FACIES	33	107-120	Pl. 22-24	4 Figs.	--	ERLANGEN 1995

The Oligocene Argyrotopos Profile in the External Ionian Basin (Epirus, Greece): Microfacies and Microfossils

Spyridon M. **Bellas**, Patras, Dorothee **Mertmann**, Emmanuil **Manutsoglu**, Jan **Bartholdy**, Berlin and Dimitris **Frydas**, Patras

KEYWORDS: CALCAREOUS NANNOPLANKTON – FORAMINIFERA – *LEPIDOCYCLINA* – EXTERNAL IONIAN BASIN – EPIRUS (GREECE) – OLIGOCENE - CENOZOIC

CONTENTS

SUMMARY

The Argyrotopos profile of the Oligocene Ayii Pantes Formation in the NW Greece was studied using litho- and biofacies-analysis. The exposed sequence is mainly composed of monotonous marls and sandy marls. A rich fossil content, e.g. calcareous nannoplankton, is recorded. Some sandstone beds and two graded limestone beds with abundant lepidocyclinids and globigerinids are intercalated. The nannofossil assemblages from the measured profile of the Ayii Pantes Formation are attributed to the *Sphenolithus distentus* Zone (NP 24) which is equivalent to the *Cyclicargolithus floridanus* Subzone (CP 19a) of the Chattian, Upper Oligocene. The deposition took place in an euphotic subtidal environment situated on the eastern margin of the Apulian Platform. The lepidocyclinids were derived from this platform and were transported basinwards. The formation of the marls is influenced by sediment flux from the west.

1 INTRODUCTION

Different hydrocarbon zones are distributed over wide areas on both margins of the Adriatic and Ionian Seas in the Periadriatic region (Zappaterra 1994). Major episodes of paleogeographically widespread source-bed deposition occurred in the Mesozoic and Cenozoic. Cenozoic marly to terrigenous source rocks accumulated preferentially in foreland basins, e.g. the Ionian Zone (External Hellenides). This basin is suitable for hydrocarbon exploration.

The Upper Eocene to Lower Miocene sedimentation area of western Epirus is situated in the External Hellenides. In the concept of Aubouin (1959) the area belongs to the Ionian Zone which is subdivided into an internal, middle and external part (Fig. 1). Further subdivision of the external Ionian Zone in two parts, an eastern and a western one, was introduced by the Institut de Géologie et Recherches du Sous-Sol - Athènes & Institut Francais du Pétrole - Mission Grèce, I.G.S.R./I.F.P. (1966), which presented detailed information on its stratigraphical development. After the accumulation of predominantly calcareous sediments during the Late Mesozoic and the Paleocene-Eocene, uplift and subsequent erosion of the cordillera situated to the east of the Ionian Zone caused clastic deposition in the active Pindus Foreland Basin associated with Meso- and Neohellenic tectonic cycles (Fleury 1980, Jacobshagen 1986). The proximal clastics of the internal areas are thicker and coarser than the distal ones of the middle or even external parts. Accordingly, flysch sedimentation, mainly clays and sandstones with conglomeratic beds (Bizon 1967), started earlier in the east than in the west. The western border of the Ionian trough is the slope of the Apulian Platform, known as the Pre-Apulian Zone, and it was not covered by flysch sediments. The litoral carbonatic-pelitic sedimentation on this platform continued up to the Upper Miocene (I.G.S.R./I.F.P. 1966, British Petroleum Corporation, BP, 1971).

According to Richter (1974, 1976a, b, c) the internal, middle and external parts of the Ionian Basin are separated

Addresses: Dipl. Geol. S.M. Bellas, Department of Geology, Patras University, GR-26110 Patras, Greece and Freie Universität Berlin, Institut für Paläontologie, Malteserstr. 74-100, D-12249 Berlin, Dr. D. Mertmann, Dr. E. Manutsoglu, cand. geol. J. Bartholdy, Freie Universität Berlin, Institut für Geologie, Geophysik und Geoinformatik, Fachrichtung Allgemeine Geologie, Malteserstr. 74-100, D-12249 Berlin; .Prof. Dr. D. Frydas, Department of Geology, Patras University, GR-26110 Patras, Greece.

by intrabasinal highs, e.g. the Plokista-unit of Paramythia Anticline. This arrangement of the sea-floor was the main factor which controlled the flow direction and the extension of the clastic terrigenous turbidity currents. Recently, RICHTER et al. (1993) studied flysch sediments of the Pindos Zone. They assigned Oligocene nannofossil associations to a NP24/NP25 combined zone which was identified from marly and conglomeratic successions of the western flysch facies of the latter zone.

BIZON (1967) analysed the planktonic foraminifera of different sections within the Ionian Zone and established a biozonal scheme. Following the I.G.S.R./I.F.P. (1966), she subdivided the Upper Eocene to Lower Miocene rock sequence into five groups: 1. Burdigalian, 2. Upper Flysch, 3. Ayii Pantes Formation, 4. Radhovizi Formation, and 5. Flysch Facies. The latter facies corresponds to the Flysch de base (I.G.S.R./I.F.P. 1966), while the Ayii Pantes Formation interfingers laterally with it. The Upper Flysch overlies the Flysch Facies or the Ayii Pantes Formation depending on the paleogeographical position of the former within the Ionian Basin. The Radhovizi Formation is equivalent to a part of the Upper Flysch.

Of special interest is the Ayii Pantes Formation, which is well-developed in the Ayii Pantes-Paramythia Syncline (Fig.1). In the eastern external Ionian Zone this formation separates a Lower (Flysch de base) from an Upper Flysch (Flysch supérieur) sequence, and consists of marls and limestones, the latter with benthic and planktonic fossil remains. It passes laterally eastwards into flysch sediments.

The type succession at the Ayii Pantes locality, near the boundary to Albania (Fig. 1), was described by I.G.S.R./ I.F.P. (1966) (from bottom to top):

1) The Lower Flysch overlies Eocene limestones. It is up to 80 m thick and is composed of intercalations of sandstones, siltstones and claystones. It is dated as Upper Eocene.

2) The formation of Ayii Pantes is characterized by limestones and marls with occasional intercalating sandstones. The limestones yield large foraminifera (lepidocyclinids), algae, bryozoans, echinoderms and other fossils. The formation is about 1300 m thick and of Oligocene age. Reworked foraminifera mostly of Eocene age have been found.

3) The Upper Flysch is about 800 m thick and was probably deposited during the Aquitanian. It starts with a limestone bank containing abundant miogypsinoids. Sandstones and marly claystones alternate. Planktonic foraminifera are rare and badly preserved.

This sequence reveals the difference between the Ayii Pantes Formation and the Lower and Upper Flysch. An analysis of the depositional environment of the various sediments of the Ayii Pantes Formation is still missing. Sedimentary influences derived from the west have to be considered. BIZON (1967) interpreted the marls of the Ayii Pantes Formation to be azoic.

The study area of Plataria is situated in the eastern external Ionian Zone. I.G.S.R./I.F.P. (1966) stated the possible absence of the Lower Flysch sequence in the Plataria Syncline. The 750(?) m thick marls with some minor carbonate beds were, however, assumed to be coeval to the typical Lower Flysch and/or the formation of Ayii Pantes by the previous authors. The area was mapped by PERRIER & KOUKOUZAS (1969); their composite section shows the Ayii Pantes Formation as directly overlying Upper Eocene limestones. The boundary with the Upper Flysch was drawn below a distinct limestone bed with abundant miogypsinoids. The top of the Upper Flysch is not exposed within the syncline.

The Argyrotopos profile is used as a reference one for the Ayii Pantes Formation in the Plataria area (Epirus, Greece, figs. 1, 2). The study of the exposed part of the latter formation gave us the opportunity to investigate the litho- and biofacies, and to determine the age of these deposits biostratigraphically using large foraminifera (especially lepidocyclinids) and calcareous nannofossils. The paleogeographical relationships within the External Hellenides, particularly the Pre-Apulian Zone and the Ionian Basin are discussed.

2 THE ARGYROTOPOS PROFILE

The measured profile is named "Argyrotopos" after the small village nearby. It is located about 14 km southeast of Igoumenitsa and about 2 km south of the Plataria village, Epirus area, Greece (Fig. 1, 2).

The NW/SE striking Plataria Syncline exhibits good outcrops of the clastic sediments of Tertiary age on its lower SW flank. A thickness of 120 m was measured for the profile (Fig. 2), 30 m of which are concealed by the road from Plataria to Argyrotopos village. Higher up in the profile, 12 m are lacking again. Eastwards of the national road Igoumenitsa-Plataria parts of the Upper Flysch sequence are exposed. The opposite side of the Plataria Syncline is tectonically disturbed by a number of subparallel faults.

Description of the profile from bottom to top (Fig. 2):

1. The basal part (1.50 m) is composed of mainly white, well cemented, median to fine-bedded limestones with intercalations of chert nodules parallel to the bedding planes. This part belongs to the Upper Eocene Ionian limestones (part 1 in Fig. 2).

2. They pass gradually into light green marls and greenish-gray marly limestones with intercalated 2 - 8 cm thick, medium-grained, moderately cemented sandstones. Pale orange, very fine-bedded limestones are overlying. We interpret this part of the profile (7.80 m) as a lithostratigraphic transition from the underlying limestones to the overlying strata (part 2 transitional beds in Fig. 2).

