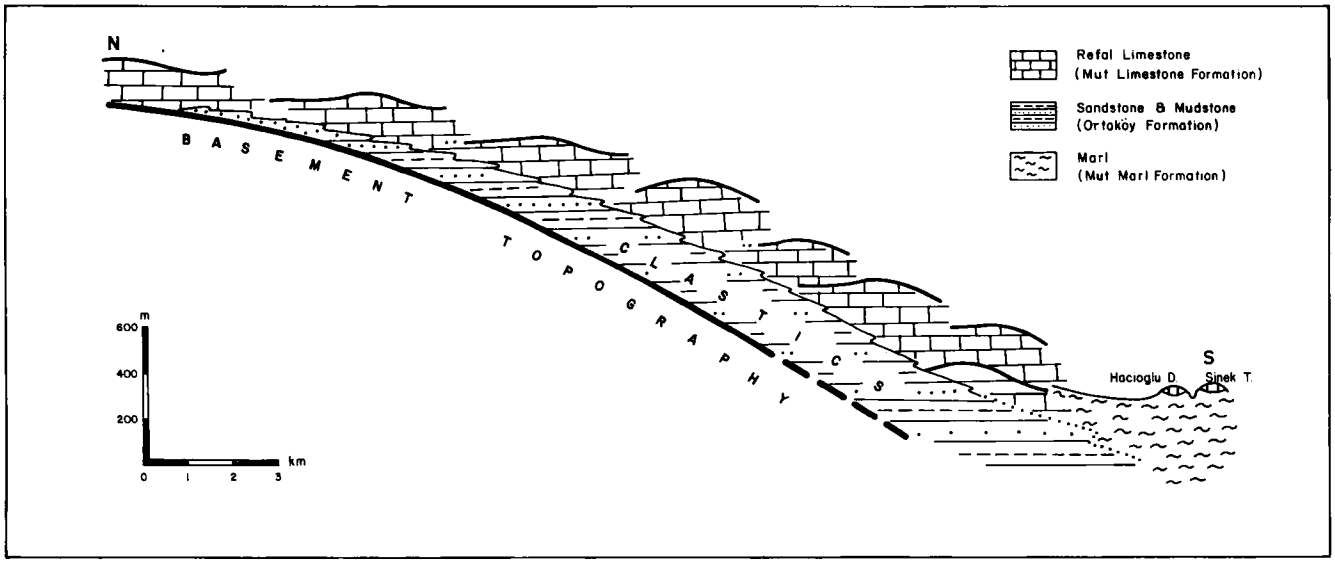

Fig. 1. Lateral facies changes in the Mut Basin (after Sezer, 1975).

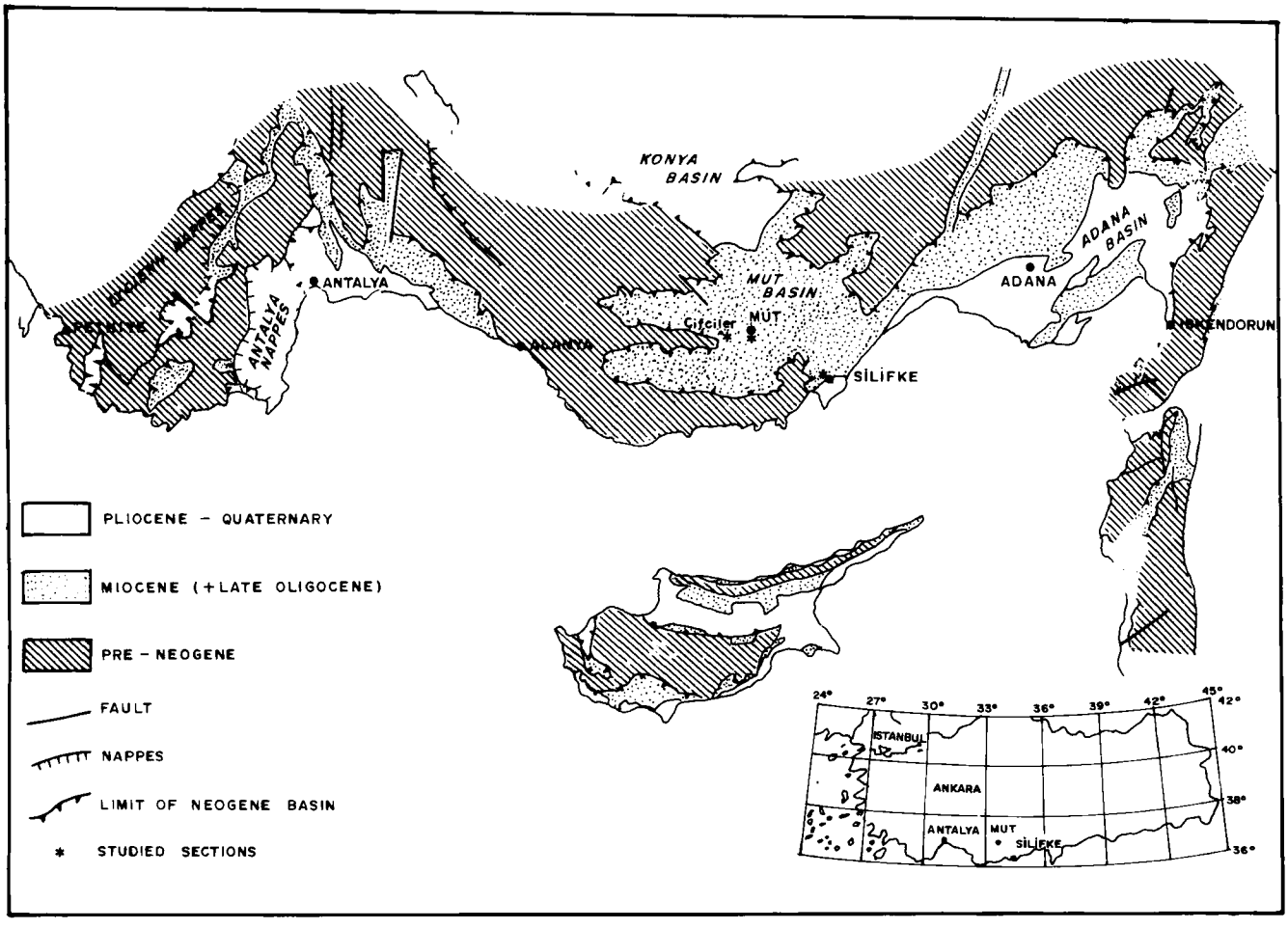

Fig. 2. Location of the Cifciler, Mut and Silifke Sections within the Mut Basin.

