

## The occurrence of *Bolboforma* in the Upper Miocene Metochia Section, Gavdos Island, south of Crete (Greece)

by A. ANTONARAKOU and H. DRINIA\*

with 5 figures, 1 table and 1 plate

**Abstract.** Biostratigraphy based on *Bolboforma* is applied for the first time in the Metochia Section, Gavdos Island, south of Crete (Greece). The sequence interval investigated spans, according to planktonic foraminiferal biostratigraphy, a time interval from 9.7 to 6.6 Ma (Late Miocene). Two *Bolboforma* species, one incertae sedis, and the *Bolboforma intermedia* Zone (7.7–5.6 Ma) have been identified. The *B. metzmacheri* Zone (9.7–7.7 Ma) has not been found in the studied section, may be due to palaeoecological reasons. *Bolboforma* specimens are shown to be useful both in stratigraphical and palaeoclimatological analysis.

**Zusammenfassung.** Eine biostratigraphische Gliederung, die auf Bolboformen basiert, wurde zum ersten Mal auf das Metochia-Profil der Insel Gavdos, südlich von Kreta (Griechenland) angewendet. Das untersuchte Zeitintervall deckt, nach der Biostratigraphie der planktonischen Foraminiferen, einen Zeitraum von 9.7 bis 6.6 Millionen Jahre (Obermiozän) ab. Zwei Bolboforma-Arten, eine Art incertae sedis und die *Bolboforma intermedia* Zone (7.7–5.6 Ma) wurden nachgewiesen. Die *B. metzmacheri* Zone (9.7–7.7 Ma) wurde in dem untersuchten Abschnitt nicht nachgewiesen, vermutlich aus paläoökologischen Gründen. Es konnte gezeigt werden, daß die Bolboforma-Gruppe sowohl für die Stratigraphie als auch die Paläoklima-Analyse sehr nützlich ist.

### 1 Introduction

Miocene sections are traditionally dated using planktonic foraminifers and calcareous nannofossils. In particular, the distribution and geochemistry of planktonic foraminifera make up an important component of the marine sediment archive of past global environmental changes. However, planktonic foraminifera alone do not deliver the desired level of stratigraphic resolution, especially when they are used in shallow-water settings. More precise assignments may be obtained by combining the bioevents of different fossil groups, which can also be integrated with chemostratigraphic events.

In this paper we present an example of this integrated stratigraphic approach applied to the relatively deep-water Metochia section, outcropping in the northern part of Gav-

\* Author's addresses: A. ANTONARAKOU and H. DRINIA, National and Kapodistrian University of Athens, Dept. of Geology, Section of Hist. Geology and Paleontology, Panepistimiopolis, 157 84, Greece. e-mail: aantonar@geol.uoa.gr

dos Island (Fig. 1), using assemblages of planktonic foraminifers and specimens of the *Bolboforma* group.

*Bolboforma* specimens comprise a group of marine calcareous microfossils of uncertain origin with affinities to protophytic algae. VON DANIELS & SPIEGLER (1974) first introduced *Bolboforma* as a genus of incertae sedis belonging to a group of problematic marine protozoans. Since then, speculations have been presented about its affinity to protozoans (ODRZYWOLSKA-BIENKOWA 1976, VON DANIELS et al. 1981) or to algae (BIZON et al. 1977, RÖGL & HOCHULI 1976, TAPPAN 1980, MÜLLER et al. 1984, MURRAY 1984, ECHOLS 1985, HODGSON & FUNNELL 1987, SPIEGLER 1987). However, since encapsulated tests have been detected (POAG & KAROWE 1986, 1987; SPIEGLER 1987), the affinity to protophytes seems more likely.

Specimens belonging to this group characterize lower Eocene to upper Pliocene sediments (SPIEGLER 1991, 1999; COOKE et al. 2002), predominantly from middle and higher latitudes in both the northern and southern hemispheres. *Bolboforma* specimens are *Lagena*-shaped, possess a calcitic monocrystalline, spheroidal to subspheroidal, mostly single chamber. Specimens range in size from 50  $\mu\text{m}$  to 250  $\mu\text{m}$ , but their diameter is usually less than 150  $\mu\text{m}$  (SPIEGLER 1987).