3. The major part of the section (68.70 m) consists of olive-brown sandy marls and pale olive marls (part 3 in Fig. 2). Detrital, clastic material, consisting mainly of quartz grains and micas, occurs at the bottom and at the top of the measured section, while in the middle part their amount is significantly low. Small, sand-sized plant debris is fre-

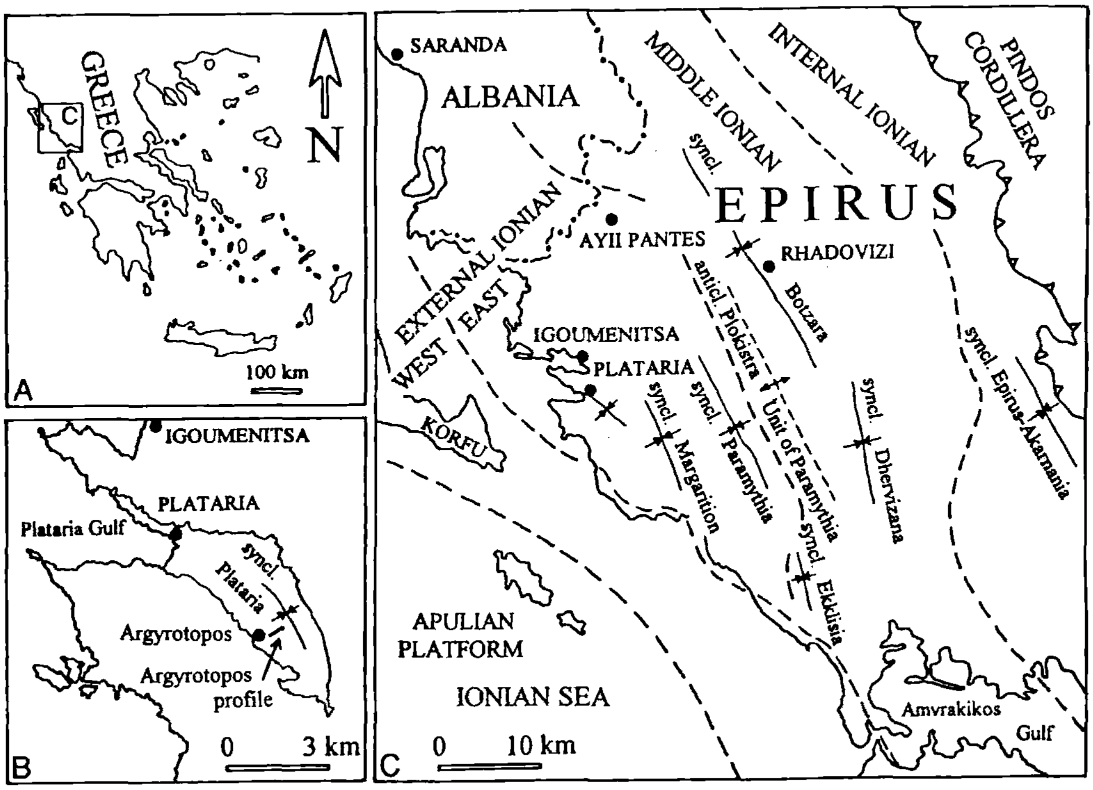


Fig. 1. General map of Greece (A), showing the location of the Epirus region (C). Within the northwestern part of the external Hellenides representative axes of synclines and an anticline are indicated. The sketch map of the Plataria Syncline (B) shows the Argyrotopos village southeast of Igoumenitsa town. The Argyrotopos profile is situated on the SW flank of the Plataria Syncline (indicated by an arrow).

quent. Burrows are mainly found in the lower part. Four sandstone beds are present (samples 24, 26, 28, 29). They are 10 - 15 cm thick, and graded, from coarse to fine sand. Their lower contact is always sharp. The upper contact to the marls is transitional.

Prominent features of the measured profile are two limestone beds, each about 10 cm thick, with a lower erosional contact and well preserved large benthic foraminifera (samples 38, 40). These grade upward into very fine grained limestones.

Due to the predominance of marls, the main part 3 of the profile is assigned to the Ayii Pantes Formation. Its topmost part is locally covered by alluvial fan deposits. The Ayii Pantes Formation differs from the Lower Flysch because only few clastic intercalations are present. Limestone beds in the exposed sequence are rare, in contrast to the type locality at Ayii Pantes near the Greek/Albanian border.

2.1 Assemblage of calcareous nannoplankton

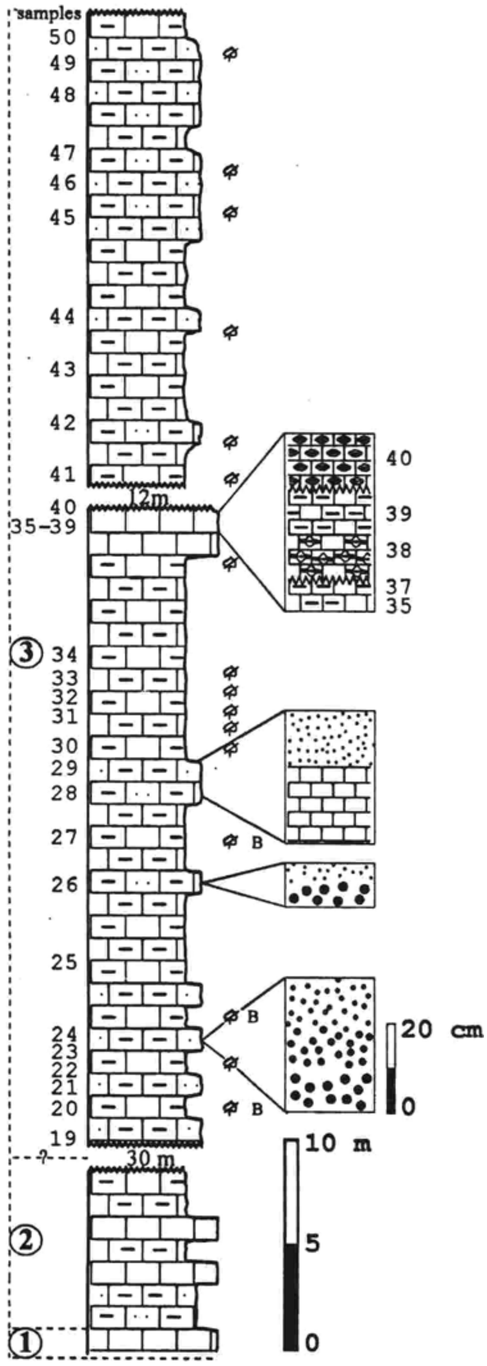
The samples of the Argyrotopos profile yield abundant fossil nannoplankton species. Samples 19 to 50 of the profile are investigated in detail to determine the biostratigraphical range of the sequence (Fig. 3). The nannoplankton species are identified mainly following the taxonomic and systematic remarks of Perch-Nielsen (1985).

Size (usually small), and state of preservation from medium to good of the nannoflora vary considerably along the profile. Diversity is rich. An ecological interpretation of the frequency of genera indicates a predominantly open marine environment (Group 2, Baldi Beke 1984). In a few samples, reworked Cretaceous and Eocene species occur sporadically, but usually they do not account for more than 5-10% of the whole nannofossil assemblage.

Various authors used different biozonations for the Oligocene. First Bramlette & Wilcoxon (1967) presented a concept for the upper part of the Oligocene using *Sphenolithus* species. A modification of Bramlette & Wilcoxon's (1967) scheme was introduced by Baumann & Roth (1969), which was followed by Roth's (1970) detailed Oligocene study from onshore samples and stratotype sections. Martini's (1971) Standard Nannoplankton Zonation (SNZ) for the Cenozoic, which is mainly based on land-sections associations, preserved the original zonal names of Bramlette & Wilcoxon (1967). The biostratigraphical concept of Bukry (1973, 1975) and Okada & Bukry (1980) is based on nannofossil determinations from low latitudes deep-sea cores; in some cases different marker species were used for subzones.

Most of the nannoplankton species recorded from the samples 19 to 50 of the Argyrotopos profile are long ranging species (Fig. 3). Only four species present are suitable for precise age determinations of deposition: *S. moriformis*, *S. distentus*, *C. floridanus* and *C. abisectus*.

Sphenolithus moriformis shows a great variation in size; some of them twice as big as smaller morphotypes (samples 34-50). Köthe (1986) recorded a culmination in



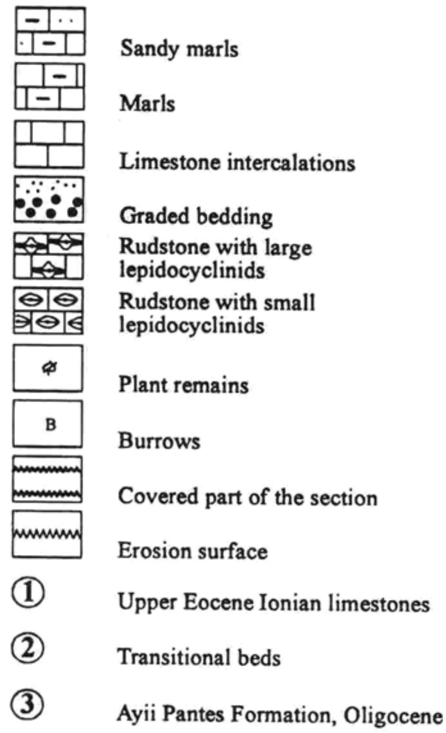


Fig. 2. The lithostratigraphical succession of the Argyrotopos profile. The main part of it (3) is attributed to the Ayii Pantes Formation, composed mainly of marls and sandy marls. The formation overlies transitional beds and Upper Eocene limestones of the Ionian Zone.

size variation of *S. moriformis* from the Eochattian/Neochattian boundary interval which is coeval to the NP24/NP25 boundary. This boundary is difficult to draw; therefore many authors use a combined NP24/NP25 "zone" (i.e. KISSEL et al. 1985). The differentiation between *C. abisectus* and *C. floridanus* based upon original definitions is almost impossible. Thus the recent studies of FIRTH (1992), FIRTH & ISIMINGER-KELSO (1992) and OLAFSSON (1992) were also used for comparisons. Only a few *C. abisectus* individuals are recorded, while *C. floridanus* is common to abundant. *S. distentus* is few to common, possibly due to the mid-paleolatitude position (about 40° N) of the studied sequence. This species generally prefers warm waters, and they are very rare or absent in the high latitudes (MARTINI 1971, BIZON & MÜLLER 1979, MARTINI & MÜLLER 1986, KÖTHE 1986, WEI & WISE 1989). One individual of *T. milowii* is present in sample 50. Although the *T.* species generally mark the Paleogene/Neogene boundary, first sporadic occurrencies of them are reported from NP 24 (HAQ 1981).

