

27. THE STRATIGRAPHIC SIGNIFICANCE OF *BOLBOFORMA* (ALGAE, CHRYSOPHYTA) IN LEG 104 SAMPLES FROM THE VØRING PLATEAU¹

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ABSTRACT

Fifteen well-preserved species of *Bolboforma* were observed in samples of late middle Miocene to early Pliocene age from Sites 642 and 643 on the Vøring Plateau (Leg 104). Seven assemblage zones are defined, dominated by *Bolboforma costairregularis*, *B. intermedia*, *B. metzmacheri*, *B. laevis*, *B. fragori*, *B. compressispinosa*, and *B. reticulata*, respectively.

INTRODUCTION

Well-preserved specimens of *Bolboforma* occurred in a large number of samples from Leg 104 Sites 642 and 643 (Fig. 1). This group of fossils has been described from most parts of the world, in sediments ranging in age from late Eocene to Pliocene. They are proven useful stratigraphic tools, but our knowledge of their distribution is still limited. *Bolboforma* were first described from deposits of Oligocene and Miocene age of western Germany (Daniels and Spiegler, 1974), but were later found in other areas in the Northern and Southern Hemispheres. A distribution chart is published in Poag and Karowe (1986). *Bolboforma* is most common in middle to high latitudes and have so far been recorded only in marine sediments.

Bolboforma was not studied in detail during the previous Vøring Plateau leg (DSDP Leg 38), but studies of Site 341 (Fig. 1) sediments were recently carried out (Nordaa, 1984; Powell, 1986). Nordaa (1984) used a different size fraction than ours and did not define specific zones, which makes a direct comparison with his results difficult. Powell (1986) used the same size fraction as in the present study, and her results are summarized here.

METHODS

Samples used for the studies of Leg 104 benthic and planktonic foraminifers (Osterman and Qvale; Spiegler and Jansen, this volume) were also used for the *Bolboforma* studies. Samples of about 18 cm³ were dried, disintegrated in lukewarm water or a dilute Calgon (sodium hexametaphosphate) solution, and then washed through 1-mm and 63- μ m sieves. The studies were carried out on the size fraction greater than 63 μ m. Scanning electron microscopy (SEM) was used for detailed taxonomic studies.

The total number of specimens per sample was not counted, but the frequency of each species is indicated by the number of individuals per square in a sample tray with 45 squares, each covering 1 cm² (Figs. 2-4). The zones are characterized by, and named after, their dominant species. Barren intervals occur between the zones in some cases.

TAXONOMY

Daniels and Spiegler (1974) introduced *Bolboforma* as protozoans *incertae sedis*. Now its affinities to protophytes are

commonly accepted. Tappan (1980) placed *Bolboforma* as an un-named cyst family within the *Chrysophyceae*. Spiegler (1987) erected the family *Bolboformaceae* under algae (*Chrysophyta*).

We have followed the classification of Daniels and Spiegler (1974), Müller et al. (1984), Powell (1986) and Spiegler (unpublished data). Due to the abundance of well-preserved *Bolboforma* in the samples studied, we observed specimens that represented transitional forms between well-defined species, e.g., between *B. metzmacheri* and *B. laevis* (Pl. 1, Fig. 4).

Under the light microscope it is sometimes difficult to distinguish between *B. pseudohystrix*, *B. badenensis*, and *B. voeringensis*, coarsely spined *B. clodiusi* to finely spined *B. spinosa*, and *B. aculeata*, *B. fragori*, and *B. subfragori*. *Bolboforma pseudohystrix* should possibly be separated into two taxa (Pl. 2, Figs. 3 and 4). The relationship between flattened and spherical taxa is unknown, but could possibly represent morphotypes or ecophenotypes.

Spiegler (1987) described encapsulated tests of *B. voeringensis*, *B. capsula*, and *B. pseudohystrix*, and showed that we have to distinguish between inner and outer tests of *Bolboforma*. Specimens possessing two chambers as well as an outer test were also observed (Daniels et al., 1981).

The fifteen species observed in the Vøring Plateau material are described briefly in the explanations to Plates 1-3.

STRATIGRAPHIC DISTRIBUTION

Specimens of *Bolboforma* are most common in samples from Site 642, where the sand fraction in certain samples (104-642B-18-1, 72-76 cm; 104-642C-18-5, 78-81 cm) consists almost entirely of *Bolboforma* tests. *Bolboforma* is found most frequently in sediments of lithological Units IIC and IID, which consist of interbedded nannofossil and siliceous nannofossil oozes and siliceous muds.

Bolboforma do not occur as frequently at Site 643, where the rich *B. reticulata* zone found at Site 642 is missing, and only parts of the overlying zones are present. *Bolboforma* is found in lithological Units IIB and IIC, which are characterized by siliceous muds with small amounts of diatomaceous nannofossil ooze.

Only one specimen of *Bolboforma* was found at Site 644, in sediments of early Pleistocene age. This single specimen may represent contamination, and more specimens are needed before we extend the age range of *Bolboforma* to include the entire Pliocene and parts of Pleistocene.