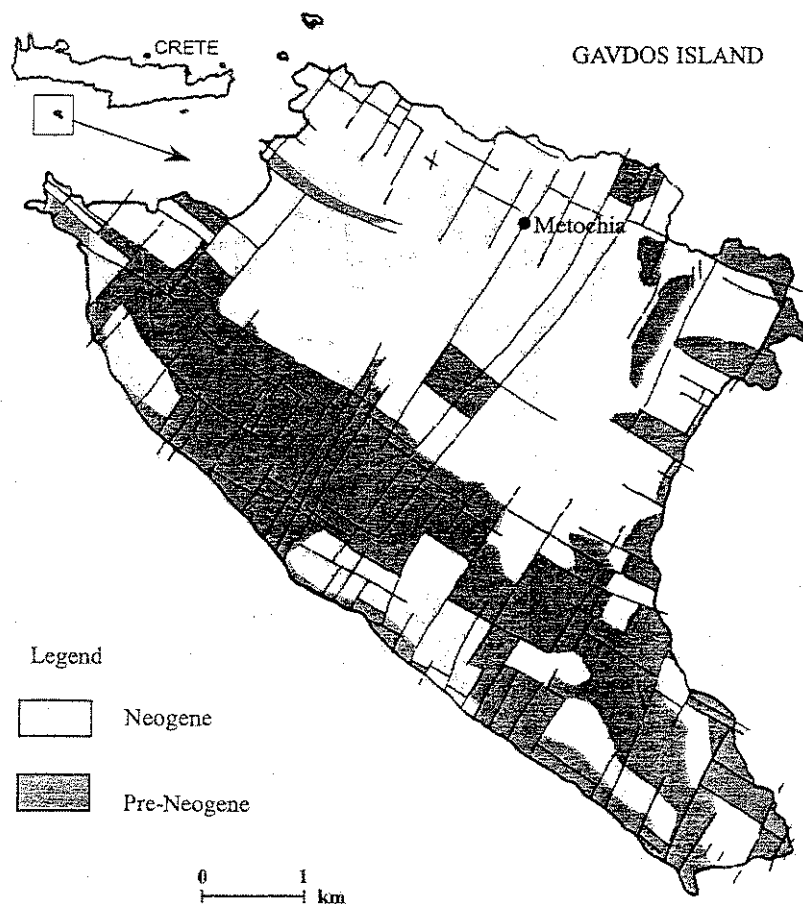


Fig. 1. Geological map of Gavdos Island with location of the Metochia Section.

Biostratigraphy based on these organisms is relatively new compared with the biostratigraphy based on other microfossil groups (QVALE & SPIEGLER 1989, SPIEGLER & VON DANIELS 1991, SPIEGLER 1999). However, their strong resistance to dissolution and their phylogenetic evolution, especially during the Miocene, make the *Bolboforma* to an important microfossil group for interpreting the stratigraphy of sediments from temperate and cool regions (SPEZZAFERRI & SPIEGLER 1998a, SPIEGLER 2001; SPEZZAFERRI et al. 2001). In particular, the use of *Bolboforma* may support and in some cases improve standard zonations based on calcareous nannofossils and foraminifers. Fourteen *Bolboforma* zones/subzones have been determined for the Neogene (SPIEGLER 1999).

The *Bolboforma* group has rarely been described from sediments in Mediterranean sections (SPIEGLER & RÖGL 1992, SPEZZAFERRI et al. 2001). Moreover, this group is determined for the first time in the Hellenic region.

## 2 Material and methods

### Geological setting and stratigraphy

The location of the section studied is near Metochia in Gavdos Island (Fig. 1). The vertical sedimentary log of the section is illustrated in Fig. 3 and represents the section as shown in Fig. 2.

The Metochia Section is approximately 100 m thick and comprises a basal part of a paleosol overlain by estuarine-type sediments with oyster banks. Strongly bioturbated shallow marine sands with a high lateral continuity and with many *Heterostegina* (benthic foraminifer), echinoids, pectinids and other gastropods and pelecypods of shallow marine origin overly the estuarine deposits. Deeper-marine sediments overly these near-shore deposits.

The main part of the section consists of alternating light grey-blue, homogeneous, hemipelagic marls and brown, organic-rich, laminated beds (sapropels). Plankton/benthos ratios from the pelagic marls of the first sapropel level indicate basin depths of the order of 850 m and more (POSTMA et al. 1993). The Metochia Section shows conspicuous clusters of sapropels at some intervals. The sapropel-bearing succession in the Metochia Section is overlain in stratigraphic continuity by cyclically bedded diatomites of Messinian age (TRIANANTAPHYLLOU et al. 1999).

The stratigraphic position of the section is known from magneto-, cyclo- and biostratigraphic data (HILGEN 1991, KRIJGSMAN et al. 1995, HILGEN et al. 1995, ANTONARAKOU 2001). Based on these data, the section covers a time interval from 9.7 to 6.6 Ma, a period of substantial changes supposed concerning the Mediterranean-Atlantic connections. In addition, an astronomically calibrated time scale for the studied section has been established through correlation to the 65° N summer insolation curve of  $L_a_{(1,1)}$  (LASKAR 1990, 1993; HILGEN et al. 1995, LOURENS et al. 1996). The Metochia Section has been correlated with other sections of Crete and Sicily, and the results provide a solid, stratigraphic framework that enables bed-to-bed correlation for Tortonian and lower Messinian strata of the Eastern Mediterranean Basin.