The co-occurrence of the marker species *S. distentus*, *C. abisectus* and *C. floridanus* as well as observations concerning individual frequency, variety and transitional forms, allow us to place the studied assemblage in MARTINI'S (1971) *Sphenolithus distentus* Zone (NP24), which is partly equivalent to the synonymous CP19 Zone of OKADA & BUKRY (1980) and especially to the *Cyclicargolithus floridanus* Subzone (CP19a) of the latter authors. Therefore a late Oligocene age is proposed for the sediments of the investigated section (Fig. 3).

2.2 Assemblage of foraminifera

Sample 38 yielded small benthic foraminifera (e.g. *Nodosaria* sp., *Bulimina* sp., *Lagena* sp.), and globigerinids (*Globigerina ciperoensis* BOLLI 1954, *Globigerina* cf. *yeguaensis* WEINZIERL & APPLIN 1929, and *Globigerina* sp.). Larger benthic foraminifera are more abundant. The preservation of twelve individuals of *Operculinoides* sp. is too bad for further determination. Only very rare specimens of *Nummulites* cf. *N. vascus* JOLY & LEYMERIE 1848 occur. The good preservation of various lepidocyclinids is remarkable. The genus *Lepidocyclina* has been subject of

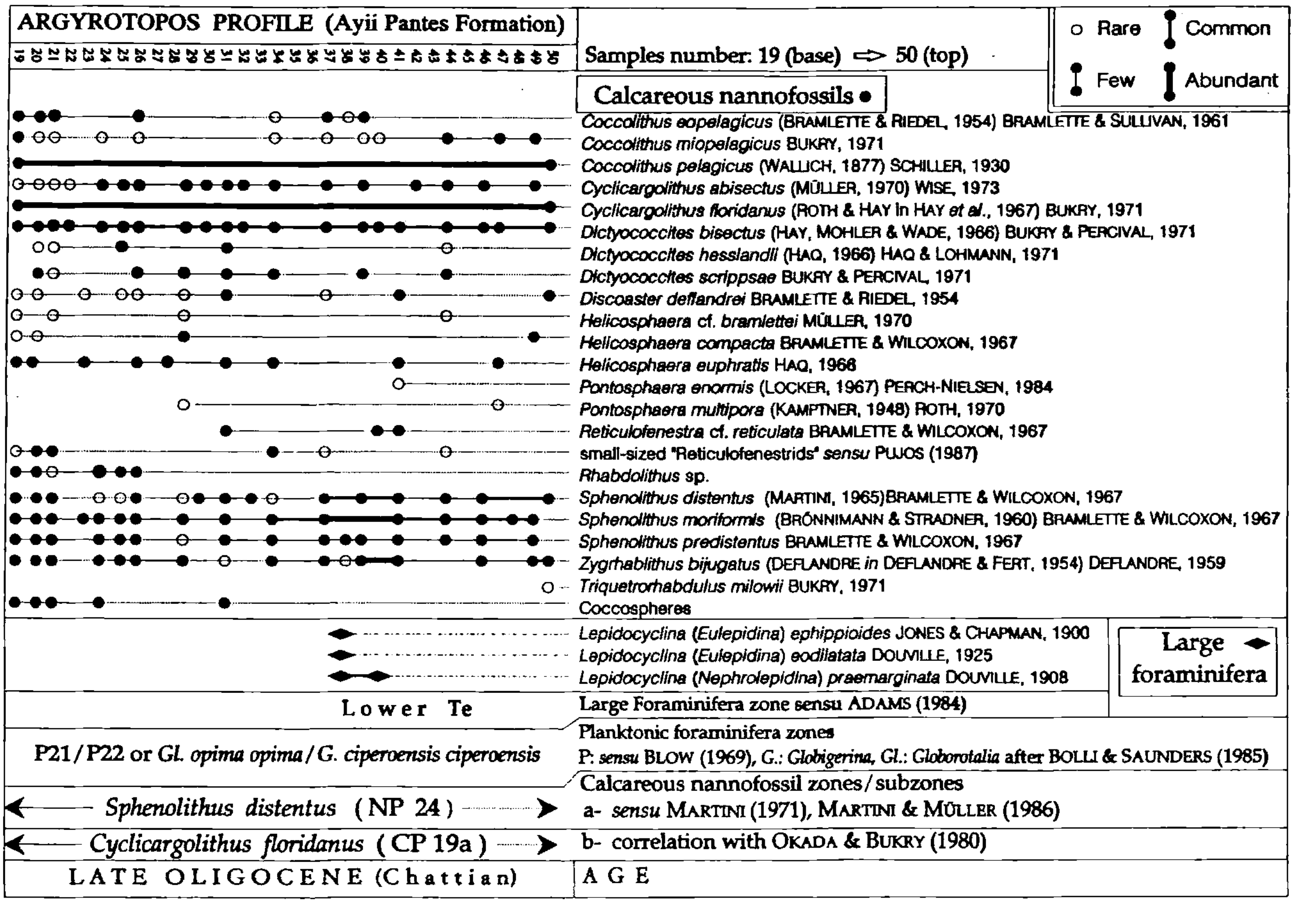


Fig. 3. Distribution of the calcareous nannofossils and large foraminifera (samples 19 to 50) along the Argyrotopos profile and their stratigraphical interpretation.

numerous taxonomic and stratigraphical studies (LANGE 1968, DE MULDER 1975, ADAMS 1987, DROOGER & ROHLING 1988, BUTTERLIN 1987, 1990, 1991). 480 specimens of this genus were analysed. 130 of them belong to three different species and are identified as follows:

Lepidocyclina (Eulepidina) ephippioides JONES & CHAPMAN 1900 (91 specimens),
Lepidocyclina (Eulepidina) eodilatata DOUVILLÉ 1925 (26 specimens), and
Lepidocyclina (Nephrolepidina) praemarginata DOUVILLÉ 1908 (13 specimens).

Sample 40 differs by abundant globigerinids, a few nodosariids and only small individuals of *Lepidocyclina (Nephrolepidina) praemarginata* DOUVILLÉ 1908.

Morphological remarks on the Lepidocyclinidae species

Lepidocyclina (Eulepidina) ephippioides JONES & CHAPMAN 1900 (Pl. 22/1-3)

The macrospheric generation is 1.5 to 2.1 mm thick, its diameter varies between 1.9 to 6.5 mm. The microspheric generation is 1.6 to 2.3 mm thick, its diameter is 5.3 to 8.4 mm. The shape of the test is extremely variable. The test shows a thick central portion thus demarcated from the thin peripheral flange. Papillae are missing. An external pattern or ornament is formed by reticulate ridges which represent the more or less thickened walls of the lateral chambers. They are always coarser and more apparent near the centre of the test. The embryonic apparatus measures 0.9 to 1.1 mm. The protoconch seems almost entirely to surround the smaller deuteroconch which is found in a trybliolepidine to eulepidine form (factor A between 50 to 65%, LANGE 1968).

Lepidocyclina (Eulepidina) eodilatata DOUVILLÉ 1925 (Pl. 22/4-6)

The macrospheric generation is 1.2 to 1.5 mm thick with a diameter 5.2 to 6.8 mm. The microspheric generation is 1.2 to 1.9 mm thick, diameter from 5.2 to 10.7 mm. A flange is missing, the test is without a remarkable central high, the flanks dip constantly towards the periphery. Few small papillae are present on the upper surface, while the lateral chamber walls are rarely stiffed. Pilae are missing. The surrounding of the deuteroconch within the protoconch resembles a trybliolepidine to eulepidine character. Therefore the factor A is more or less equivalent to the one of *Lepidocyclina (Eulepidina) ephippioides* JONES & CHAPMAN

Lepidocyclina (Nephrolepidina) praemarginata DOUVILLÉ 1908 (Pl. 22/7-9)

The macrospheric generation is 0.9 to 1.0 mm thick, the diameter is 2 mm. The microspheric generation is 1.2 to 1.4

mm thick with a diameter between 2.1 to 3.4 mm. The shape of the test shows no distinct flange. The dip in front of the central portion of the test is steeper in the macrospheric generation than in the microspheric. Pillars or papillae are missing. The embryonic chambers are bilocular, a smaller being partly embraced by a larger one. The apparatus measures 0.3 to 0.4 mm. The protoconch and the deuteroconch are more or less equally sized.