(Upper Burdigalian-Lower Helvetian which is equivalent to Langhian) on the basis of *Globigerinoides subquadratus* Brönnimann (N5-N13), *Orbulina suturalis*, Brönnimann (N9-N23) and *Orbulina universa* d'Orbigny (N9-N23). The overlapping ranges of these species would restrict the age of the Medetsiz Member to within N9-N13.

STUDIED SECTIONS

Samples were collected from three separate sections in the Cifciler, Mut and Silifke areas of the Mut Basin, the locations of which are indicated in Fig. 2.

Cifciler section

Twenty-nine samples were collected for calcareous nannofossil examination from the marl at the locality described by Sezer (1975). Thirty-four species of calcareous nannofossils are recognised and their ranges and relative abundance are recorded in Fig. 3.

The species are moderately well preserved and many of them show signs of overgrowth. Samples from this section contain calcareous nannofossil assemblages with a relatively low species diversity. *Helicosphaera carteri*, (Wallich) Kamptner, 1954, *H. ampliaperta* Bramlette & Wilcoxon, 1967 and *Sphenolithus hetermorphus* Deflandre, 1953 are the biostratigraphically important species recovered from this section. Apart from the above mentioned forms, *Coccolithus pelagicus* (Wallich) Schiller, 1930 and *Reticulofenestra pseudoumbilica* (Gartner) Gartner, 1969 are recorded commonly throughout the studied section.

Pontosphaera japonica (Takayama) Nishida, 1971 and *Homozygosphaera tholifera* (Kamptner) Halldal & Markali, 1955 display older stratigraphical ranges than previously reported. *Syracosphaera mediterranea* Lohmann, 1902 is found in the Early Miocene and was also reported from the Early Miocene by Baldi-Beke (1979).

In this section, from top to bottom, the following zones are recognised: *Sphenolithus heteromorphus* zone, *Helicosphaera ampliaperta* zone and *Helicosphaera carteri* zone.

Mut section

Fourteen samples were collected from a section within the Mut Marl Formation and examined for their calcareous nannofossil content. Thirty species are recognised and the relative abundance of the species and their stratigraphic ranges are given in Fig. 4.

Overall abundance and diversity of calcareous nannofossils increase towards the top of the studied section. The following are the most common species, of which the first three are found throughout the sampled material: *Coccolithus pelagicus* (Wallich) Schiller, 1930, *Reticulofenestra pseudoumbilica* (Gartner) Gartner, 1969, *Helicosphaera ampliaperta* Bramlette & Wilcoxon 1967 and *Sphenolithus heteromorphus* Deflandre, 1953.

The following zones are recognised in the Early Miocene: *Helicosphaera ampliaperta* zone and *Helicosphaera carteri* zone.

Silifke section

Eleven samples were collected from a section within the Medetsiz Member of the Silifke Formation and examined for their calcareous nannofossils. The samples from this section provided fairly well preserved assemblages of calcareous nannofossils which exhibit relatively low species diversity. The stratigraphic distributions of the species, many of which are long-ranging, are shown in Fig. 5.

Commonly recorded species include *Cyclicargolithus floridanus* (Roth & Hay) Bukry, 1971, *Helicosphaera carteri* (Wallich) Kamptner, 1954, *Coccolithus pelagicus* (Wallich) Schiller, 1930, Reticulofenestra *pseudoumbilica* (Gartner) Gartner, 1969, *Umbilicosphaera jafari* Müller, 1974, *Umbilicosphaera lordii* Varol, 1982 and *Umbilicosphaera petaliformis* Varol, 1982. In this section the rare occurrence of *Rhabdosphaera clavigera* Murray & Blackman, 1898, *Syracosphaera nodosa* Kamptner, 1941, *Braarudosphaera bigelowi* (Gran & Braarud) Deflandre, 1947 and *Syracosphaera mediterranea* Lohman, 1902 were also observed.

The presence of *Cyclicargolithus floridanus*, (Roth & Hay) Bukry, 1971, in the absence of the older taxon *Sphenolithus heteromorphus* Deflandre, 1953, is taken to indicate the *Cyclicargolithus floridanus* zone which is of Middle Miocene age.

ZONATION SCHEME

The zonation scheme proposed in this study utilises previously described zones. A correlation between the previously published zonation and the present scheme is given in Fig. 6.

***Helicosphaera carteri* Zone** Edwards, 1971 emend. Varol (1983) (*non* Okada & Bukry, 1980)

Definition. The base of this zone is not recognised in this study; the top of this zone is recognised by the first occurrence of *Sphenolithus heteromorphus* Deflandre, 1953.

Age. Early Miocene.

Common species. *Helicosphaera carteri*, (Wallich) Kamptner, 1954, *H. ampliaperta* Bramlette & Wilcoxon, 1967, *Coccolithus pelagicus* (Wallich) schiller, 1930 and *Sphenolithus moriformis* (Brönnimann & Stradner) Bramlette & Wilcoxon 1967.

Remarks. *Triquetrorhabdulus carinatus* Martini, 1965 and *Sphenolithus belemnos* Bramlette & Wilcoxon, 1967 are absent in the Early Miocene of southern Turkey; it is also reported as being very rare or absent in S.E. Asia. Varol (1983) found it necessary to combine

the *Discoaster druggi* subzone (CN1a) and the *Sphenolithus belemnos* zone (CN2) of Okada & Bukry (1980).

This zone is equivalent to the "Unnamed Neogene Zone" of Edwards (1971). However, in his study Edwards primarily marked the upper limit of this zone by the evolutionary appearance of *Discoaster divaricatus* Hay (in Hay *et al.*, 1967) and the evolutionary appearance of *Sphenolithus heteromorphus* Deflandre, 1953 is used secondarily. Varol (1983) used only the evolutionary appearance of *Sphenolithus heteromorphus* Deflandre, 1953, which is cosmopolitan and solution resistant. The *Helicosphaera kamptneri* Zone of Chi (1979) corresponds to the lower part of the present zone. Zones NN2-NN3 of Martini (1971) are also approximately equivalent to the *H. carteri* zone. The first occurrence of *Discoaster pugnosa* Hojjatzadeh 1978, *Rhabdosphaera clavigera* Murray & Blackman, 1898 and *Syracosphaera mediterranea* Lohmann, 1902 were observed in this zone.