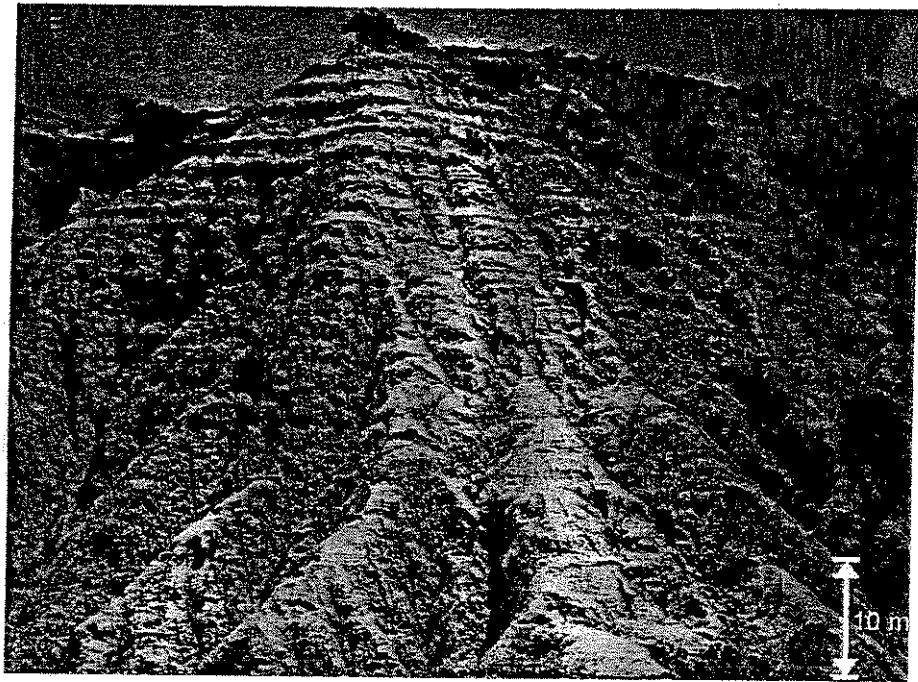


Fig. 2. The Metochia Section.

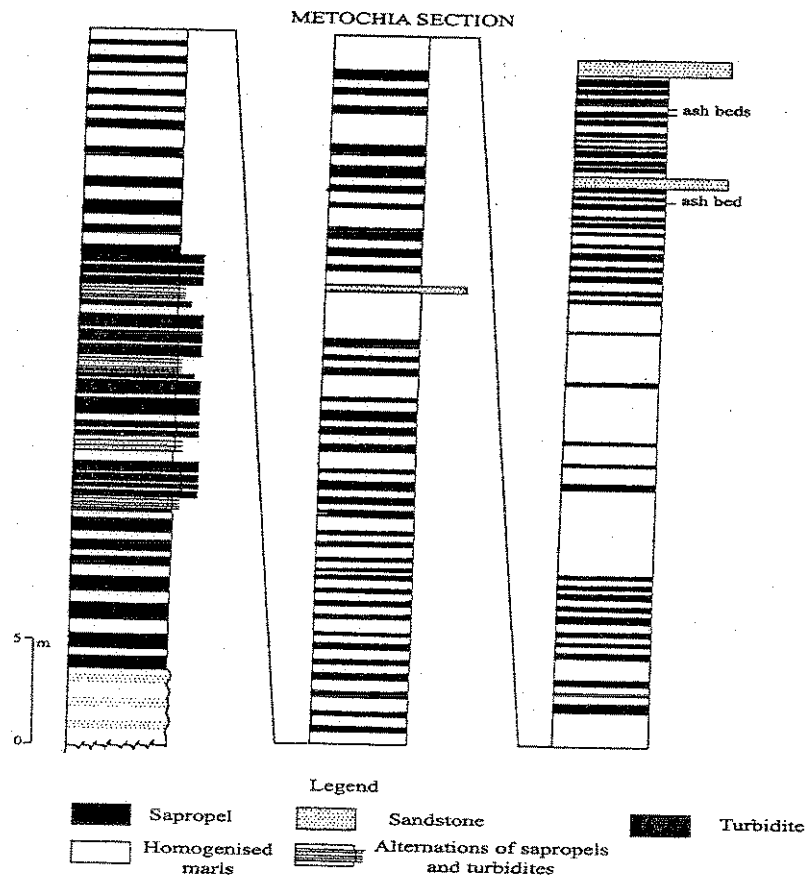


Fig. 3. Lithostratigraphy of the sediments from the Metochia Section.

### Micropaleontological analysis

For micropalaeontological studies, 560 samples of 1 cm thickness have been taken at intervals of approximately 20 cm, if necessary in correspondence with changes in lithology. The collected samples were treated with H<sub>2</sub>O<sub>2</sub>, washed through a 125 µm mesh sieve and dried at 50° C. The preparation method used to obtain *Bolboforma* specimens is the same as used for foraminifers. Foraminifera and *Bolboforma* specimens were then hand-picked under a binocular microscope from randomized splits of each dried sample and mounted on a slide. The preservation of the specimens is good throughout the studied sequence.

### 3 Biostratigraphy

#### Planktonic foraminiferal biostratigraphy

The faunal assemblages are generally very well preserved and abundant throughout the sequence. Planktonic foraminiferal biostratigraphy of the Metochia Section is based on the stratigraphic distribution of six species and the coiling ratio of *Neogloboquadrina acostaensis*. The stratigraphic distribution of these species is given by qualitative terms (presence/absence) and provides eleven first order bioevents (No. 1–11 in Fig. 3 and Table 1), which improve the biostratigraphic resolutions of this time span (KRIJGSMAN et al. 1995, ANTONARAKOU 2001). All events are accurately dated using the astronomically calibrated time scale for the Late Miocene (KRIJGSMAN et al. 1995).