There are different views regarding the paleoecology of *Lepidocyclina*. CHAPRONIERE (1975) found associations of *Lepidocyclina* in Australia in water depths down to about 20 m. HAYNES (1981) collected *Lepidocyclina* (*Eulepidina*) *ephippioides* on a soft sea-bottom associated with seagrass in a sheltered marine environment shallower than 12 m, and *Lepidocyclina* (*Nephrolepidina*) sp. in a more open marine setting. BOSSELINI & RUSSO (1992) recorded *Lepidocyclina* (*Nephrolepidina*) *praemarginata* and *Lepidocyclina* (*Eulepidina*) within bioclastic grainstones of a reef flat setting (Castro Limestone of Chattian age, Apulia, Southern Italy). JONES & HUNTER (1994) examined an isolated carbonate bank of the Cayman Brac, West Indies which was deposited in Oligocene to Pliocene times. The occurrences of lepicyclinids are limited to the presence of *Thalassia* in a water depth not deeper than 10 m. On the other hand, different *Lepidocyclina* species were reported to occur in a fore reef environment (FROST et al. 1983, BOSSELINI et al. 1987, BOSSELINI & RUSSO 1992), and in an outer ramp setting (BUXTON & PEDLEY 1989). BETZLER & CHAPRONIERE (1993) and CHAPRONIERE & BETZLER (1992) gave a compilation of the data. The distribution ranges from lagoonal to fore reef environments, down to approximately 120 m, although a distribution minimum is recognized within patch reefs.

Coexistence of *Lepidocyclina* (*N.*) *praemarginata* (synonymous with *N. praetournoueri* (DROOGER & ROHLING 1988)) together with *Eulepidina formosoides* (considered synonymous with *E. ephippioides* (LANGE 1968)) shows that this association has been deposited during the middle to lower upper part of the Oligocene (DROOGER & ROHLING 1988). Both associations of the Argyrotopos profile can be assigned to the P21/P22 of the planktonic foraminifera zonation sensu BLOW (1969), which are equivalent to the *Globorotalia opima opima* Zone and *Globigerina ciperoensis ciperoensis* Zone (BOLLI & SAUNDERS 1985). This result is in accordance to GIBSON & MARGERUM (1991), who placed a similar assemblage from the western Pacific Ocean into the lower Te large foraminifera zone (sensu ADAMS 1984).

2.3 Microfacies types

The limestone intercalations reveal two facies types:

MF-I: Bioturbated mudstones show less than 5 % allochems (Pl. 23/1). Benthic fossils are lacking, only small fragile shells of planktonic foraminifera occur. These mudstones form distinct layers, from millimeter to a few centimetres thick, within the sequence with a higher argillaceous content, in between the foraminiferal rudstones (Pl. 23/4), and in patches or lenses within the foraminiferal rudstones. Some wavy bedding occurs.

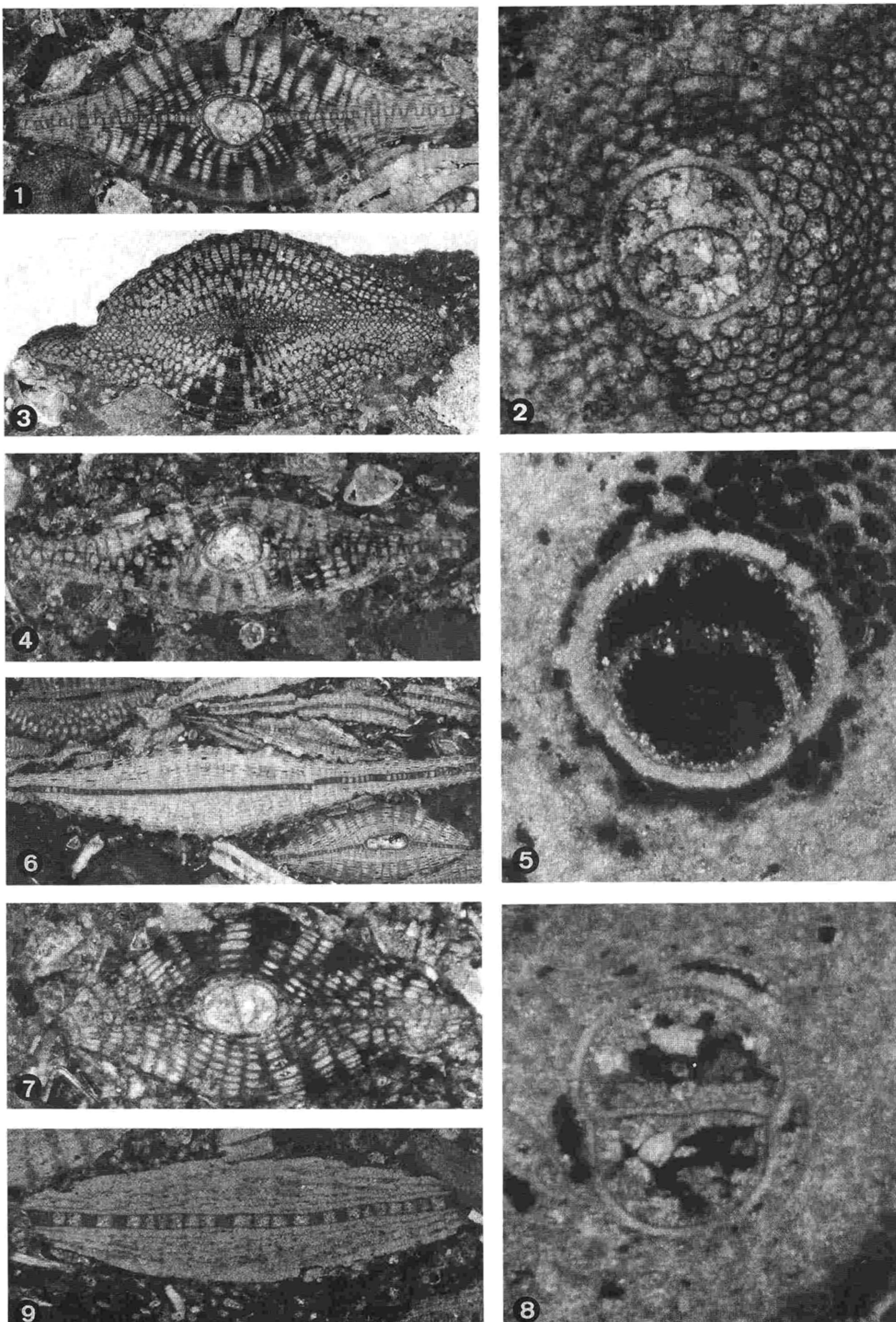
MF-II: Foraminiferal rudstones contain abundant benthic and planktonic foraminifera (Pl. 23/2), and melobesiid algae (Pl. 23/5, Pl. 24/1). Minor constituents include echinoid fragments, bryozoans, molluscan fragments, ostracodes and rounded sponge clasts (Pl. 24/2). Non-skeletal grains consist of some micritic lithoclasts (Pl. 23/3). The matrix of these rocks ranges from micrite to microsparite. The grain size of the allochems varies between pebble and sand/silt sizes. They are closely packed in the basal part (Pl. 23/1) and more loosely packed in the upper part. The amount of matrix between the components increases in the upper part of the limestone beds. The boundary to the underlying sediments is sharp and erosive. The large foraminifera belong to lepidocyclinids. They are well preserved, however the very end of the flanges of the individuals is sometimes eroded. *Lithophyllum* sp. and *Lithothamnium* sp. occur as fragments of branches and crusts. Fragile *Lithophyllum* sp. branches are settled on large foraminifera (Pl. 23/6). The planktonic foraminifera make up between

Plate 22 — Lepidocyclinidae of the Argyrotopos profile, Ayii Pantes Formation, Oligocene (Chattian) of Western Greece.

Fig. 1.-3. *Lepidocyclina* (*Eulepidina*) *ephippioides* JONES & CHAPMAN 1900
Fig. 1. Vertical section of a macrospheric generation. Sample 38. x 14.8
Fig. 2. Equatorial section of an embryonic apparatus. Sample 38. x 83.3
Fig. 3. Vertical section of a microspheric generation. x 12.7

Fig. 4.-6. *Lepidocyclina* (*Eulepidina*) *eodilatata* DOUVILLÉ 1925
Fig. 4. Vertical section of a macrospheric generation. Sample 38. x 15.4
Fig. 5. Equatorial section of an embryonic apparatus. Sample 38. x 54.1
Fig. 6. Vertical section of a microspheric generation. Sample 38. x 10.4

Fig. 7.- 9. *Lepidocyclina* (*Nephrolepidina*) *praemarginata* DOUVILLÉ 1908
Fig. 7. Vertical section of a macrospheric generation. Sample 40. x 34.2
Fig. 8. Equatorial section of an embryonic apparatus. Sample 40. x 116.7
Fig. 9. Vertical section of a microspheric generation. Sample 40. x 36.7


1
3
2
4
6
5
7
9
8

2% and 10% of the allochems present. Remarkably, their distribution is analogous to that of the matrix.

In general the constituents of the foraminiferal rudstone facies represent a subtidal environment. The good preservation of globigerinid tests points against significant transport or agitation in shallow water. Their presence argues for an open marine sea with no restrictions. They thrive in the ocean surface layers and can be incorporated into shelf and slope sediments. On the other hand the large foraminifera are worn. They exhibit signs of transport. This is consistent with the observation of lithoclasts, the grading of the calcareous sediment, and the erosive base of the beds. However, it is concluded that sedimentation took place within the euphotic zone and, especially, in areas of possible in situ growth of melobesiid algae associations.