Localities. Mut and Cifciler sections.

***Helicosphaera ampliaperta* Zone** Bramlette & Wilcoxon, 1967

Definition. Interval from the first occurrence of *Sphenolithus heteromorphus* Deflandre, 1953 to the last occurrence of *Helicosphaera ampliaperta* Bramlette & Wilcoxon, 1967.

Age. Early Miocene.

Common species. *Sphenolithus heteromorphus* Deflandre, 1953, *S. moriformis* (Brönniman & Stradner) Bramlette & Wilcoxon, 1967, *Helicosphaera carteri* (Wallich) Kamptner, 1954, *H. ampliaperta* Bramlette & Wilcoxon, 1967, *Coccolithus pelagicus* (Wallich) Schiller, 1930 and *Reticulofenestra pseudoumbilica* (Gartner) Gartner, 1969.

Remarks. The first occurrence of *Pontosphaera japonica* (Takayama) Nishida, 1971 is observed in this zone.

Localities. Mut and Cifciler sections.

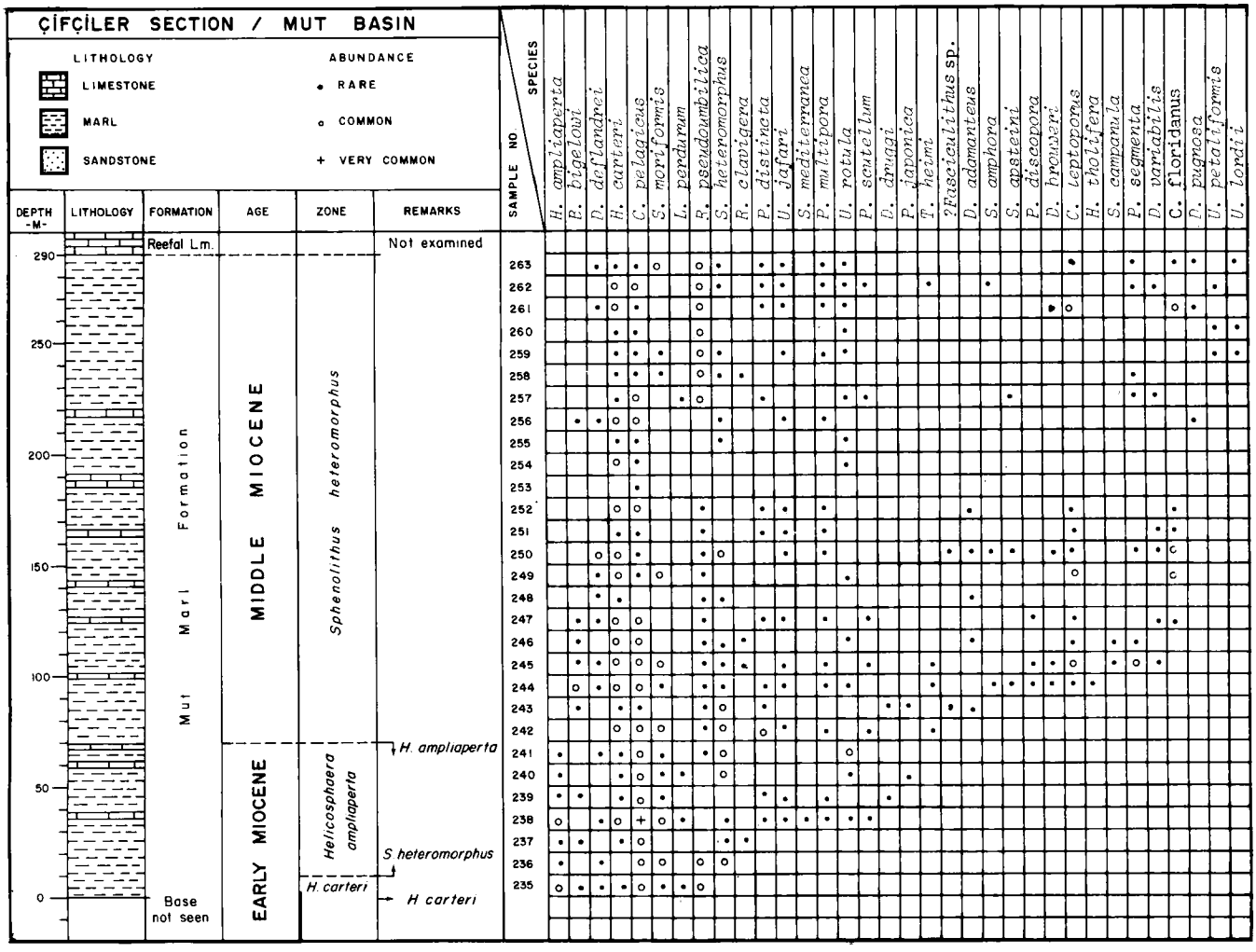

Fig. 3. Cifciler Section: stratigraphic distribution of calcareous nannofossils.

***Sphenolithus heteromorphus* Zone** Bramlette & Wilcoxon, 1967

Definition. The base of this zone recognised by the last occurrence of *Helicosphaera ampliaperta* Bramlette & Wilcoxon, 1967; the top of this zone is not recognised in this study.

Age. Middle Miocene.

Common species. *Sphenolithus hetermorphus* Deflandre 1953 *Reticulofenestra pseudoumbilica* (Gartner) Gartner 1969, *Helicosphaera carteri* (Wallich) Kamptner 1954, *Coccolithus pelagicus* (Wallich) Schiller 1930.

Remarks. *Homozygosphaera tholifera* (Kamptner) Halldal and Markali 1955 first appears within this zone.

Locality. Cifciler Section.

***Cyclicargolithus floridanus* Zone** Chi, 1979

Definition. The base and top of this zone were not recognised in this study.

Age. Middle Miocene.