The planktonic foraminiferal bioevents identified in the section are listed in Table 1:

Table 1 Planktonic foraminiferal bioevents in the Metochia Section (HILGEN et al. 1995).

No.	Bioevents	Stratigraphic level	Astronomical age (Ma)	Foraminiferal zones
11	<i>G. nicolae</i> , FO	99.25–99.35 m	6.82–6.83	<i>G. cono-</i> <i>miozea</i>
10	<i>G. miotumida</i> group, FRO	90.25–90.33 m	7.23–7.24	
9	<i>G. menardii</i> 5, FO	87.90–87.97 m	7.35	<i>N. acosta-</i> <i>ensis</i>
8	<i>G. falconarae</i> , LO	85.20–85.69 m	7.44–7.46	
7	<i>G. menardii</i> 4, LCO	84.12–84.24 m	7.50–7.51	
6	<i>S. seminulina</i> , HRO	79.06–79.31 m	7.72–7.73	N16
5	<i>S. seminulina</i> , LRO	74.44–74.60 m	7.91–7.92	
4	<i>G. falconarae</i> , FS	57.31–57.84 m	8.42–8.44	
3	<i>G. falconarae</i> , LCO	44.10–44.27 m	8.86	
2	<i>G. menardii</i> 4, LCO	29.35–29.76 m	9.31–9.32	
1	<i>N. acostaensis</i> , HRO	9.81–9.93 m	9.54	

Based on these bioevents and the distributional pattern of planktonic foraminifers, the zonations of BLOW (1969, 1979) and ZACHARIASSE (1975) have been tentatively applied to the Metochia Section. According to these zonations, planktonic foraminiferal data indicate that the section covers a time interval from 9.7–6.6 Ma, spanning the *N. acostaensis* Zone and the *G. conomiozea* Zone or the N16 and N17 zones, respectively (BLOW 1969).

### Bolboforma biostratigraphy

In the sediments of the Metochia Section the following species have been identified: *B. cf. clodiusi*, *B. intermedia* and a species of incertae sedis, forma A (Plate I).

Specimens of Incertae sedis, forma A, occur throughout the sequence (Fig. 4). Its lowest common occurrence (LCO) is above the lowest common occurrence of *Globorotalia menardii* 4 (bioevent 2, dated as 9.31 Ma). The last occurrence (LO) of the species is reported almost from the top of the section and coincides with the first occurrence (FO) of *Globorotalia nicolae* (at 6.82 Ma).

*Bolboforma cf. clodiusi* shows a very short influx just below the frequency shift of *Globorotaloides falconarae* (at 8.4 Ma). *Bolboforma intermedia* is of great biostratigraphic significance, as its first occurrence marks the base of the *Bolboforma intermedia* Zone. The total range (TR) of *B. intermedia* defines the *B. intermedia* Zone and spans the interval 7.7–5.6 Ma (SPIEGLER 1999). In the studied section, the first occurrence of *B. intermedia* is reported just above the lower common occurrence of *Sphaeroidinellopsis seminulina*, dated as 7.8 Ma. The base of this interval coincides with the brief re-occurrence of large sized *Globorotaloides falconarae* specimens, while the top corresponds with the base of the longer term absence interval of *G. menardii* 4 preceding its last common occurrence level. *S. seminulina* and *B. intermedia* show the same distribution pattern.

## 4 Discussion

*Bolboforma* associations in the samples were analyzed and correlated to the planktonic foraminiferal bioevents of the Metochia Section. The major event observed is the first occurrence of the *B. intermedia* which defines the *B. intermedia* Zone for the upper part of the section (Fig. 5).

---

### Faunal reference list (Plate I)

Type references are given for each species recognized.

*Bolboforma clodiusi* VON DANIELS & SPIEGLER, 1974, p. 63, pl. 7, figs. 4–6.

*Bolboforma intermedia* VON DANIELS & SPIEGLER, 1974, pp. 66–67, pl. 8, figs. 7–9.

Incertae sedis, forma A SPEZZAFERRI & SPIEGLER, 1998, p. 128, pl. 2, figs. 1–11. Incertae sedis, forma A is known from Pliocene to early Pleistocene, but was never described from Late Miocene sequences of the Eastern Mediterranean.