3 ASSUMPTIONS AND DATA FOR THE INTERPRETATION

The Ayii Pantes Formation studied in the Argyrotopos profile yields abundant fossils, e.g. the calcareous nannoplankton of the marls, the lepidocyclinids and globigerinids of the limestones. The content of nannofossils together with the bioturbation contrast the concept of a generally azoic character of the marls demanded by BIZON (1967) for the Ayii Pantes Formation. The association and abundance of the calcareous nannoplankton indicate the NP24 *Sphenolithus distentus* Zone sensu MARTINI (1971), an equivalent to the deep sea sediments CP19a *Cyclicargolithus floridanus* Subzone after OKADA & BUKRY (1980). Therefore a late Oligocene age (Chattian) is documented for the studied Argyrotopos profile exposing the Ayii Pantes Formation (Fig. 3). The assemblage of foraminifera is attributed to the P21/22 Zone (BLOW 1969). Following the correlation chart of BERGGREN et al. (1985), these biozones are equivalent. Within these zones, reworking and redeposition of the large foraminifera took place.

The migration of *L.* (*N.*) *praemarginata* from NW-Africa to the Mediterranean area started in the P21 Zone (DROOGER & ROHLING 1988, BUTTERLIN 1991). The occurrence of lepidocyclinids in the western external Ionian Basin of Greece and Albania is probably among the closest to its northeastern limit in the Mediterranean.

The Upper Oligocene depositional environment of nowadays Plataria Syncline was a subtidal euphotic realm. The foraminiferal rudstones (MF II) indicate redeposition. Lepidocyclinids and other benthic organisms were recorded in greater frequencies from the western external Ionian Basin (Ithaki-Island, LANGE 1968), and from the type area of the Ayii Pantes Formation to the northeast. The general pattern of sedimentation, modelled in figure 4, is limited to the west by the slope of the Apulian Carbonate Platform. The middle and internal parts of the Ionian Basin are dominated by coarse clastic flysch sediments. The area of Plataria, at the western margin of the eastern External Ionian Basin, is situated between the carbonate and the clastic realms, and shows a marly sedimentation which was influenced from both sides by allochthonous sediments. The interpretation of the relationship between the type locality and the Plataria area is assessed using the interpretations of KISSEL et al. (1985). Based on paleomagnetic data they pointed out that two clockwise rotational events, the first during the Lower Miocene, and the second during the Pliocene/Pleistocene, with a total shift of 50°, affected the area. A study by SPERANZA et al. (1992) on the rotation of the Ionian Zone of Albania gave similar results. A prolongation of the sedimentation area of the Ayii Pantes region southwest into the Plataria area may be postulated, and is supported by the number of limestone intercalations, their thickness, and fossil content. Considering the bio- and lithofacies, parts of the profile Saranda studied by KICO (1985) are probably comparable to the Argyrotopos profile, which suggest deposition in the same paleo-basin. Subsequently the Ayii Pantes Formation may extend also northwards into the southwest Albania.

As some of the sandstone intercalations found in the Argyrotopos profile are graded and show erosional bases, a turbiditic sedimentation is suggested. According to RICHTER (1981) and CLEWS (1989), scattered turbidites may indicate a particular paleotopography of the sea-bottom,

Plate 23 — Lithofacies of the carbonate layers of the Argyrotopos profil, Ayii Pantes Formation, Oligocene (Chattian) of Western Greece.

Fig. 1. Globigerinid wackestone (MF 1), coiled shells cut in numerous different planes show globular chambers. Smaller fragments are embedded in the matrix. Sample 40. x 80

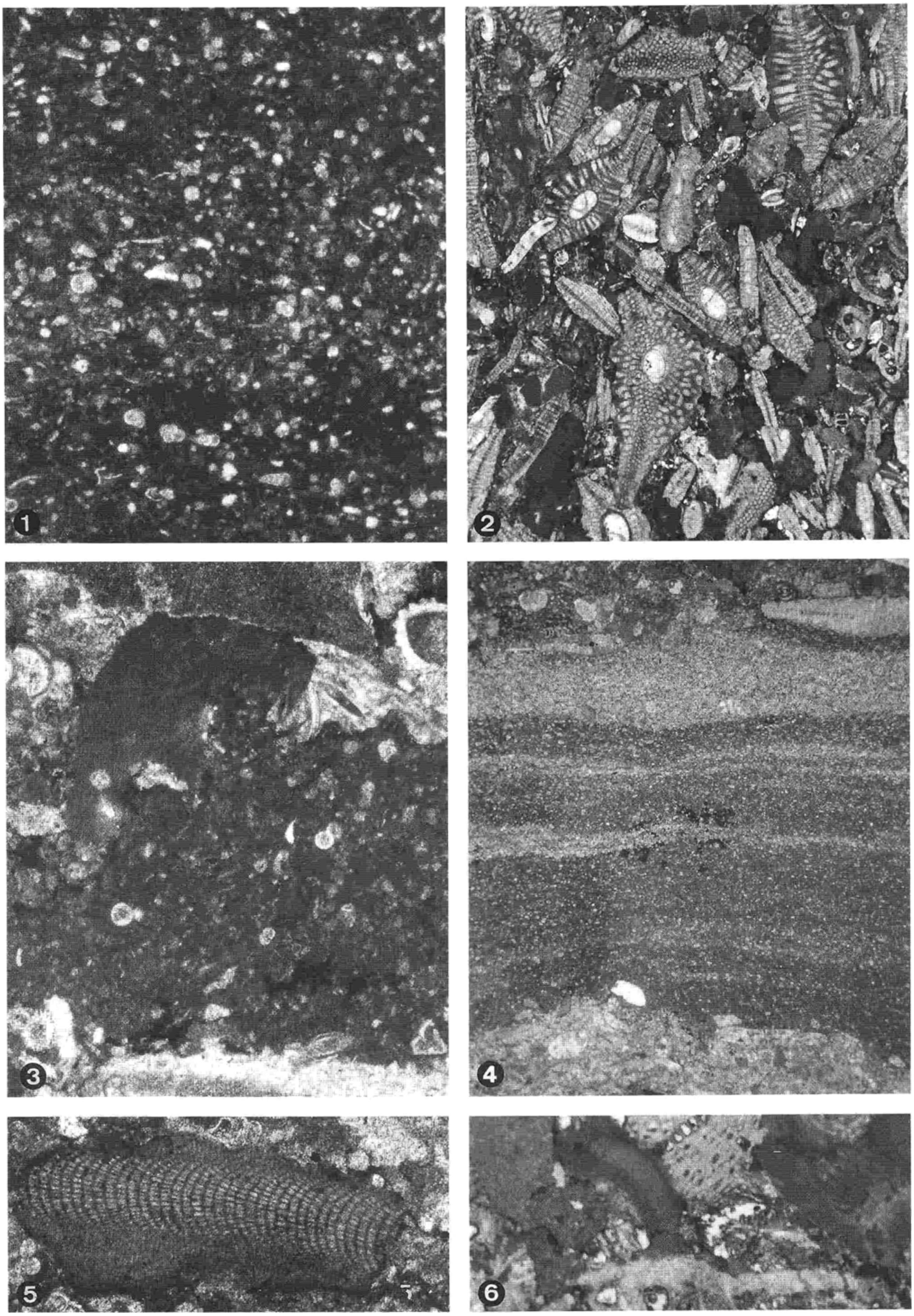
Fig. 2. Foraminiferal rudstone (MF 2), closely packed lepidocyclinids and melobesiid algae are the main constituents. Sample 38. x 8

Fig. 3. Globigerinid wackestone (MF 1) incorporated within the primary foraminiferal rudstone (MF 2). Sample 38. x 30

Fig. 4. Layer of finely laminated mudstone with smaller fragments of globigerinids embedded in the matrix intercalated within foraminiferal rudstone (MF 2). x 8

Fig. 5. Well preserved fragment of a coralline algae with larger cells of the hypothallus and finer ones of the perithallus. It could be *Lithophyllum* sp. Sample 38. x 80

Fig. 6. In situ coralline algae settling upon a fragment of a lepidocyclinid foraminifera. Sample 38. x 25


1
2
3
4
5
6

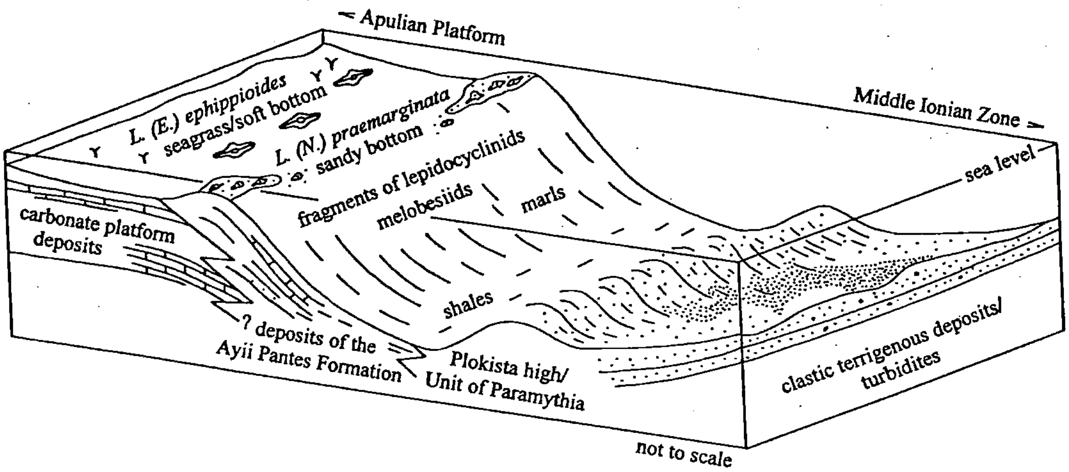


Fig. 4. Paleogeographic reconstruction for the depositional environment of the Ayii Pantes Formation stretching out between the Apulian Platform and part of the middle Ionian Basin.

which acted as a barrier to the influx of larger amounts of coarser clastic sediments from the east. Not only an influx of fine carbonate material from the west (MEULENKAMP & HILGEN 1986, ALEXANDER et al. 1990), but also a clastic input cannot be excluded.