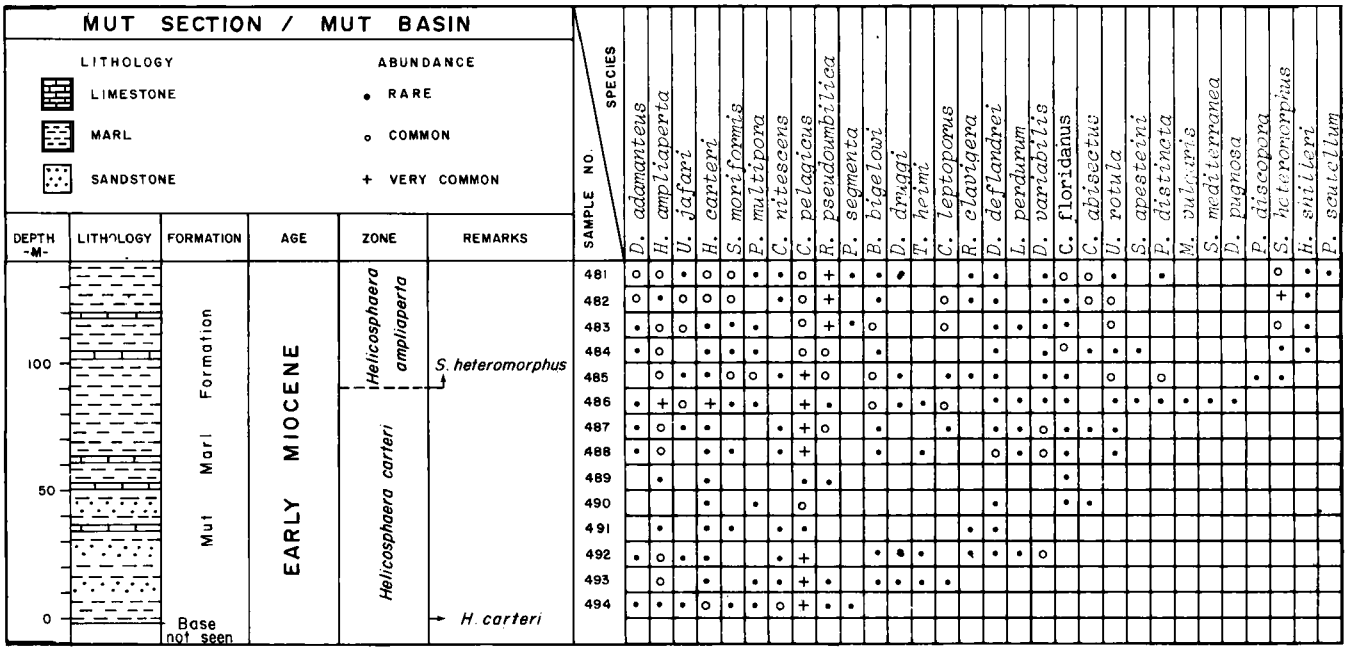

Fig. 4. Mut Section: stratigraphic distribution of calcareous nannofossils.

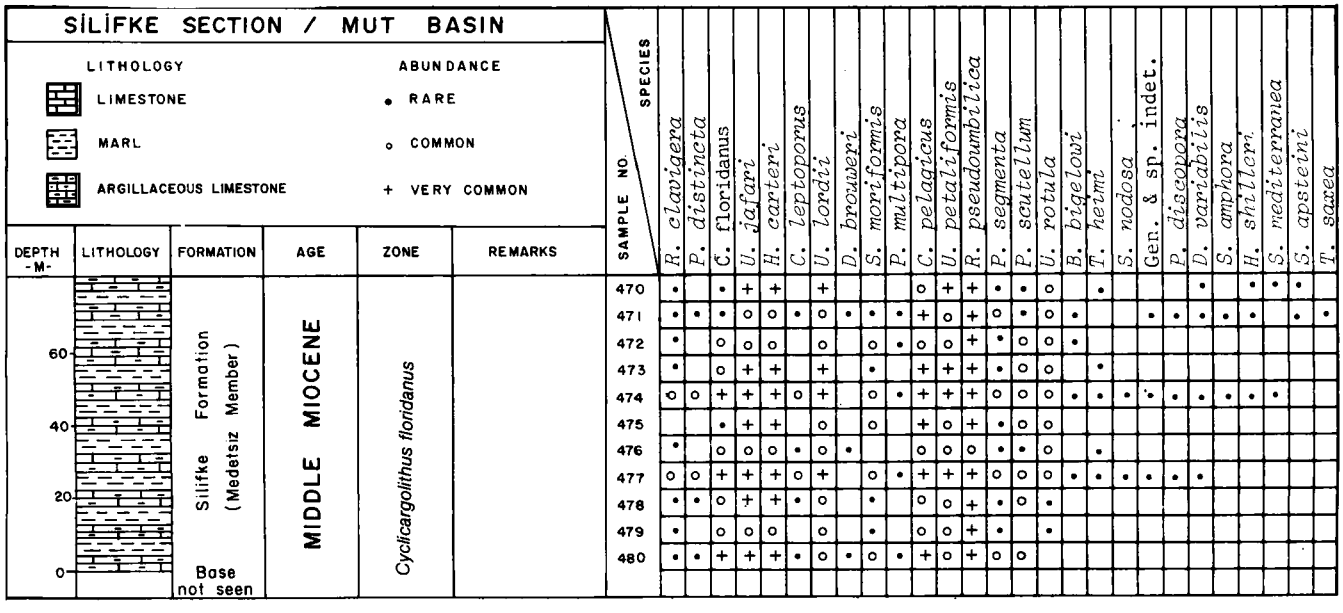

Fig. 5. Silifke Section: stratigraphic distribution of calcareous nannofossils.