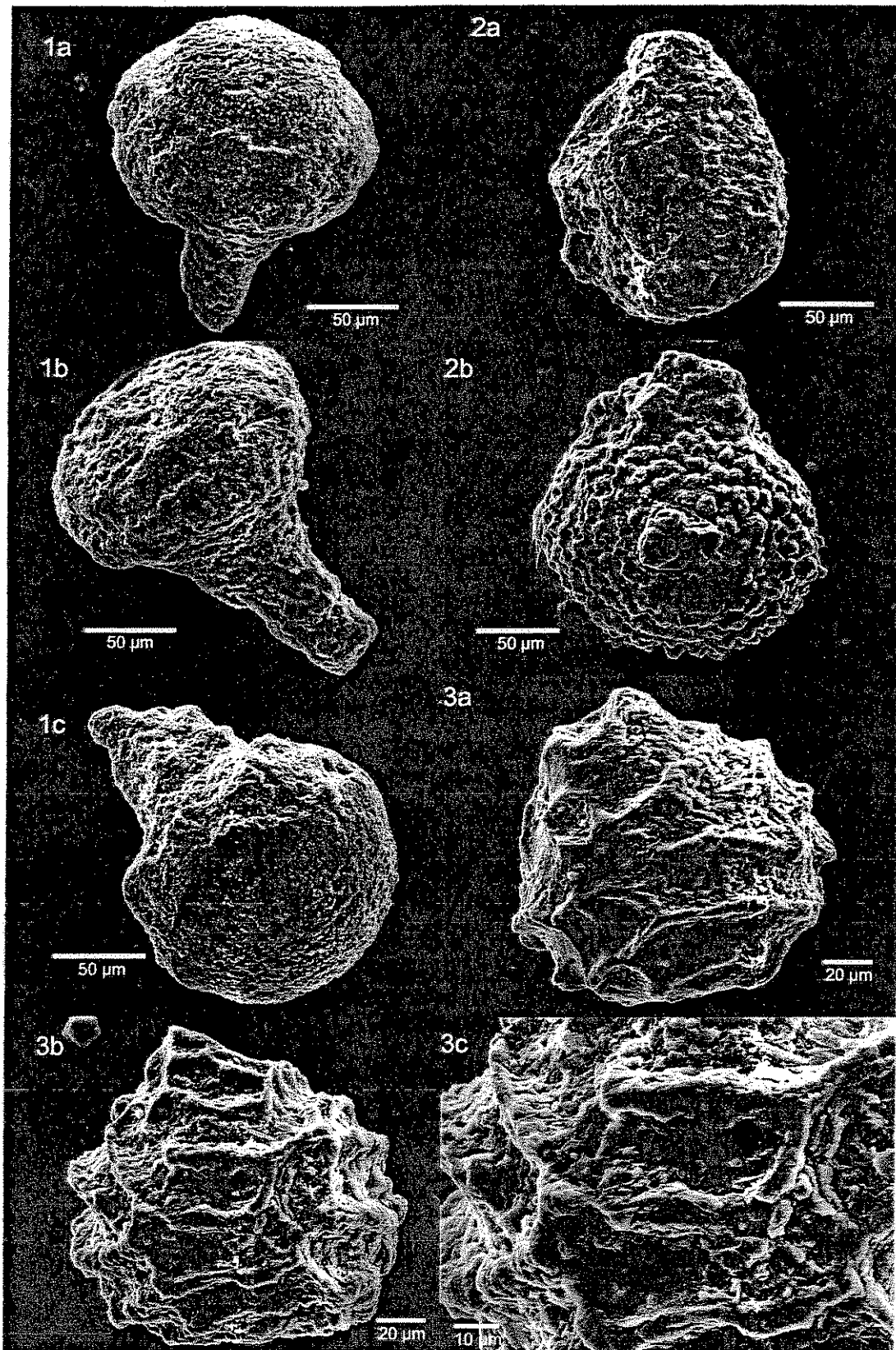


Plate 1: Fig. 1a–c: Incertae sedis, forma A. Fig. 2a–b: *Bolboforma* cf. *clodiusi*. Fig. 3a–c: *Bolboforma intermedia*.