The *Bolboforma* zones for Leg 104 and their correlation with the DSDP Leg 38 Site 341 zones (Powell, 1986) are shown in Figure 5. The Miocene sediments recovered in Holes 642B,

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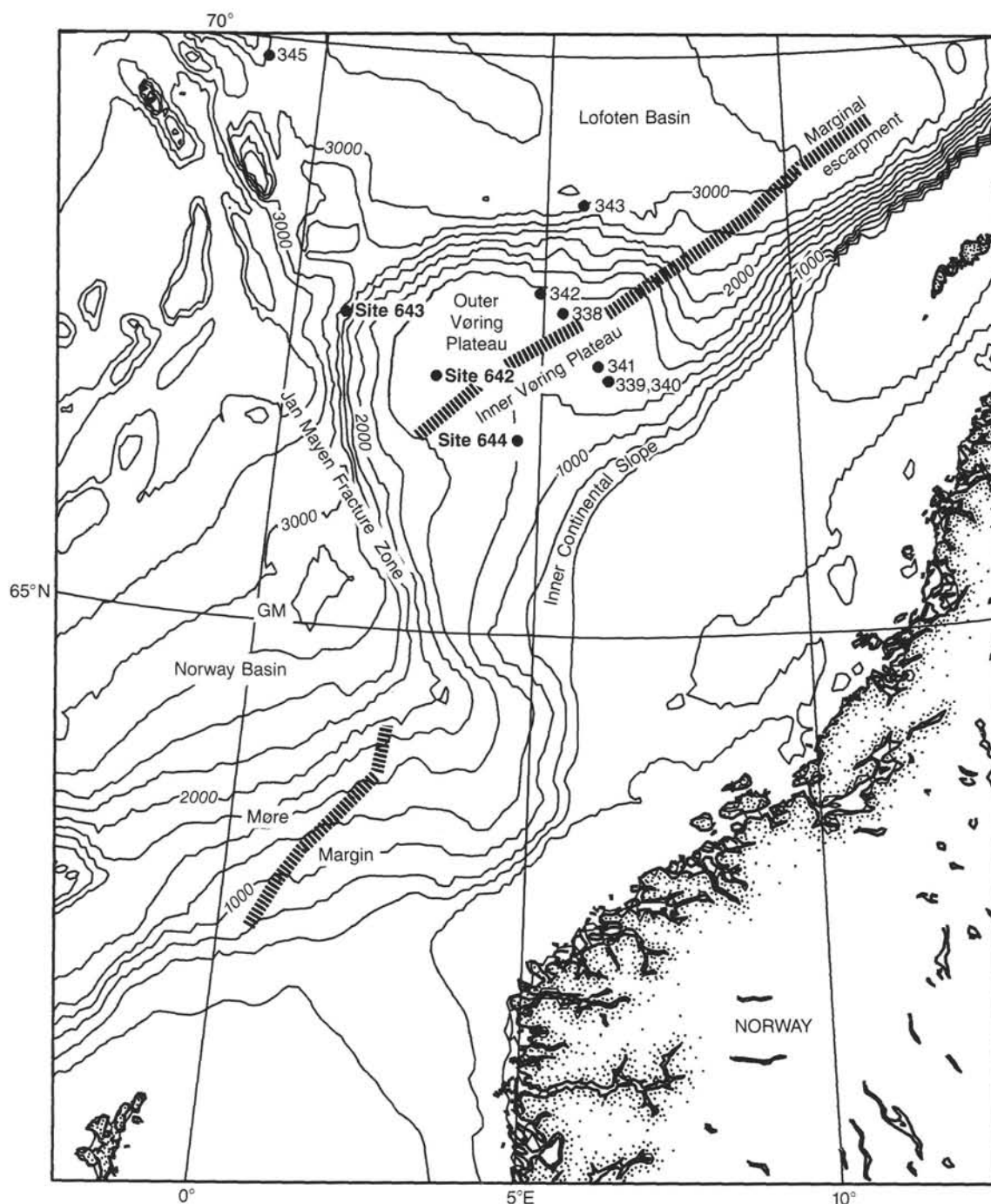


Figure 1. Locations of ODP Leg 104 and nearby DSDP Leg 38 sites. Contour interval, 250 m.

642C, and 643A have been divided into seven *Bolboforma* zones. The zonation is defined in Spiegler (unpublished data) and summarized below. Well-defined species that are easy to recognize were chosen to characterize each zone. A succession of morphotypes can be observed; ranging from coarsely reticulated *B. reticulata* in the lower part of the interval via the spinose-reticulate *B. badenensis*, *B. compressibadenensis*, and *B. voeringensis*, into spinose forms like *B. spinosa* and *B. compressispinosa* and finally the flattened, spinose *B. fragori* and *B. subfragori* in the youngest part of the sequence. The age ranges from late middle Miocene to the latest Miocene.

The *Bolboforma* zones are characterized as follows:

***B. costairregularis* Total Range Zone**

Age: early Pliocene to (?)Pleistocene.