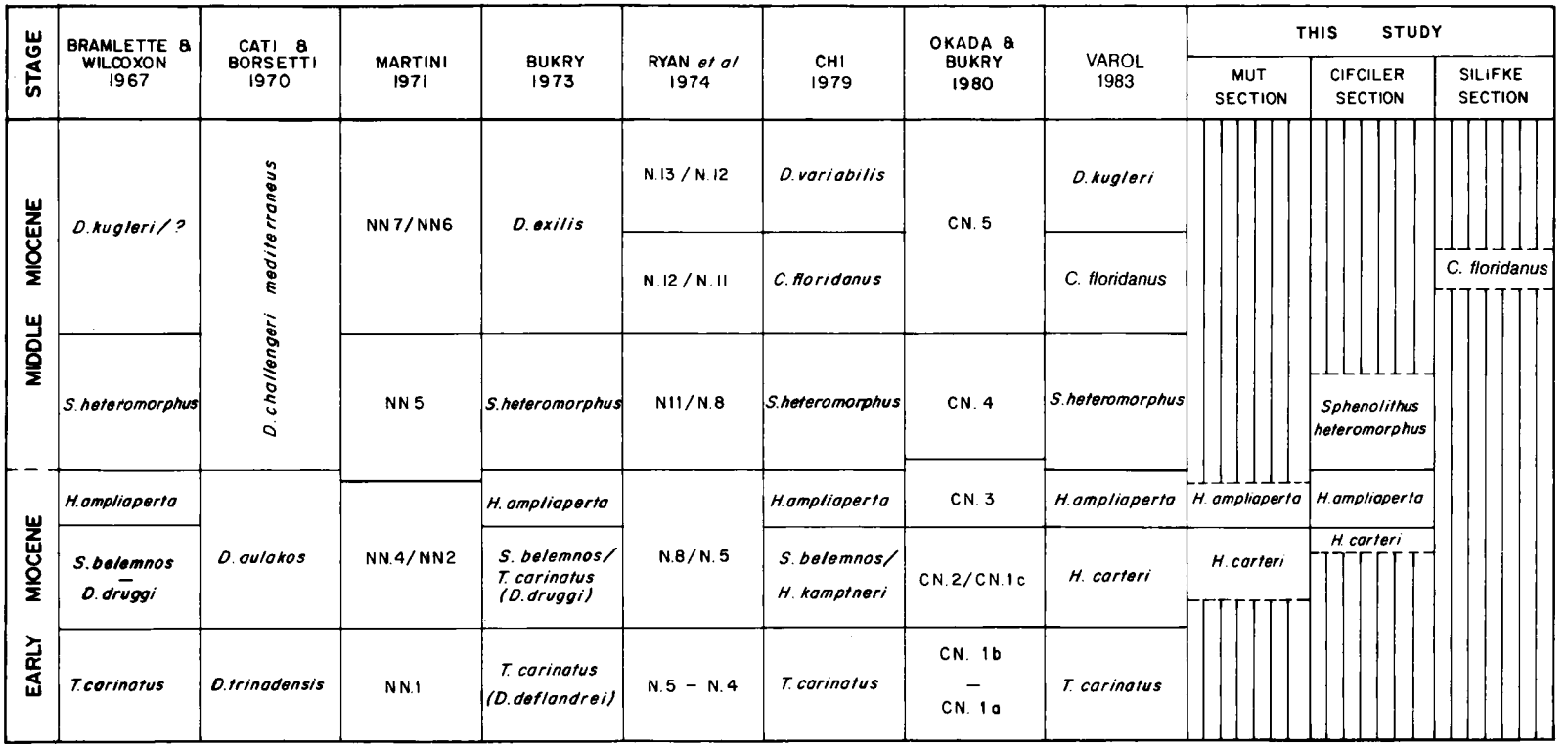

Fig. 6. Calcareous nannofossil zones of present study as compared with previously established zonation schemes.

Common species: *Cyclicargolithus floridanus* (Roth & Hay) Bukry, 1971, *Helicosphaera carteri* (Wallich) Kamptner, 1954, *Reticulofenestra pseudoumbilica* (Gartner) Gartner, 1969, *Coccolithus pelagicus* (Wallich) Schiller, 1930 and *Umbilocosphaera* spp.

Remarks. This zone is approximately equivalent to zone NN6 of Martini (1971) and zone CN5a of Okada & Bukry (1980). *Discoaster kugleri* Martini & Bramlette, 1963 and *Discoaster exilis* Martini & Bramlette, 1963 are absent from the studied material whereas *C. floridanus* is commonly present and easily applicable to the Mut Basin. Bukry (1975) also used the nominate species as a second marker to define the same boundary in the absence of *Discoaster kugleri* Martini & Bramlette, 1963.

REMARKS ON PRESERVATION AND PALAEOECOLOGY

Palaeoecological control and preservational conditions are the two main factors which affect both species diversity and abundance of calcareous nannofossil assemblages. It is always, however, very difficult to determine whether palaeoecological control, preservational conditions or a combination of both were responsible for species diversity and abundance.

In the present study, all studied sections contained moderately well preserved calcareous nannofossils. Certain species, however, are slightly more affected in the Cifciler Section than in the Mut and Silifke sections by preservational conditions. Some specimens of *Braarudosphaera bigelowi* (Gran & Braarud) Deflandre, 1947 from the Cifciler Section, for example, are strongly etched which other displays overgrowths. In all sections, Discoasters and the central part of *Coccolithus pelagicus* (Wallich) Schiller, 1930, show signs of overgrowths. Similarly, various degrees of slight etching are observed in *Pontosphaera* spp., *Rhabdosphaera clavigera* Murray & Blackman, 1898, *Syracosphaera* spp. and *Scyphosphaera* spp. Coccospheres of *Coccolithus pelagicus* (Wallich) Schiller, 1930 and *Reticulofenestra pseudoumbilica* (Gartner) Gartner, 1969 are common in all sections.

Warm water indicators present in the studied section include *Helicosphaera carteri* (Wallich) Kamptner, 1954, *Rhabdosphaera clavigera* Murray & Blackman, 1898, *Pontosphaera* spp. and *Scyphosphaera* spp. of which *Helicosphaera carteri* (Wallich) Kamptner, 1954 is especially common. Supportive evidence for the presence of warm water is provided by the presence of coral reefs along the edge of the basins.

Species which are known to preferentially occupy shallower water are rare to common in the studied sections and include *Helicosphaera* spp., *Pontosphaera* spp., *Scyphosphaera* spp., *Rhabdosphaera* spp., *Thorocesphaera* spp., *Braarudosphaera* spp. and *Sphenolithus* spp. Discoasters which occupy relatively deeper water are, in contrast, rare in the studied sections. The combined evidence from the observed association of these forms, together with compartively low species diversity, enables a relatively shallow water depositional environment to be tentatively concluded.

SYSTEMATIC NOTES

Pontosphaera segmenta (Bukry & Percival) Varol comb. nov.
(Pl. 1, figs. 26-28)

1971 *Discolithina segmenta* Bukry & Percival, p. 130, pl. 4, figs. 4-6.

Remarks. Ellipitical imperforate species with central area constructed of radially arranged elements. A very distinct suture lies along the long axis. *Pontosphaera segmenta* is easily distinguished from *P. scutellum* by the construction of the central area.

Known range. Oligocene-Miocene.

Indet. gen. et sp.
(Pl. 1, fig. 12)

Description. This small elliptical form is constructed of 18-22 wedge-shaped elements of variable size in each shield. The elliptical central area is almost equally divided into two segments along the short axis of the coccolith. Proximal and distal shields are equal in diameter.