METOCHIA SECTION

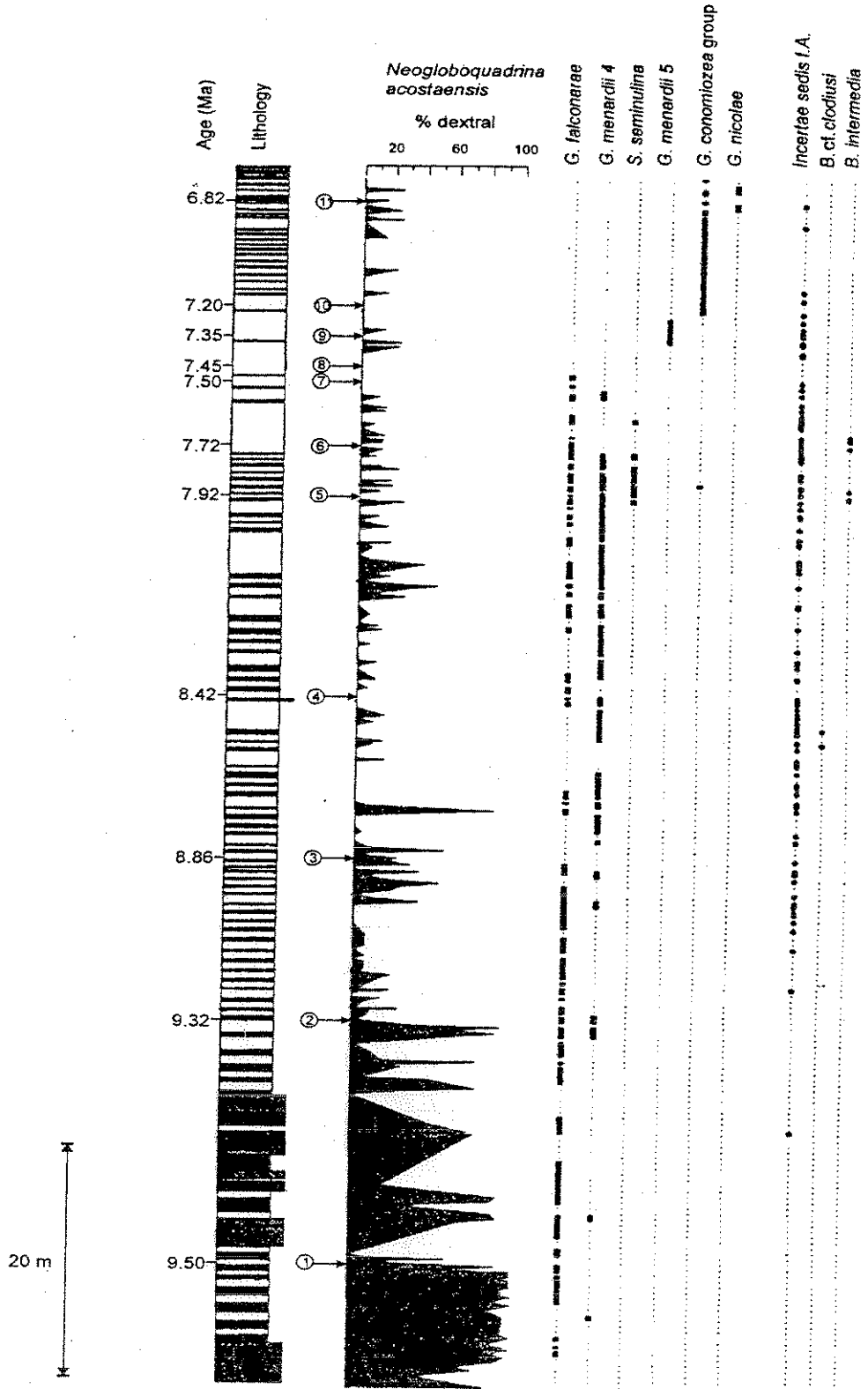


Fig. 4. Stratigraphic distributional pattern of planktonic foraminifers and *Bolboforma* species from the Metochia Section (KRIJGSMAN et al. 1995, modified herein).



EPOCH	AGE (Ma)	CHRON	SUBCHRON	POLARITY	Nannoplankton Zones (Martini 1971)	Nannoplankton Zones (Okada & Bukry 1980)	Foraminifera Zones (Blow 1969)	Foraminifera Zones (Zachariasse 1975)	<i>Bolboforma</i> Zone (Spieger & v. Daniels 1991; Spieger 1999)	AGE (Ma)
LATE MIOCENE	7-10	C3An	C3An.2n	Black	NN11	CN9	N17	G. conomiozea	<i>B. intermedia</i>	7.7
		C3Ar	C3Ar	White						
		C3Br	C3Br	Black						
		C3Br	C3Br.2r	White						
		C4n	C4n.1n	Black						
		C4n	C4n.1r	White						
		C4n	C4n.2n	Black						
		C4r	C4r.1r	White						
		C4r	C4r.2r	Black						
		C4An	C4An	Black						
LATE MIOCENE	9-10	C4Ar	C4Ar.1r	Black	NN10	CN8	N16	<i>N. acostaensis</i>	<i>B. metzmacheri</i>	9.7
		C4Ar	C4Ar.1n	White						
		C4Ar	C4Ar.2r	Black						
		C4Ar	C4Ar.2n	White						
		C4Ar	C4Ar.3r	Black						
		C5n	C5n.1n	White						
		C5n	C5n.1r	Black						
		C5n	C5n.2n	White						
		C5n	C5n.2r	Black						
		C5n	C5n.2n	White						



Fig. 5. Correlation of *Bolboforma* zones with the planktonic foraminiferal zones as identified in the Metochia Section.

The potential for finding index *Bolboforma* taxa in older sedimentary units of the Metochia Section is rather low. We expected to find *B. metzmacheri*, the total range of which characterizes the *B. metzmacheri* Zone spanning the time interval from 10.5 to 7.7 Ma. We suggest that palaeoecological and palaeoenvironmental reasons have caused the absence of this *Bolboforma* species.

Palaeotemperature trends play a crucial role in the development of the *Bolboforma*. SPIEGLER & VON DANIELS (1991) and COOKE et al. (2002) mentioned that *Bolboforma* specimens prefer rather temperate climatic conditions. When the climate becomes warmer, conditions are unfavorable for them so they usually disappear. This may be the reason that they are mostly missing in low latitudes in both hemispheres and in Tertiary sequences of the Pacific.

## 5 Conclusions

Combined *Bolboforma* and planktonic foraminiferal biostratigraphy provide a precise age assignment of Miocene sediments from the Metochia Section. An expanded use of *Bolboforma* bioevents may significantly improve the stratigraphy of other outcropping Miocene sequences. However, further studies are necessary to identify the stratigraphic potential of this group of microfossils.