Definition: Interval with zonal marker. 104-642B-10H-3 to -10H-4 (79.4–80.8 mbsf). 104-642C-11H-4 to -11H-6 (78.5–89.4 mbsf). 104-644A-14H-1 (121.7 mbsf) (1 specimen only, (?)contamination). Barren intervals surround this zone.

***B. intermedia* Interval Zone**

Age: late Miocene.

Definition: Top: Last occurrence of *B. intermedia*
Base: Last occurrence of *B. metzmacheri*

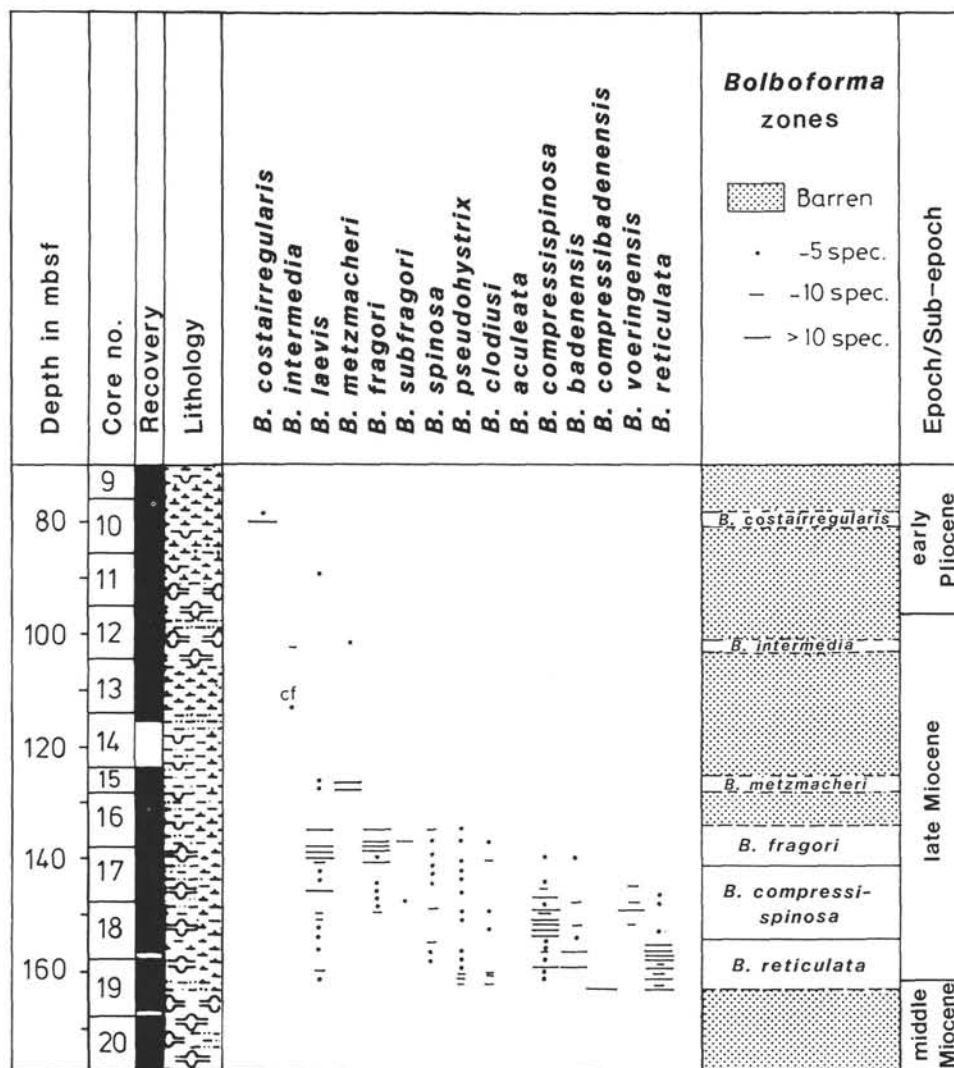


Figure 2. Distribution of *Bolboforma* in samples from Hole 642B. The frequency refers to the number of specimens per cm² when the sand fraction of a 18-cm³ sample is spread on a 45-cm² counting tray. The shading indicates barren intervals.

104-642B-12H-6 (103.0 mbsf).

104-642C: Not present.

38-341-7-2 (Powell, 1986).

B. metzmacheri Total Range Zone

Age: late Miocene.

Definition: Interval with zonal marker. 104-642B-15H-2 to -15H-3 (126.2–127.7 mbsf). 104-642C-16H-3 to -16H-4 (124.5–126.2 mbsf). 104-643A-9H-1 to -10H-4 (72.2–86.2 mbsf).

B. laevis Partial Range Zone

Age: late Miocene.

Definition: Top: First occurrence of *B. metzmacheri*

Base: Last occurrence of *B. fragori/subfragori*

B. laevis is abundant.

104-643A-10H-4 to -11H-1 (86.2–91.2 mbsf).

B. fragori Partial Range Zone

Age: late Miocene.