4 CONCLUSIONS

The difference between the Ayii Pantes Formation and the Lower and Upper Flysch was already noted by I.G.S.R./ I.F.P. (1966) and BIZON (1967). Tectonic movements during the uppermost Eocene to lowermost Oligocene led to the Lower Flysch sedimentation in extended areas of the Ionian Basin. During the Oligocene (Chattian) a phase of relative tectonic quietness occurred in the external part of the Ionian Basin, and the marly sediments of the Ayii Pantes Formation were deposited. The following tectonic paroxysm of the Neohellenic Cycle (Miocene) led to the accumulation of the Upper Flysch which filled up the active Pindus Foreland Basin inclusively its external marginal parts.

The sequence of the Ayii Pantes Formation thus represents a transitional facies between the flysch formation in the middle, eastern Ionian Basin and the carbonates of the Pre-Apulian Zone to the west (Fig. 4). The model of WALKER et al. (1983), with respect to the terminology discussed by ZUFFA (1984) and WALKER et al. (1984), suggests a transitional shaly zone between carbonate and

Plate 24 — Lithofacies (figs. 1, 2) and calcareous nannoplankton species (figs. 3 - 22) of the Argyrotopos section, Ayii Pantes Formation, Oligocene (Chattian) of Western Greece.

Fig. 1. Encrusting coralline algae exhibiting conceptacles in the well developed perithallus. Sample 38. x 40

Fig. 2. Fragment of a recrystallized sponge infilled with mud. Sample 38. x 40

Figs. 3-7. *Sphenolithus predistentus* BRAMLETTE & WILCOXON, 1967. Fig. 3 parallel nicols, Fig. 4 crossed nicols. Both sample 47. Fig. 5, 7 crossed nicols, Fig. 6 parallel nicols. Sample 19. x 1270

Figs. 8., 9. *Cyclicargolithus abisectus* (MÜLLER 1970) WISE 1973. Fig. 8 parallel nicols, Fig. 9 crossed nicols. Both sample 19. x 1270

Fig. 10. *Cyclicargolithus floridanus* (ROTH & HAY in HAY *et al.*, 1967) BUKRY 1971. Crossed nicols. Sample 49. x 1270

Figs. 11., 12. *Zygrhablithus bijugatus* (DEFLANDRE in DEFLANDRE & FERT, 1954) DEFLANDRE 1959. Fig. 11 parallel nicols, Fig. 12 crossed nicols. Both sample 49. x 1270

Figs. 13., 14. *Dictyococcites bisectus* (HAY, MOHLER & WADE 1966) BUKRY & PERCIVAL 1971. Fig. 13 parallel nicols, Fig. 14 crossed nicols. x 1270

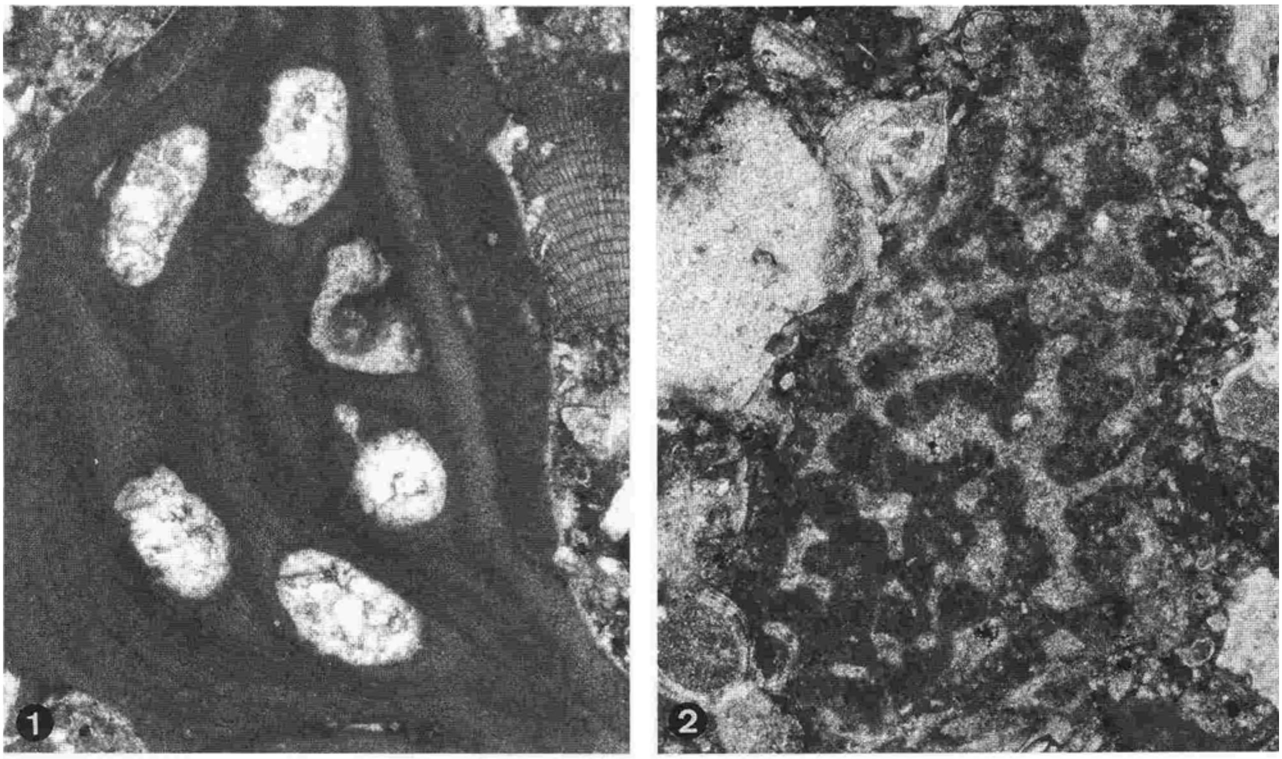
Fig. 15. *Pontosphaera multipora* (KAMPTNER 1948) ROTH 1970. Crossed nicols. Sample 47. x 1270

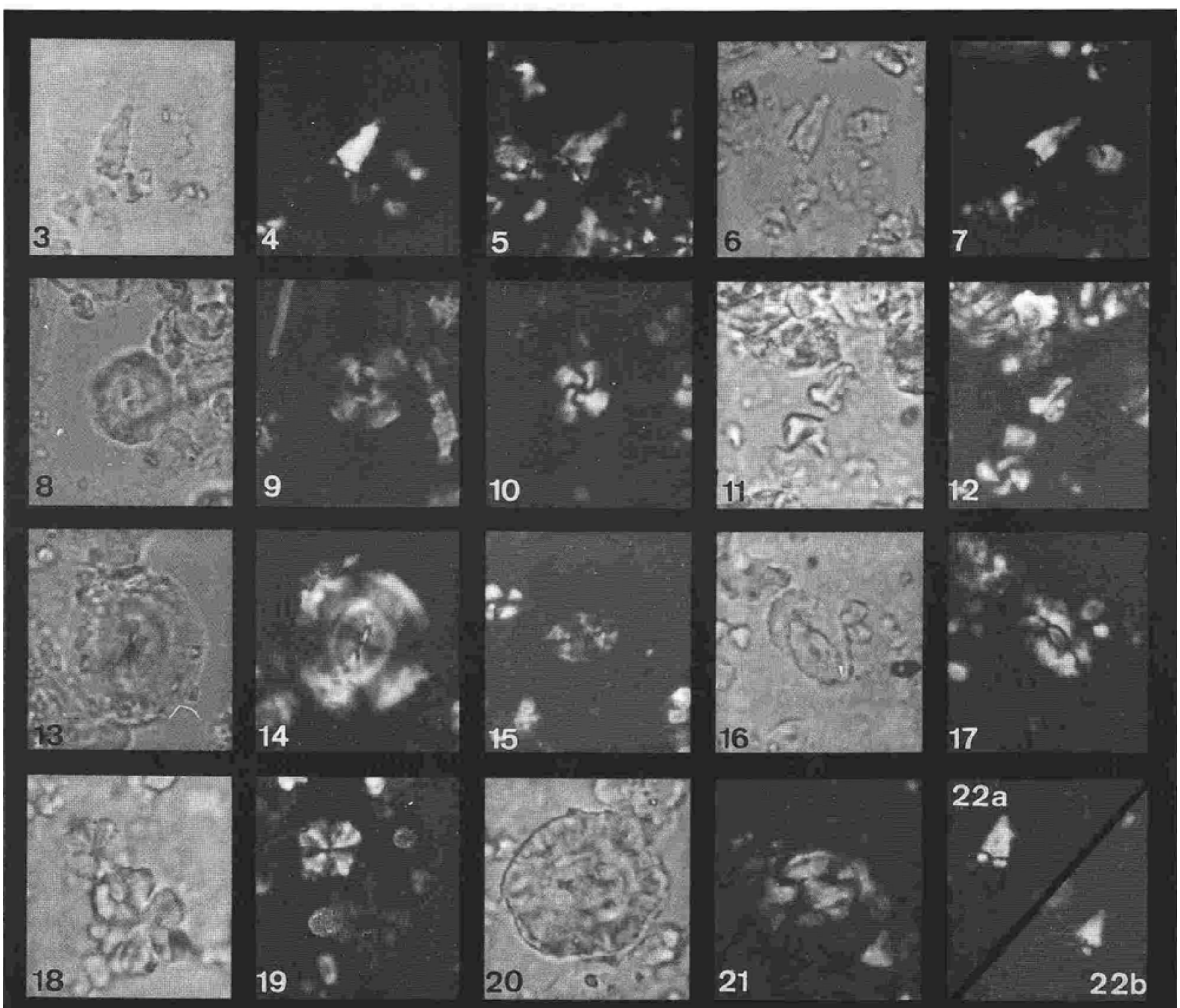
Figs. 16., 17. *Helicosphaera euphratis* HAQ 1966. Fig. 16 parallel nicols, Fig. 17 crossed nicols. Sample 49. x 1270