**Acknowledgements.** The Mast-III Miomor Program of the European Community financially supported parts of this work. D. SPIEGLER is thanked for reviewing the paper.

## References

- ANTONARAKOU, A. (2001): Biostratigraphic and palaeoenvironmental interpretation of the Miocene sediments of Eastern Mediterranean (Gavdos Island). – PhD thesis, University of Athens, 176 p.
- BIZON, G., TAUGOURDEAU-LANTZ, J. & WRIGHT, R. (1977): Présence d'algues enkystées: *Pachysphaera* et des microfossiles d'affinités incertaines: *Bolboforma* dans le Miocène de Méditerranée. – *Revue de Micropaléontologie*, 20, 140–146, Paris.
- BLOW, W. H. (1969): Late middle Eocene to Recent planktonic foraminiferal biostratigraphy. – In: BRONNIMAN, P. & RENZ, H. H. (Eds), *Proc. First Int. Conf. Planktonic Microfossils*, Geneva, 1967, 1: 199–422, Leiden (E. J. BRILL).
- (1979): *The Cainozoic Globigerinida*, Leiden (E. J. BRILL).
- COOKE, P. J., NELSON, C. S., CRUNDWELL, M. P. & SPIEGLER, D. (2002): *Bolboforma* as monitors of palaeoceanographic changes in the Southern Ocean. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, 188: 73–100, Amsterdam.
- DANIELS, C. H. von & SPIEGLER, D. (1974): *Bolboforma* n. gen. (Protozoa?) – eine neue stratigraphisch wichtige Gattung aus dem Oligozän/Miozän Nordwestdeutschlands. – *Paläont. Z.*, 48, 57–76, Stuttgart.
- DANIELS, C. H. von, SPIEGLER, D. & BIJVANK, G. (1981): Zweikammerige *Bolboforma* (Microproblematica, Protozoa?). – *Paläont. Z.*, 55: 175–177, Stuttgart.
- ECHOLS, D. J. (1985): "*Bolboforma*" – a Miocene algae (?) of possible biostratigraphic and palaeoclimatic value. – In: BOUGAULT, H., CANDE, S. C. et al., *Init. Repts. DSDP*, 82: 605–610, Washington.