Definition: Top: Last occurrence of *B. fragori/subfragori*

Base: Abundant *B. compressispinosa*

104-642B-16H-6 to -17H-2 (135.3–140.7 mbsf). 103-642C-17H-2 to -17H-6 (132.6–138.3 mbsf). 104-643A-11H-2 to -11H-6 (92.7–98.7 mbsf). 104-341-26-3 to -27-2 (Powell, 1986).

B. compressispinosa Partial Range Zone

Age: late Miocene.

Definition: Top: Under abundant *B. fragori*

Base: Last occurrence of *B. reticulata*

104-642B-17H-3 to -18H-4 (142.7–153.5 mbsf). 104-642C-17, CC to -19H-2 (139.2–151.2 mbsf). 104-643A-11H-6 to -11H-7 (98.7–99.9 mbsf). 38-341-27-2 (Powell, 1986).

B. reticulata Total Range Zone

Age: middle Miocene to early late Miocene.

Definition: Top: Last occurrence of *B. reticulata*

Base: First occurrence of *B. reticulata*

104-642B-18H-5 to -19H-4 (155.0–163.3 mbsf). 104-642C-19H-3 to -20H-1 (152.6–159.3 mbsf). 38-341-28-2 (Powell, 1986, where *B. metzmacheri* may be *B. reticulata*).

The older parts of the sediment sequence are barren of *Bolboforma*.

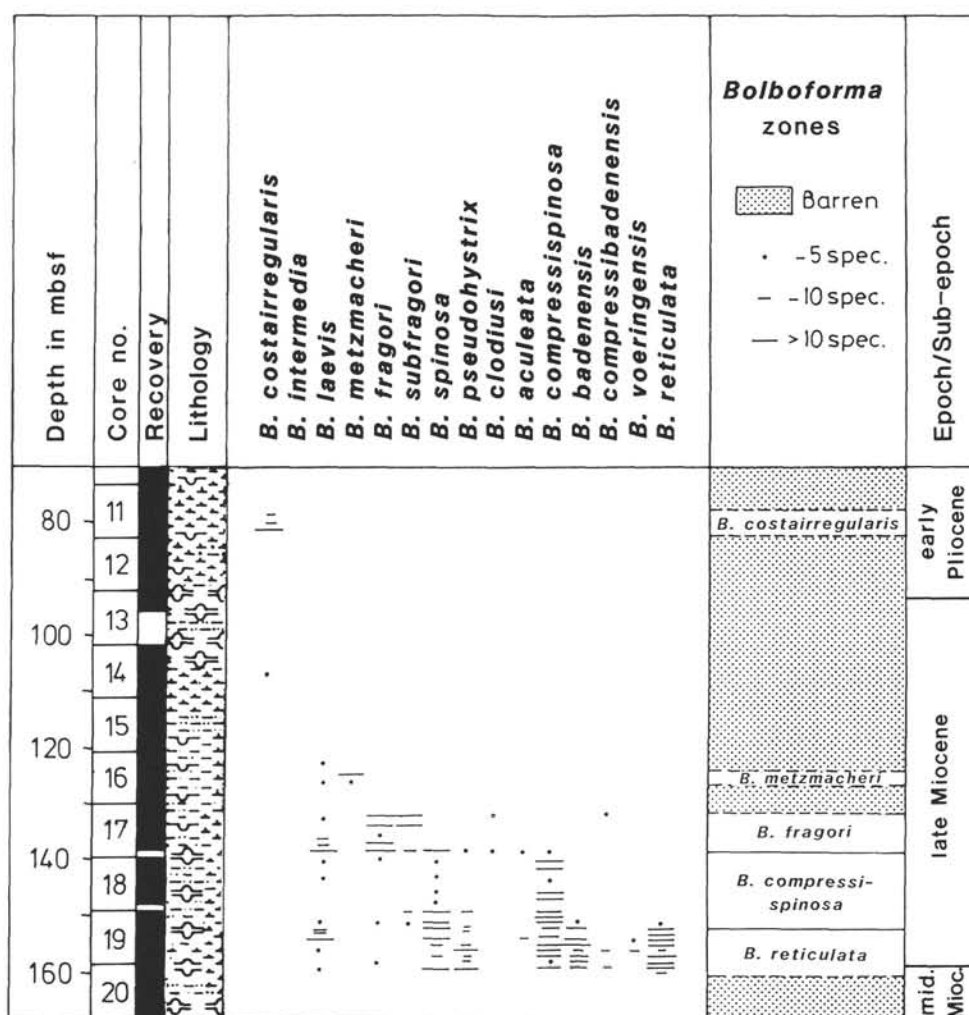


Figure 3. Distribution of *Bolboforma* in samples from Hole 642C. The frequency refers to the number of specimens per cm² when the sand fraction of an 18-cm³ sample is spread on a 45-cm² counting tray. The shading indicates barren intervals.

DISCUSSION

Most of the Vøring Plateau samples containing *Bolboforma* are of late Miocene age. The *B. reticulata* zone ranges into the middle Miocene. The occurrence of *B. costairregularis*, found in lower Pliocene deposits in the Netherlands (Toering and Voorthuysen, 1973; Doppert, 1980), England (Hodgson and Funnell, 1987), Belgium (Laga, 1972) and Rockall Plateau (Murray, 1984; 1987) indicates an early Pliocene age for the Leg 104 samples. As stated earlier, the occurrence of a single specimen of *B. costairregularis* in the Pleistocene must be regarded with some reservation.