Figs. 18., 19. *Sphenolithus moriformis* (BRÖNNIMANN & STRADNER, 1960) BRAMLETTE & WILCOXON 1967. In parallel nicols (Fig. 18) an overgrown *Discoaster* sp. individual is also shown, Fig. 19 crossed nicols. Sample 19. x 1270

Figs. 20., 21. *Coccolithus miopelagicus* (WALLICH 1877) SCHILLER 1930. Fig. 20 parallel nicols, Fig. 21 crossed nicols. Sample 49. x 1270

Figs. 22a, b. *Sphenolithus distentus* (MARTINI 1965) BRAMLETTE & WILCOXON, 1967. Fig. 22a from sample 19, Fig. 22b from sample 47. Both crossed nicols. x 1270


1
2


3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22a
22b

clastic terrigenous depocenters, both with a high rate of subsidence and sediment accumulation. The depositional environment of the Ayii Pantes Formation indicates a position situated between the carbonate platform and deeper shaly sedimentation areas.

ACKNOWLEDGEMENTS

For the critical reading Profs. Drs. V. JACOBSHAGEN, H. KEUPP (Freie Universität Berlin) and an anonymous reviewer are gratefully acknowledged. The authors are indebted to Prof. Dr. E. MARTINI (Universität Frankfurt a.M.) for the access to his material, stimulating discussions on the subject of Oligocene nannoplankton biostratigraphy and the critical review of the manuscript. Dr. R.T. BECKER (Freie Universität Berlin) and Mrs. N. BELESSI tried to improve the English of the manuscript. S. BELLAS (Patras University) received partial financial support through the Postgraduate Erasmus Program during his stay in Berlin. G. SCHREIBER (FU-preparator) and B. ERNST (FU-photographer) are thanked for their technical assistance.

REFERENCES

ADAMS, C.G. (1984): Neogene larger foraminifera, evolutionary and geological events in the context of datum planes. – In: IKEBE, N. & TSUCHI, R. (eds.): Pacific Neogene datum planes. – 47-67, Tokio

ADAMS, C.G. (1987): On the classification of the Lepidocyclinidae (Foraminiferida) with redescriptions of the unrelated Paleogene genera *Actinosiphon* and *Orbitosiphon*. – Micropaleontology **33**, 289-317, 4 Pls., 7 Figs., 1 Table, New York

ALEXANDER, J., NICHOLS, G.J. & LEIGH, S. (1990): The origins of marine conglomerates in the Pindus foreland basin, Greece. – Sedimentary Geology **66**, 243-254, 11 Figs., Amsterdam

AUBOUIN, J. (1959): Contribution a l'étude géologique de la Grèce septentrionale: le confins de l'Epire et de la Thessalie. – Ann. Géol. Pays héllen. **10**, 1-484, 40 Pls., 127 Figs., 6 Figs. out of text, 7 Tables, 1 Geol. Map, Athen

BALDI-BEKE, M. (1984): The nannoplankton of the Transdanubian Palaeogene Formations. – Geologica Hungarica (Series Palaeontologica) **43**, 1-307, 42 Pls., 49 Figs., 17 Tables, Budapest

BAUMANN, P. von & ROTH, P.H. (1969): Zonierung des Obereozäns und Oligozäns des Monte Cagnero (Zentralapennin) mit planktonischen Foraminiferen und Nannoplankton. – Eclog. geol. Helv. **62**, 303-323, 2 Figs., Basel

BERGGREN, W.A., KENT, D.V., FLYNN, J.J. & VAN COUVERING, J.A. (1985): Cenozoic geochronology. – Bull. Geol. Soc. Am. **96**, 1407-1418, New York

BETZLER, C. & CHAPRONIERE, G.C.H. (1993): Paleogene and Neogene Larger Foraminifers from the Queensland Plateau: Biostratigraphy and Environmental significance. – In: MCKENZIE, J.A., DAVIES, P.J., PALMER-JULSON, A., et al.,- Proc. ODP, Sci. Results **133**: 51-66, 5 Pls., 4 Figs., 4 Tables, College Station, Texas

BIZON, G. (1967): Contribution a la connaissance des foraminifères planctoniques d'Epire et des eles ioniennes (Grèce occidentale) depuis le Paléogène supérieur jusque'au Pliocène. – Publ. Inst. Francais Pétrole, 142 p., 37 Pls., 22 Figs., Paris

BIZON, G. & MÜLLER, C. (1979): Remarks on the Oligocene/Miocene boundary based on results obtained from the Pacific and the Indian Oceans. – Ann. géol. Pays héllen., tome hors série, 1979/1, 101-111, 2 Figs., Athen

BLOW, W.H. (1969): Late Eocene to Recent planktonic foraminiferal biostratigraphy. In: BRONNIMANN, R. & RENZ, H.H. (eds.): Proc. First Int. Conf. Plankt. Microfossils **1**, 199-421, 54 Pls., 43 Figs., Rome

BOLLI, H.M. & SAUNDERS, J.B. (1985): Oligocene to Holocene low latitude planktic foraminifera. – In: BOLLI, H.M., SAUNDERS, J.B. & PERCH-NIELSEN, K. (eds.): Plankton Stratigraphy. – 155-262, 46 Figs., Cambridge

BOSSELINI, F.R. & RUSSO, A. (1992): Stratigraphy and facies of an Oligocene fringing reef (Castro Limestone, Salento Peninsula, Southern Italy). – Facies **26**, 145-166, 8 Pls., 6 Figs., Erlangen

BOSSELINI, F.R., RUSSO, A., ARUSH, M.A. & CABDULQUADIR, M.M. (1987): The Oligo-Miocene of Eil (NE Somalia): a prograding coral-*Lepidocyclina* system. – J. African Earth Sci., **6**, 583-593, Oxford

BRITISH PETROLEUM CORPORATION (1971): The geological results of petroleum exploration in western Greece. – Inst. Geol. Subsurf. Research **10**, 73 p., 6 Pls., 10 Figs., Athens

BRAMLETTE, M.N. & WILCOXON, J.A. (1967): Middle Tertiary calcareous nannoplankton of the Cipero section, Trinidad, W.I. – Tulane Stud.Geol. **5**, 93-131, 10 Pls., New Orleans

BUKRY, D. (1973): Low-Latitude Coccolith Biostratigraphic Zonation. – Initial Reports of the Deep Sea Drilling Project **15**, 685-703, 4 Pls., 5 Figs., 4 Tables, Washington

-- (1975): Coccolith and Silicoflagellate stratigraphy, Northwestern Pacific Ocean, Deep Sea Drilling Project, Leg. 32. – Initial Reports of the Deep Sea Drilling Project **32**, 677-701, 2 Figs., 1 Table, Washington

BUTTERLIN, J. (1987): Origin and evolution of the Lepidocyclines from the Caribbean region. Comparisons and relations with the Lepidocyclines from the other regions of the world. – Revue de Micropaléontologie **29**, 203-219, 2 Pls., 7 Figs., Paris

-- (1990): Problémes posées par la systématique de la famille Lepidocyclinidae (Foraminiferida). – Revista Espanola de Micropaleontologica **XXII**, 101-126, 5 Pls., 7 Figs., Madrid

-- (1991): Observations about the origin and evolution of the Lepidocyclinids from the Mediterranean basin. – Revue de Micropaléontologie **34**, 175-183, 6 Figs., Paris

BUXTON, M.W.N. & PEDLEY, H.M. (1989): Short paper: A standarized model for Tethyan carbonate ramps. – J. Geol. Soc. London **146**, 746-748, 3 Figs., Northern Ireland

CHAPRONIERE, G.C.H. (1975): Paleoecology of Oligo-Miocene larger foraminifera, Australia. – Alcheringa **1**, 37-58, 3 Figs., Sydney

CHAPRONIERE, G.C.H. & BETZLER, C. (1992): Larger foraminiferal biostratigraphy of sites 815, 816 and 826, LEG 133, Northeastern Australia. – In: MCKENZIE, J.A., DAVIES, P.J., PALMER-JULSON, A. et al. – Proc. ODP, Sci. Results **133**, 39-49, 1 Pls., 2 Figs., 5 Tables, College Station, Texas.