Remarks. This form cannot be placed within any of the established genera, and lack of adequate illustration of the distal side, and light micrographs, unfortunately precludes further taxonomic treatment in this paper.

Known range. Middle-Late Miocene.

Additional species recognised in this study include:

Braarudosphaera bigelowi (Gran & Braarud) Deflandre, 1947
Coccolithus pelagicus (Wallich) Schiller, 1930
Coronocyclus nitescens (Kamptner) Bramlette & Wilcoxon, 1967
Cyclicargolithus abisectus (Müller) Wise, 1973
Cyclicargolithus floridanus (Roth & Hay) Bukry, 1971
Cyclococcolithus leptoporus (Murray & Blackmann) Kamptner, 1954
Discoaster adamanteus Bramlette & Wilcoxon, 1967
Discoaster brouweri Tan, 1927
Discoaster deflandrei Bramlette & Riedel, 1954
Discoaster druggi Bramlette & Wilcoxon, 1967
Discoaster pognosa Hojjatzadeh, 1978
Discoaster variabilis Martini & Bramlette, 1963
?Fasciculithus sp.
Helicosphaera ampliaperta Bramlette & Wilcoxon, 1967
Helicosphaera carteri (Wallich) Kamptner, 1954

Homozygosphaera schilleri (Kamptner) Okada & McIntyre, 1977
Homozygosphaera tholifera (Kamptner) Halldal & Markali, 1955
Lithostromation perdurum Deflandre, 1942
Micrascidites vulgaris Deflandre & Deflandre-Rigaud, 1956
Pontosphaera discopora Schiller, 1925
Pontosphaera distincta (Bramlette & Sullivan) Burns, 1973
Pontosphaera japonica (Takayama) Nishida, 1971
Pontosphaera multipora (Kamptner) Roth, 1970
Pontosphaera scutellum (Kamptner) Kamptner, 1952
Reticulofenestra pseudoumbilica (Gartner) Gartner, 1969
Rhabdosphaera clavigera Murray & Blackmann, 1898
Scyphosphaera amphora Deflandre, 1942
Scyphosphaera apsteini Lohmann, 1902
Scyphosphaera campanula Deflandre, 1942
Sphenolithus heteromorphus Deflandre, 1953
Sphenolithus moriformis (Brönnimann & Stradner) Bramlette & Wilcoxon, 1967
Syracosphaera mediterranea Lohmann, 1902
Syracosphaera nodosa Kamptner, 1941
Thoracosphaera heimi (Lohmann) Kamptner, 1941
Thoracosphaera saxea Stradner, 1961
Umbilicosphaera jafari Müller, 1974
Umbilicosphaera lordii Varol, 1982
Umbilicosphaera petaliformis Varol, 1982
Umbilicosphaera rotula (Kamptner) Varol, 1982

CONCLUSIONS

1. Within the Early Miocene, the *Helicosphaera carteri* and *Helicosphaera ampliaperta* zones are identified, and in the Middle Miocene the *Sphenolithus heteromorphus* and *Cyclicargolithus floridanus* zones are identified.
2. The age of the Mut Marl Formation ranges from Early to Middle Miocene and includes the *Helicosphaera carteri, Helicosphaera ampliaerta* and *Sphenolithus heteromorphus* zones. This confirms and refines the biostratigraphical results obtained by foraminiferal analyses. Previous authors such as Özer *et al.* (1974), Bizon *et al.* (1974) and Sezer (1975) concluded an Early to Middle Miocene age for the Mut Marl Formation using planktonic foraminifera.
3. The present study indicates that the Medetsiz Member of the Silifke Formation falls within the *Cyclicargolithus floridanus* zone which is equivalent to the upper part of zone N11 to the lower part of the zone N12 of Blow (1969, 1979). This conclusion is more refined than that of Gökten (1976) and slightly older than the determination of Bizon *et al.* (1974) but lies well within the zonal ages indicated by the planktonic foraminifera quoted by these workers.
4. A new combination, *Pontosphaera segmenta* is introduced.
5. Several of the species identified are found to have older ranges than previously recorded. *Syracosphaera nodosa* Kamptner, 1941 and *Homozygosphaera tholifera* (Kamptner) Halldal & Markali, 1955 range from the Middle Miocene, zones *Cyclicargolithus floridanus* and *Sphenolithus heteromorphus* respectively. The ranges of *Discoaster pugnosa* Hojjatzadeh, 1978 and *Pontosphaera japonica* (Takayama) Nishida, 1971 are now extended into the *Helicosphaera carteri* and *Helicosphaera ampliaperta* zones respectively of the Early Miocene.