At the Rockall Plateau (Murray, 1984; 1987) many of the common *Bolboforma* species range into the early Pliocene (NN13–NN15). We found only *B. costairregularis* in the Pliocene samples. This may indicate an environmental response, probably the onset of the ice age on the Northern Hemisphere.

Murray (1984, 1987) found most species of *Bolboforma* to be long-ranging and therefore of limited stratigraphic value. This study shows that they are very useful, at least in the upper Miocene section. The stratigraphic significance of *Bolboforma* may be restricted to high latitudes, but even then they are of great importance. Other calcareous microfossils may be difficult to use due to their low diversity, and a zonation based on

their distribution in lower latitudes does not always apply to the polar regions.

The present study confirms that *Bolboforma* is most diverse and abundant in high latitudes, as assumed by Murray (1984, 1987). This conclusion may, however, be an effect of the various methods used to study these specimens. The choice of sieve in sample preparation is essential. Many authors use a 125- μ m sieve, some even 150- μ m mesh size. Most *Bolboforma* are 120–180- μ m (Müller et al., 1984); thus, a large part of the specimens will be washed away if using a 150- μ m sieve. Our study of the fraction >63 μ m may partly be the reason for the high diversity and abundance in the Vøring Plateau material compared to other studies.

The distribution of *Bolboforma* is still poorly known, and more studies with careful examination of the smaller fraction will hopefully increase our knowledge about and the stratigraphic use of these organisms.

CONCLUSIONS

Well-preserved specimens of *Bolboforma* occur in sediments of middle Miocene to early Pliocene age at Sites 642 and 643. Seven zones are defined, characterized by *B. reticulata*, *B. compressispinosa*, *B. fragori*, *B. laevis*, *B. metzmacheri*, *B. intermedia*, and *B. costairregularis*, respectively. The occurrence of *Bol-*

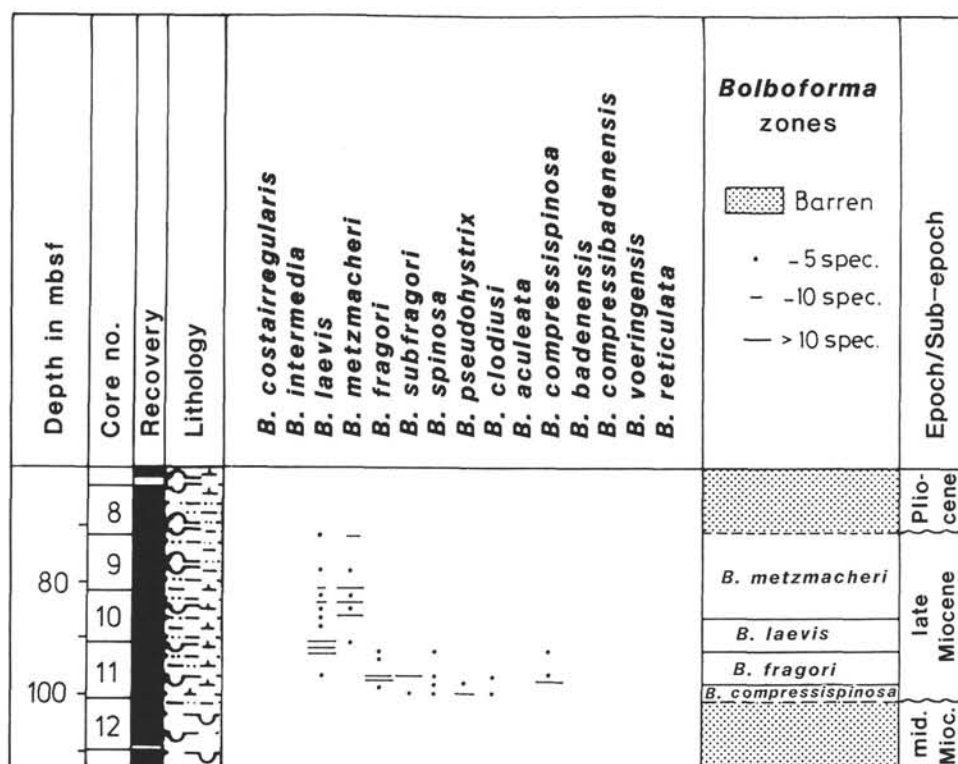


Figure 4. Distribution of *Bolboforma* in samples from Hole 643A. The frequency refers to the number of specimens per cm² when the sand fraction of an 18-cm³ sample is spread on a 45-cm² counting tray. The shading indicates barren intervals.

bolboforma in the Vøring Plateau sites can be correlated to other occurrences in the North Atlantic region.

The *Bolboforma* zones complement the middle and high planktonic foraminifer zonations quite well.