- HILGEN, F.J. (1991): Extension of the astronomically calibrated (polarity) time scale to the Miocene/Pliocene boundary. – *Earth Planet. Sci. Lett.*, 107: 349–368, Amsterdam.
- HILGEN, F.J., KRIJGSMAN, W., LANGEREIS, C. G., LOURENS, L. J., SANTARELLI, A & ZACHARIASSE, W. J. (1995): Extending the astronomical (polarity) time scale into the Miocene. – *Earth Planet. Sci. Lett.*, 136: 495–510, Amsterdam.
- HODGSON, G. E. & FUNNELL, B. M. (1987): Foraminiferal biofacies of the Early Pliocene Coralline Crag. – In: Hart, M. B. (Ed), *Microplaeontology of Carbonate Environments*, 44–73, London (British Micropaleont. Soc.).
- KRIJGSMAN, W., HILGEN, F.J., LANGEREIS, C. G., L. J., LOURENS, SANTARELLI, A. & ZACHARIASSE, W. J. (1995): Late Miocene magnetostratigraphy, biostratigraphy and cyclostratigraphy from the Mediterranean. – *Earth Planet. Sci. Lett.*, 136: 475–494, Amsterdam.
- LASKAR, J. (1990): The chaotic motion of the solar system: A numerical estimate of the size of the chaotic zones. – *Icarus*, 88: 266–291, New York.
- LASKAR, J., JOUTEL, F. & BOUDIN, F. (1993): Orbital, precessional, and insolation quantities for the Earth from –20 Myr to +10 Myr. – *Astron. Astrophys.*, 270: 522–533, Berlin.
- LOURENS, L. J., ANTONARAKOU, A., HILGEN, F. J., VAN HOOFF, A. A. M., VERNAUD-GRAZZINI, C. & ZACHARIASSE, W. J. (1996): Evaluation of the Plio-Pleistocene astronomical time scale. – *Paleoceanography*, 11 (4): 391–413, Washington.
- MÜLLER, C., SPIEGLER, D. & PASTOURET, L. (1984): The genus *Bolboforma* v. Daniels and Spiegler in the Oligocene and Miocene sediments of the North Atlantic and northern Europe. – In: de Graciansky, P. C., Poag, C. W. et al., *Init. Repts. DSDP*, 80: 669–675, Washington.
- MURRAY, J. W. (1984): Biostratigraphic value of *Bolboforma*. Leg 81, Rock-all Plateau. – In: Roberts, D. G., Schnitker, D et al., *Init. Repts. DSDP*, 81: 535–539, Washington.
- ODRZYWOLSKA-BIENKOWA, E. (1976): On some species of the genus *Bolboforma* (Protozoa?) from Miocene of Poland. – *Kwartalnik Geol.*, 20: 551–558, Warszawa.
- POAG, C. W. & KAROWE, A. L. (1986): Stratigraphic potential of *Bolboforma*, significantly increased by new finds in the North Atlantic and South Pacific. – *Palaios*, 1: 162–171, Tulsa.
- POAG, C. W. & KAROWE, A. L. (1987): *Bolboforma* (Chrysophyta?) from the western North Atlantic. – In: Poag, C. W., Watts, A. B. et al., *Init. Repts. DSDP*, 95: 429–438, Washington.
- POSTMA, G., HILGEN, F. J. & ZACHARIASSE, W. J. (1993): Precession-punctuated growth of a late Miocene submarine-fan lobe on Gavdos (Greece). – *Terra Nova*, 5: 438–444, Oxford.
- QVALE, G. & SPIEGLER, D. (1989): The stratigraphic significance of *Bolboforma* (algae, Chrysophyta) in Leg 104 samples from the Vøring Plateau. – In: Eldholm, O., Thiede, J., Taylor, E. et al., *Proc. ODP, Sci. Results*, 104: 487–495, Austin.
- RÖGL, F. & HOCHULI, P. (1976): The occurrence of *Bolboforma*, a probable algal cyst, in the Antarctic Miocene of DSDP Leg 35. – In: Hollister, C. D., Craddock, C., et al., *Init. Repts. DSDP*, 35: 713–719, Washington.
- SPEZZAFERRI, S. & SPIEGLER, D. (1998a): Pliocene and Pleistocene biostratigraphy of *Bachmayerella tenuis* and *Incertae sedis*, forma A, Eastern Mediterranean, Holes 965A, 966B, 967A and 969A. – In: ROBERTSON, A. H. F., EMEIS, K.-C., RICHTER, C. & CAMERLENGHI, A. (Eds), *Proc. ODP, Sci. Results*, 160, 125–135, Austin.
- SPEZZAFERRI, S. & SPIEGLER, D. (1998b): *Bolboforma* biostratigraphy from the southeast Greenland margin, Hole 918D. – In: SAUNDERS, A. D., LARSEN, H. C. & WISE, S. W. Jr. (Eds), *Proc. ODP, Sci. Results*, 152: 201–207, Austin.
- SPEZZAFERRI, S., MUTTI, M. & SPIEGLER, D. (2001): Integrated planktonic foraminifera, *Bolboforma* and carbon isotope stratigraphy in a mid/early late Miocene carbonate ramp setting from the Acreide area (Sicily). – *Marine Micropaleontology*, 43: 223–238, Amsterdam.
- SPIEGLER, D. & MÜLLER, C. (1992): Correlation of *Bolboforma* zonation and nannoplankton stratigraphy in the Neogene of the North Atlantic. – *Marine Micropaleontology*, 20: 45–58, Amsterdam.
- SPIEGLER, D. & RÖGL, F. (1992): *Bolboforma* (Protozoa incertae sedis) im Oligozän und Miozän des Mediterran und der zentralen Paratethys. – *Ann. Nat. Mus. Wien* 94A: 59–95, Wien.

- SPIEGLER, D. & VON DANIELS, C.H. (1991): A stratigraphic and taxonomic atlas of *Bolboforma* (Protophytes, Incertae sedis, Tertiary). – J. Foram. Res., 21: 126–158, Lawrence.
- SPIEGLER, D. (1987): Encapsulated *Bolboforma* (Algae, Chrysophyta) from upper Miocene deposits in the North Atlantic. – *Werkgroup Tertiaire Kwartaire Geologie*, 24: 157–166, Leiden.
- (1991): The occurrence of *Bolboforma* (Algae, Chrysophyta) in the Subantarctic (Atlantic) Paleogene, drilled during ODP Leg 114. – In: CIESIELSKI, P.F., KRISTOFFERSEN, Y. et al. (Eds), *Proc. ODP. Sci. Results*, 114: 325–334, Austin.
- (1999): *Bolboforma* biostratigraphy from the Hatton-Rockall Basin (North Atlantic). – In: RAYMO, M.E., JANSEN, E., BLUM, P. & HERBERT, T.D. (Eds), *Proc. ODP, Sci. Results*, 162: 35–49, Austin.
- (2001): *Bolboformen* aus dem Miozän der Forschungsbohrung Nieder Ochtenhausen (Niedersachsen, Nord-Deutschland). – *Geol. Jb.*, A 152: 175–193, Hannover.
- TAPPAN, H. (1980): *The Paleobiology of Plant Protists*, San Francisco (W.H. Freeman).
- TRIANAPHYLLOU, M.V., TSAPARAS, N., STAMATAKIS, M. & DERMITZAKIS, M.D. (1999): Calcareous nannofossil biostratigraphy and petrological analysis of the pre-evaporitic diatomaceous sediments from Gavdos Island, southern Greece. – *N. Jb. Geol. Paläont. Mh.*, 161–178, Stuttgart.
- ZACHARIASSE, W.J. (1975): Planktonic foraminiferal biostratigraphy of the Late Neogene of Crete. – *Utrecht Microplaeont. Bull.*, 11: 171 p, Utrecht.

Typescript received 15. 11. 2002, revised version accepted for print 2. 4. 2003