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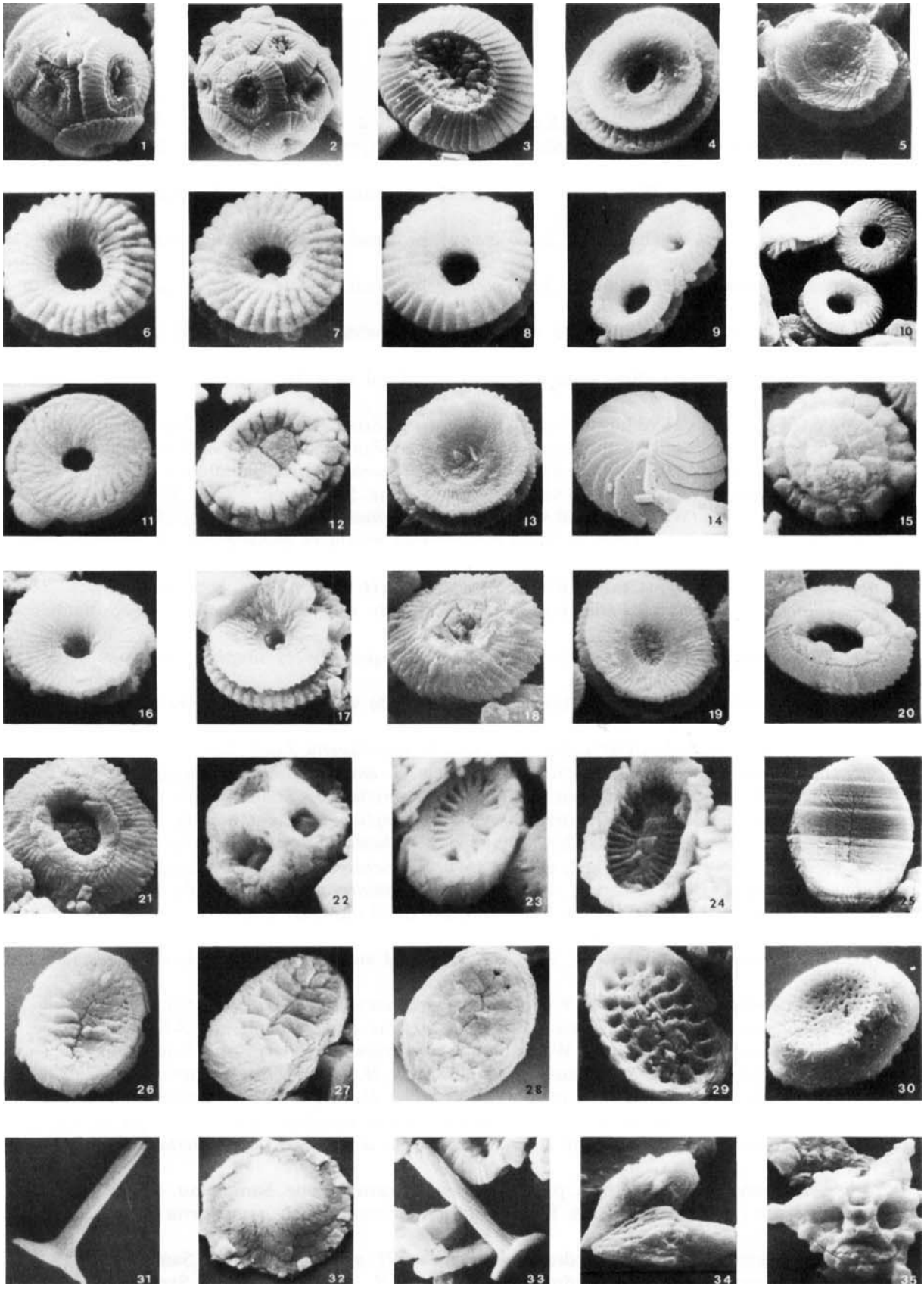
Explanation of Plate 1
Scanning electron micrographs

Fig. 1. *Coccolithus pelagicus* (Wallich), view of coccosphere, *S. heteromorphus* Zone. Sample no. 244 (×2500).
Fig. 2. *Coccolithus pelagicus* (Wallich), view of coccosphere, *S. heteromorphus* Zone. Sample no. 246 (×2000).
Fig. 3. *Coccolithus pelagicus* (Wallich), distal view, *S. heteromorphus* Zone. Sample no. 246 (×4000).
Fig. 4. *Coccolithus pelagicus* (Wallich), proximal view, *S. heteromorphus* Zone. Sample no. 256 (×4500).
Fig. 5. *Coccolithus pelagicus* (Wallich), proximal view, *H. carteri* Zone. Sample no. 492 (×4500).
Fig. 6. *Umbilicosphaera jafari* Müller, distal view, *S. heteromorphus* Zone. Sample no. 250 (×7000).
Fig. 7. *Umbilicosphaera jafari* Müller, distal view, *S. heteromorphus* Zone. Sample no. 250 (×7000).
Fig. 8. *Umbilicosphaera jafari* Müller, distal view, *C. floridanus* Zone. Sample no. 477 (×7000).
Fig. 9. *Umbilicosphaera jafari* Müller, distal view, *C. floridanus* Zone. Sample no. 477 (×5000).
Fig. 10. *Umbilicosphaera jafari* Müller, *U. petaliformis* Varol and *Cyclicargolithus floridanus* (Roth & Hay), *C. floridanus* Zone. Sample no. 477 (×4500).
Fig. 11. *Umbilicosphaera petaliformis* Varol, plan view, *C. floridanus* Zone. Sample no. 477 (×7000).
Fig. 12. *Gen. et sp. indet.*, proximal view, *C. floridanus* Zone. Sample no. 477 (×10000).
Fig. 13. *Cyclicargolithus floridanus* (Roth & Hay), proximal view, *H. ampliaperta* Zone. Sample no. 482 (×4500).
Fig. 14. *Cyclicoccolithus leptoporus* (Murray & Blackmann), distal view, *C. floridanus* Zone. Sample no. 477 (×5000).
Fig. 15. *Cyclicoccolithus leptoporus* (Murray & Blackmann), proximal view, *C. floridanus* Zone. Sample no. 477 (×4500).
Fig. 16. *Cyclicargolithus floridanus* (Roth & Hay), proximal view, *C. floridanus* Zone. Sample no. 471 (×4000).
Fig. 17. *Cyclicargolithus floridanus* (Roth & Hay), proximal view, *C. floridanus* Zone. Sample no. 477 (×4000).
Fig. 18. *Cyclicargolithus abisectus* (Müller), distal view, *H. ampliaperta* Zone. Sample no. 482 (×3000).
Fig. 19. *Reticulofenestra pseudoumbilica* (Gartner), proximal view, *C. floridanus* Zone. Sample no. 477 (×5000).
Fig. 20. *Reticulofenestra pseudoumbilica* (Gartner), distal view, *C. floridanus* Zone. Sample no. 477 (×5500).
Fig. 21. *Reticulofenestra pseudoumbilica* (Gartner), distal view, *S. heteromorphus* Zone. Sample no. 262 (×5500).
Fig. 22. *Homozygosphaera tholifera* (Kamptner), side view, *S. heteromorphus* Zone. Sample no. 244 (×7000).
Fig. 23. *Syracosphaera nodosa* Kamptner, proximal view, *C. floridanus* Zone. Sample no. 477 (×10500).
Fig. 24. *Syracosphaera meditterranea* Lohmann, distal view, *H. carteri* Zone. Sample no. 486 (×9500).
Fig. 25. *Pontosphaera japonica* (Takayama), proximal view, *S. heteromorphus* Zone. Sample no. 243 (×3500).
Fig. 26. *Pontosphaera segmenta* (Bukry & Percival), proximal view, *S. heteromorphus* Zone. Sample no 245 (×3500).
Fig. 27. *Pontosphaera segmenta* (Bukry & Percival), proximal view, *C. floridanus* Zone. Sample no. 471 (×4000).
Fig. 28. *Pontosphaera segmenta* (Bukry & Percival), proximal view, *H. ampliaperta* Zone. Sample no. 483 (×3500).
Fig. 29. *Pontosphaera distincta* (Bramlette & Sullivan), distal view, *S. heteromorphus* Zone. Sample no. 244 (×3500).
Fig. 30. *Pontosphaera multipora* (Kamptner), proximal view, *C. floridanus* Zone. Sample no. 477 (×3500).
Fig. 31. *Rhabdosphaera clavigera* Murray & Blackmann, side view, *S. heteromorphus* Zone. Sample no. 245 (×4000).
Fig. 32. *Rhabdosphaera clavigera* Murray & Blackmann, view of basal plate, *C. floridanus* Zone. Sample no. 477 (×6000).
Fig. 33. *Rhabdosphaera clavigera* Murray & Blackmann, side view, *H. ampliaperta* Zone. Sample no. 482 (×4000).
Fig. 34. *Micrascidites vulgaris* Deflandre & Deflandre-Rigaud, plan view, *H. carteri* Zone. Sample no 486 (×4000).
Fig. 35. *Lithostromation perdurum* Deflandre, plan view, *H. ampliaperta* Zone. Sample no 483 (×2000).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Explanation of Plate 2