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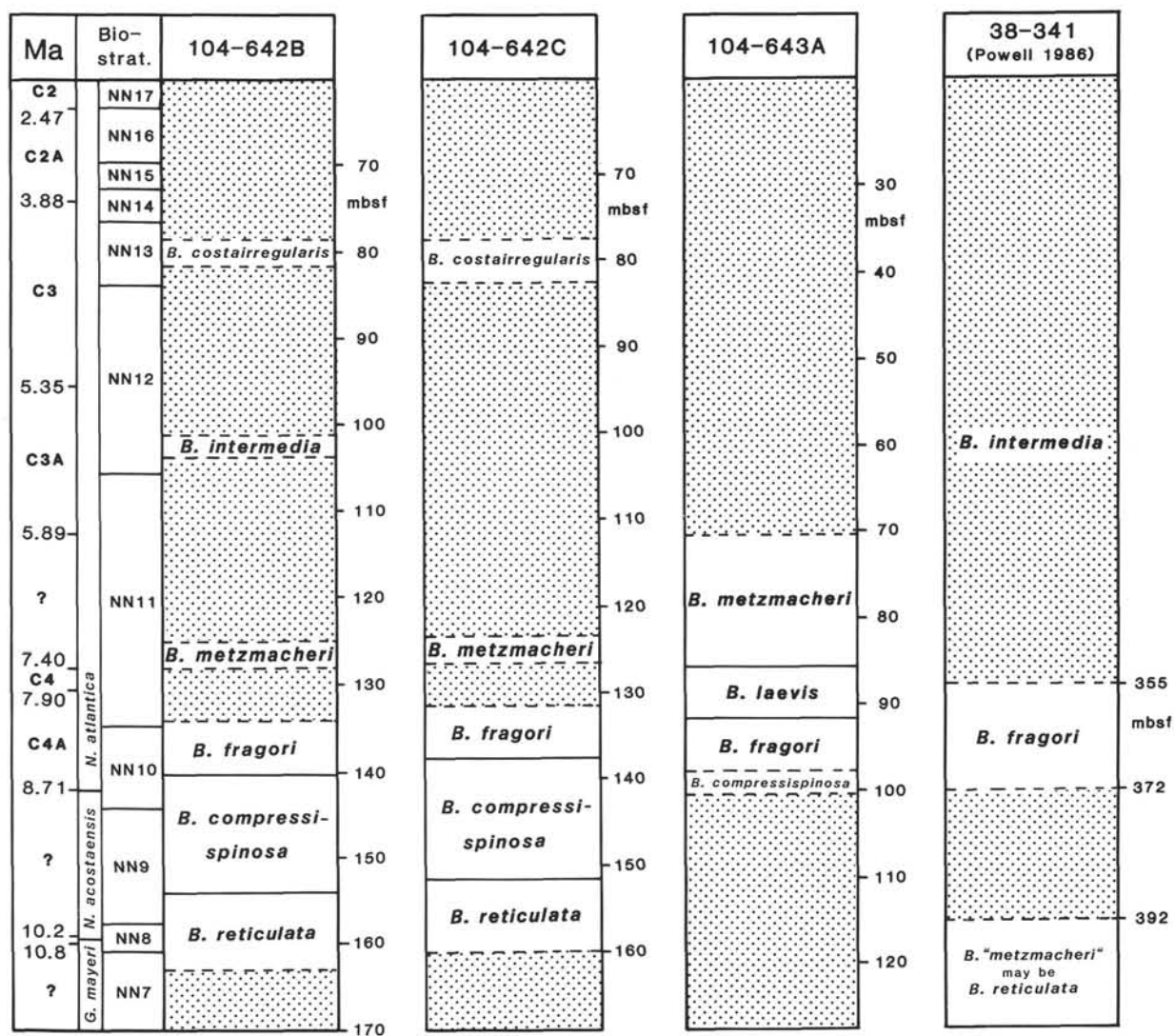


Figure 5. *Bolboforma* zones of Leg 104 sites. Absolute age (Berggren et al., 1985), chrons (Bleil, this volume), calcareous nannoplankton zonation (from Berggren et al., 1985) and correlation to the planktonic foraminiferal zonation (Spiegler and Jansen, this volume) are given on the left side, and correlation to Leg 38 Site 341 is shown on the right side of the diagram. The shading indicates barren intervals.

Plates 1 through 3. *Bolboforma* species from the Miocene to Pliocene Vøring Plateau samples. A short description is given for each species. The GIK-numbers refer to the collections of the Geological Institute and Museum, University of Kiel.