CLEWS, J.E. (1989): Structural controls on basin evolution: Neogene to Quaternary of the Ionian zone, Western Greece. – J. Geol. Soc. London **146**, 447-457, 9 Figs., Northern Ireland

DROOGER, C.W. & ROHLING, E.J. (1988): Lepidocyclina migration across the Atlantic. Proc. Kon. Ned. Ak. Wet. **B 91**, 39-52, 3 Figs., Utrecht

FIRTH, J.V. (1992): Analysis of the taxonomic, biostratigraphic and evolutionary relationships of species of the calcareous nannofossil genus *Cyclicargolithus* (BUKRY, 1971) from the Upper Eocene and Oligocene of the North Atlantic. In: DECIMA, F.P., MONECHI, S. & RIO, D. (eds.): Proc. of the International Nannoplankton Association Conference, Firenze 1989, Memorie di Scienze Geologiche **XLIII**, 237-259, 1 Pl., 11 Figs., 9 Tables, Padova

FIRTH, J.V. & ISIMINGER-KELSO, M. (1992): Pleistocene and Oligocene-Miocene calcareous nannofossils from the Simisu Rift and Izu-Bonin Forearc Basin. – Proc. ODP, Sci. Results **126**, 237-262, 4 Pls., 8 Figs., 11 Tables, College Station, Texas.

FLEURY, J.-J. (1980): Les zones de Gavrovo-Tripolitza et du

Pinde-Olonos (Grèce continentale et Péloponnèse du Nord). Evolution d'une plate-forme et d'un bassin dans leur cadre alpin. – Soc. Géol. Nord **4**, 1-648, 10 Pls., 29 Figs., Villeneuve d'Ascq

FROST, S.H., HARBOUR, J.L., BEACH, D.K., REALINI, M.J. & HARRIS, P.M. (1983): Oligocene reef tract development, southwestern Puerto Rico. – Sedimenta IX, 1-107, 42 Figs., Miami

GIBSON, T.G. & MARGERUM, R. (1991): Larger foraminifera biostratigraphy of PEACE boreholes, Enewetak Atoll, Republic of the Marshall Islands. – U.S. Geological Survey Professional Paper **1513-D**, 1-14, 8 Figs., Washington

HAQ, B.U. (1981): Search for marker events. – In: CATI, F. (ed.), STEININGER, F.F., BORSETTI, A.M. & GELATI, R. (co-eds.): In search of the Palaeogene/Neogene boundary stratotype. Part I: Potential boundary stratotype sections in Italy and Greece and a comparison with results from the deep-sea. International Union of Geological Sciences, Commission on Stratigraphy, **3**: 27-31, 1 Fig., Bologna

HAYNES, J.R. (1981): Foraminifera. – 433 p., 10 Pls., 95 Figs., Hong Kong (MacMillan)

INSTITUT DE GÉOLOGIE ET RECHERCHES DU SOUS-SOL - ATHÈNES & INSTITUT FRANCAIS DU PÉTROLE - MISSION GRÈCE (1966): Etude géologique de l'Epire (Grèce nord-occidentale). - 306 p., 101 Figs., Paris

JACOBSHAGEN, V. (1986): Geologie von Griechenland. – 363 p., 111 Figs., Berlin-Stuttgart

JONES, B. & HUNTER, G. (1994): Evolution of an Isolated Carbonate Bank during Oligocene, Miocene and Pliocene Times, Cayman Brac, British West Indies. – Facies **30**, 25-50, 4 Pls., 15 Figs., Erlangen

KICO, V. (1985): Les nannofossiles calcaires du flysch de la Zone Ionienne d'Albanie. – Thesis, Memoires des Sciences de la Terre-Paris VI, 178 p., 15 Pls., 21 Figs., Paris

KISSEL, C., LAJ, C. & MÜLLER, C. (1985): Tertiary geodynamical evolution of northwestern Greece: paleomagnetic results. – Earth Planet. Science Letters **72**, 190-204, 10 Figs., 2 Tables, Amsterdam

KÖTHE, A. (1986): Kalkiges Nannoplankton aus dem Paläogen Nordwestdeutschlands. Geol. Jb. **A89**, 3-114, 16 Pls., 12 Figs., 7 Tables, Hannover

LANGE, H. (1968): Die Evolution von *Nephrolepidina* und *Eulepidina* im Oligozän und Miozän der Insel Ithaka (Westgriechenland). - Thesis. Ludwig-Maximilians-Universität München, 78 p., 3 Pls., 18 Figs., 2 Tables, München

MARTINI, E. (1971): Standard Tertiary and Quaternary calcareous nannoplankton Zonation. – In: FARINACCI, A. (ed.): Proceedings of the Second International Conference on Planktonic Microfossils, Roma, **2**, 739-785, 4 Pls., 6 Tables, Rome

MARTINI, E. & MÜLLER, C. (1986): Current Tertiary and Quaternary calcareous nannoplankton stratigraphy and correlations. – Newsl. Stratigr. **16**, 99-112, 7 Tables, Stuttgart

MEULENKAMP, J.E. & HILGEN, F.J. (1986): Event stratigraphy, basin evolution and tectonics of the Hellenic and Calabro-Sicilian arcs. – In: WEZEL, F.-C. (ed.): The origin of arcs. – Developments in Geotectonics **21**, 327-350, 9 Figs., Amsterdam (Elsevier)

MULDER, E.F.J. de (1975): Microfauna and sedimentary-tectonic history of the Oligo-Miocene of the Ionian islands and western Epirus (Greece). – Utrecht Micropal. Bull. **13**, 1-139, 4 Pls., 46 Figs., Utrecht

OKADA, H. & BUKRY, D. (1980): Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (BUKRY, 1973; 1975). – Mar. Micropaleontol. **5**, 321-325, 2 Tables, Amsterdam

OLAFSSON, G. (1992): Oligocene/Miocene morphometric variability of the *Cyclicargolithus* Group from the Equatorial Atlantic and Indian Oceans. – In: DECIMA, F.P., MONECHI, S. & RIO, D. (eds.): Proc. of the Intern. Nannoplankton Ass. Conf., Firenze 1989. Mem. di Scienze Geol. **43**, 283-295, 8 Figs., 3 Tables, Padova

PERCH-NIELSEN, K. (1985): Cenozoic calcareous nannofossils. In: BOLLI, H.M., SAUNDERS, J.B. & PERCH-NIELSEN, K. (eds.): Plankton Stratigraphy, 427-553, 91 Figs., Cambridge

PERRIER, R. & KOUKOUZAS, C. (1969): Geological sheet Parga, 1:50.000. – Institute for Geology and Subsurface Research (I.G.S.R.), Athens

PUJOS, A. (1987): Late Eocene to Pleistocene medium-sized and small-sized "Reticulofenestrids". – In: STRADNER, H., PERCH-NIELSEN, K. (eds.): Proc. of the Intern. Nannoplankton Ass., Vienna Meeting 1985. – Abh. Geol. B.-A. **39**, 239-277, 3 Pls., 29 Figs., Wien

RICHTER, D. (1974): Die Flyschzonen Griechenlands II. Zur Stratigraphie der basalen Schichten (Übergangsserie) des ionischen Flysches im Epiros und südlich anschließenden Gebiet. – N. Jb. Geol. Paläont. Mh. **1974**, 149-174, 7 Figs., Stuttgart

-- (1976 a): Das Flysch-Stadium der Helleniden - ein Überblick. – Z. dt. geol. Ges. **127**, 467-483, 1 Pls., 2 Figs., Hannover

-- (1976 b, c): Die Flyschzonen Griechenlands III. Flysch sowie spät- und postorogene Serien in Westgriechenland zwischen Albanien und dem Golf von Patras. Teile 1 und 2. – N. Jb. Geol. Paläont. Abh. **151**, 73-100, 10 Figs., und 224-252, 8 Figs., Stuttgart

-- (1981): Die gefaltete marine Molasse im Gebiet von Peratia-Plagia (Akarnanien, Griechenland). Mit einem Ausblick auf die marine Molasse bei Agia Kyriaki (Epiros). – N. Jb. Geol. Paläont. Mh. **1981**, 84-90, 2 Figs., Stuttgart

RICHTER, D., MÜLLER, C. & MIHM, A. (1993): Die Flysch-Zonen Griechenlands V. Zur Stratigraphie des Flysches der Pindos-Zone im nördlichen Pindos-Gebirge zwischen der albanischen Grenze und der Querzone von Kastaniotikos (Griechenland). – N. Jb. Geol. Paläont. Mh. **1993**, 257-291, 8 Figs., 1 Table, Stuttgart

ROTH, P.H. (1970): Oligocene calcareous nannoplankton Biostratigraphy. – Eclog. geol. Helv. **63**, 799-881, 14 Pls., 17 Figs., Basel

SPERANZA, F., KISSEL, C., ISLAMI, I, HYSENI, A. & LAJ, C. (1992): First paleomagnetic evidence for rotation of the Ionian zone of Albania. – Geophys. Res. Letters **19**, 697-700, 4 Figs., 1 Table, Washington D.C.

WALKER, K.R., SHANMUGAM, G., RUPPEL, S.C. (1983): A model for carbonate to terrigenous clastic sequences. – Geol. Soc. Am. Bull. **94**, 700-712, 10 Figs., Tulsa

-- (1984): Reply. A model for carbonate to terrigenous clastic sequences. – Geol. Soc. Am. Bull. **95**, 753, Tulsa

WEI, W. & WISE Jr., S.W. (1989): Paleogene calcareous nannofossil magnetobiochronology: Results from South Atlantic DSDP Site 516. – Mar. Micropaleontol. **14**, 119-152, 4 Pls., 2 Tables, Amsterdam

ZAPPATERRA, E. (1994): Source-Rock Distribution Model of the Periadriatic Region. – Amer. Ass. Petrol. Geol. Bull. **78**, 333-354, 11 Figs., Tulsa

ZUFFA, G.G. (1984): Discussion. A model for carbonate to terrigenous clastic sequences. – Geol. Soc. Am. Bull. **95**, 753, Tulsa

Manuscript received January 19, 1995
Revised manuscript received April 1, 1995