Scanning electron micrographs (figs. 1-28) and light micrographs (figs. 29-35)

Fig. 1. *Helicosphaera ampliaperta* (Bramlette & Wilcoxon), proximal view, *H. ampliaperta* Zone. Sample no. 483 (×3500).
Fig. 2. *Helicosphaera ampliaperta* (Bramlette & Wilcoxon), proximal view, *H. ampliaperta* Zone. Sample no. 482 (×3500).
Fig. 3. *Helicosphaera ampliaperta* (Bramlette & Wilcoxon), proximal view, *H. ampliaperta* Zone. Sample no. 483 (×4000).
Fig. 4. *Helicosphaera ampliaperta* (Bramlette & Wilcoxon), proximal view, *H. carteri* Zone. Sample no. 486 (×4000).
Fig. 5. *Helicosphaera ampliaperta* (Bramlette & Wilcoxon), distal view, *H. ampliaperta* Zone. Sample no. 481 (×4000).
Fig. 6. *Helicosphaera carteri* (Wallich), proximal view, *H. carteri* Zone. Sample no. 487 (×5000).
Fig. 7. *Helicosphaera carteri* (Wallich), proximal view, *H. carteri* Zone. Sample no. 486 (×4000).
Fig. 8. *Helicosphaera carteri* (Wallich), proximal view, *S. heteromorhus* Zone. Sample no. 244 (×4500).
Fig. 9. *Helicosphaera carteri* (Wallich), distal view, *H. carteri* Zone. Sample no. 492 (×5000).
Fig. 10. *Helicosphaera carteri* (Wallich), distal view, *S. heteromorhus* Zone. Sample no. 244 (×4000).
Fig. 11. *Braarudosphaera bigelowi* (Gran & Braarud), internal mould of coccosphere, *S. heteromorphus* Zone. Sample no. 244 (×2000).
Fig. 12. *Braarudosphaera bigelowi* (Gran & Braarud), plan view, *H. carteri* Zone. Sample no. 487 (×2000).
Fig. 13. *Sphenolithus moriformis* (Brönnimann & Stradner), side view, *H. ampliaperta* Zone. Sample no. 482 (×5000).
Fig. 14. *Sphenolithus moriformis* (Brönnimann & Stradner), oblique view, *H. ampliaperta* Zone. Sample no. 482 (×3000).
Fig. 15. *Sphenolithus moriformis* (Brönnimann & Stradner), side view, *H. ampliaperta* Zone. Sample no. 482 (×3500).
Fig. 16. *Sphenolithus heteromorphus* Deflandre, side view, *H. ampliaperta* Zone. Sample no. 482 (×3000).
Fig. 17. *Sphenolithus heteromorphus* Deflandre, oblique view, *H. ampliaperta* Zone. Sample no. 482 (×4000).
Fig. 18. *Sphenolithus heteromorphus* Deflandre, side view, *H. ampliaperta* Zone. Sample no. 482 (×3000).
Fig. 19. *Sphenolithus heteromorphus* Deflandre, side view, *H. ampliaperta* Zone. Sample no. 483 (×3000).
Fig. 20. *Sphenolithus heteromorphus* Deflandre, oblique view, *S. heteromorphus* Zone. Sample no. 243 (×3500).
Fig. 21. *?Fasciculithus* sp. possibly reworked, oblique view, *S. heteromorphus* Zone. Sample no. 243 (×3500).
Fig. 22. *?Fasciculithus* sp. possibly reworked, side view, *S. heteromorphus* Zone. Sample no. 250 (×3500).
Fig. 23. *Discoaster adamanteus* Bramlette & Wilcoxon, proximal view, *H. ampliaperta* Zone. Sample no. 484 (×5000).
Fig. 24. *Discoaster adamanteus* Bramlette & Wilcoxon, proximal view, *S. heteromorphus* Zone. Sample no. 250 (×5000).
Fig. 25. *Discoaster adamanteus* Bramlette & Wilcoxon, proximal view, *H. carteri* Zone. Sample no. 486 (×5000).
Fig. 26. *Discoaster brouweri* Tan, proximal view, *S. heteromorphus* Zone. Sample no. 244 (×3500).
Fig. 27. *Discoaster adamanteus* Bramlette & Wilcoxon, proximal view, *H. carteri* Zone. Sample no. 492 (×5000).
Fig. 28. *Discoaster druggi* Bramlette & Wilcoxon, proximal view, *H. carteri* Zone. Sample no. 492 (×3000).
Fig. 29. *Discoaster druggi* Bramlette & Wilcoxon, phase contrast, *H. carteri* Zone. Sample no. 492 (×1200).
Fig. 30. *Discoaster deflandrei* Bramlette & Riedel, phase contrast, *H. ampliaperta* Zone. Sample no. 483 (×1200).
Fig. 31. *Helicosphaera ampliaperta* Bramlette & Wilcoxon, phase contrast, *H. ampliaperta* Zone. Sample no. 483 (×1200).
Fig. 32. *Coronocyclus nitescens* (Kamptner), phase contrast, *H. carteri* Zone. Sample no. 494 (×1000).
Fig. 33. *Rhabdosphaera clavigera* Murray & Blackmann, phase contrast, *H. ampliaperta* Zone. Sample no. 237 (×2000).
Fig. 34. *Sphenolithus heteromorphus* Deflandre, phase contrast, *H. ampliaperta* Zone. Sample no. 483 (×1200).
Fig. 35. *Sphenolithus heteromorphus* Deflandre, cross-polarised, *H. ampliaperta* Zone. Sample no. 483 (×1200).