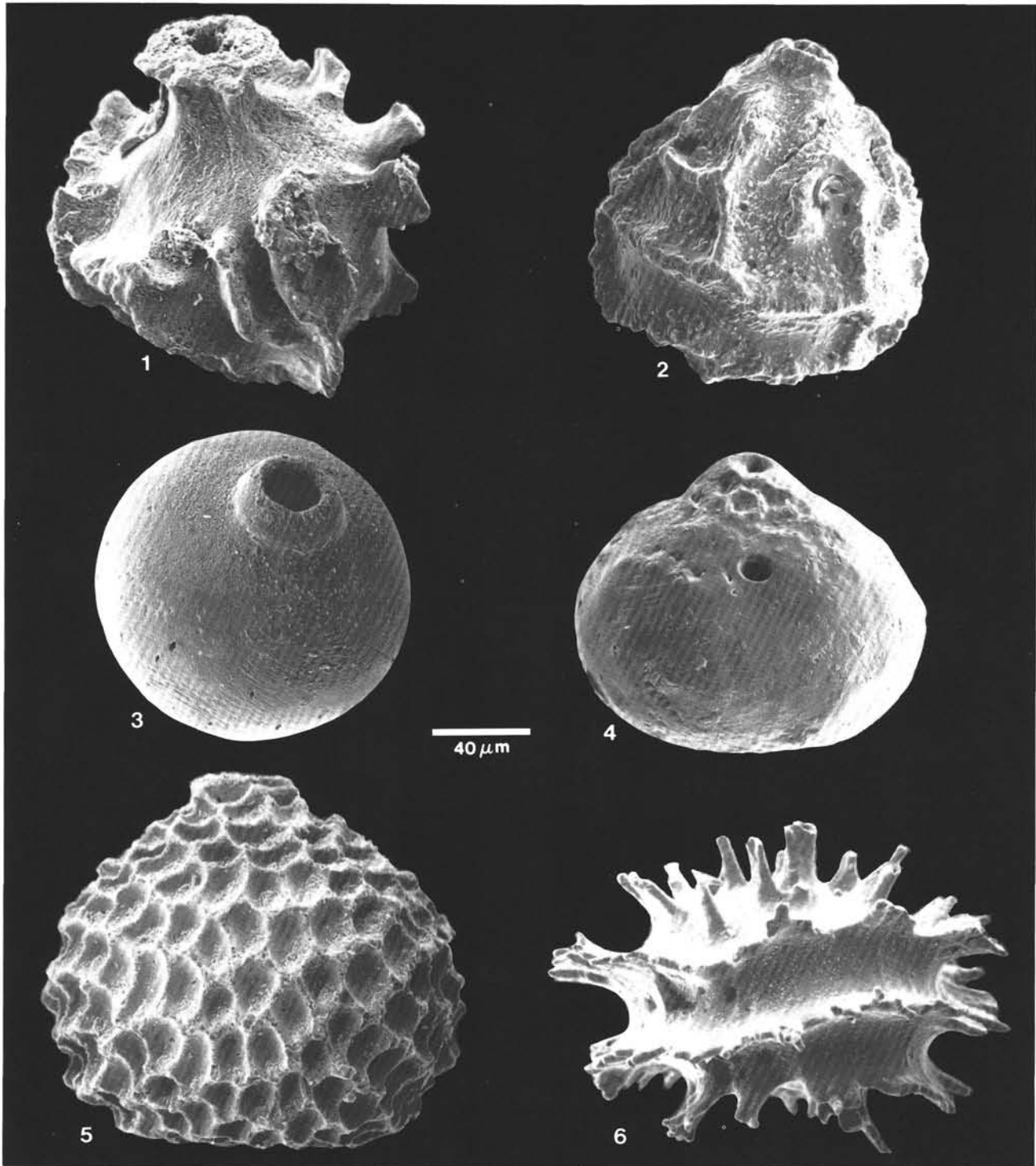


Plate 1. 1. *Bolboforma costairregularis* (Toering and Voorthuysen, 1973), 104-642C-11H-4, 102 cm (GIK-3536). = *Lagena* Y Laga, 1972; *Lagena costairregularis* Toering and Voorthuysen, 1973; *Bolboforma costata* Murray, 1984. Pear-shaped empty outer test, covered by 3–6 single or 4–6 double longitudinal ribs, ornamentation highly variable. Early Pliocene. 2. *Bolboforma intermedia* Daniels and Spiegler, 1974, 104-642C-12H-6, 102 cm (GIK-3537). Aborally flattened empty outer test covered by irregular longitudinal and equatorial ribs. Middle to late Miocene. 3. *Bolboforma laevis* Daniels and Spiegler, 1974, 104-642C-17H-6, 102 cm (GIK-3538). Aborally flattened empty smooth outer test with a distinct neck. Inner tests (cysts) of other species may also be smooth, but they are usually larger and have often two chambers. Miocene. 4. Transitional form between *Bolboforma laevis* and *Bolboforma metzmacheri*, 104-642B-16H-6, 102 cm (GIK-3539). Oral section of the smooth test is covered by fine reticulation. Late Miocene. 5. *Bolboforma metzmacheri* Daniels and Spiegler, 1974, 104-642C-16H-3, 102 cm (GIK-3540). Aborally flattened empty outer test with fine reticulation. Middle to late Miocene. 6. *Bolboforma fragori* Powell, 1986, 104-642B-17H-1, 102 cm (GIK-3541). Strongly bipolarly flattened empty test with three horizontal ridges covered by knobs and long spines. Late Miocene.

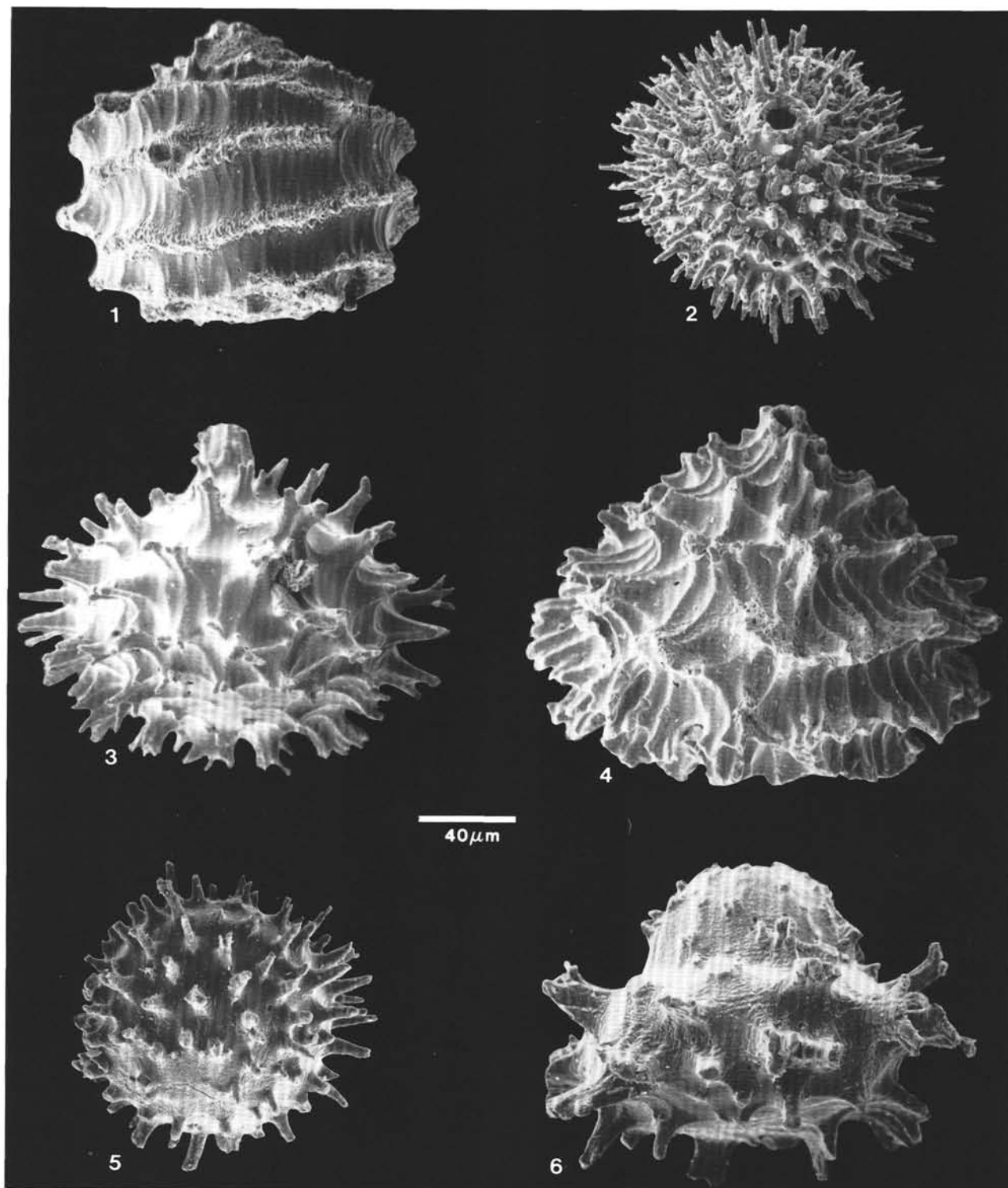


Plate 2. 1. *Bolboforma subfragori* Spiegler (in prep.), 104-642C-17H-3, 102 cm (GIK-3542). = *Bolboforma* sp. Poag and Karowe, 1986, Figs. 2K, 2L. Compressed to spheroid empty outer test with 3-5 concentric spinose flanges separated by vertical ridges. Late Miocene. 2. *Bolboforma spinosa* Daniels and Spiegler, 1974, 104-643A-11H-2, 102 cm (GIK-3543). Spheroid, finely spinose outer test. Miocene. 3-4. *Bolboforma pseudohystrix* Müller et al., 1984; 3. 104-642B-18H-1, 102 cm (GIK-3544), and 4. 104-642B-18H-2, 102 cm (GIK-3545). Aborally flattened, coarsely spinose empty outer test. The spines are connected by a few low ridges (3.) or more distinct ones (4.). 5. *Bolboforma clodiusi* Daniels and Spiegler, 1974, 104-642B-18H-1, 102 cm (GIK-3546). Aborally flattened empty outer test with coarse spines. Late Miocene. 6. *Bolboforma aculeata* Daniels and Spiegler, 1974, 104-642B-18H-1, 102 cm (GIK-3547). Aborally flattened empty outer test with irregular spines. Middle to late Miocene.

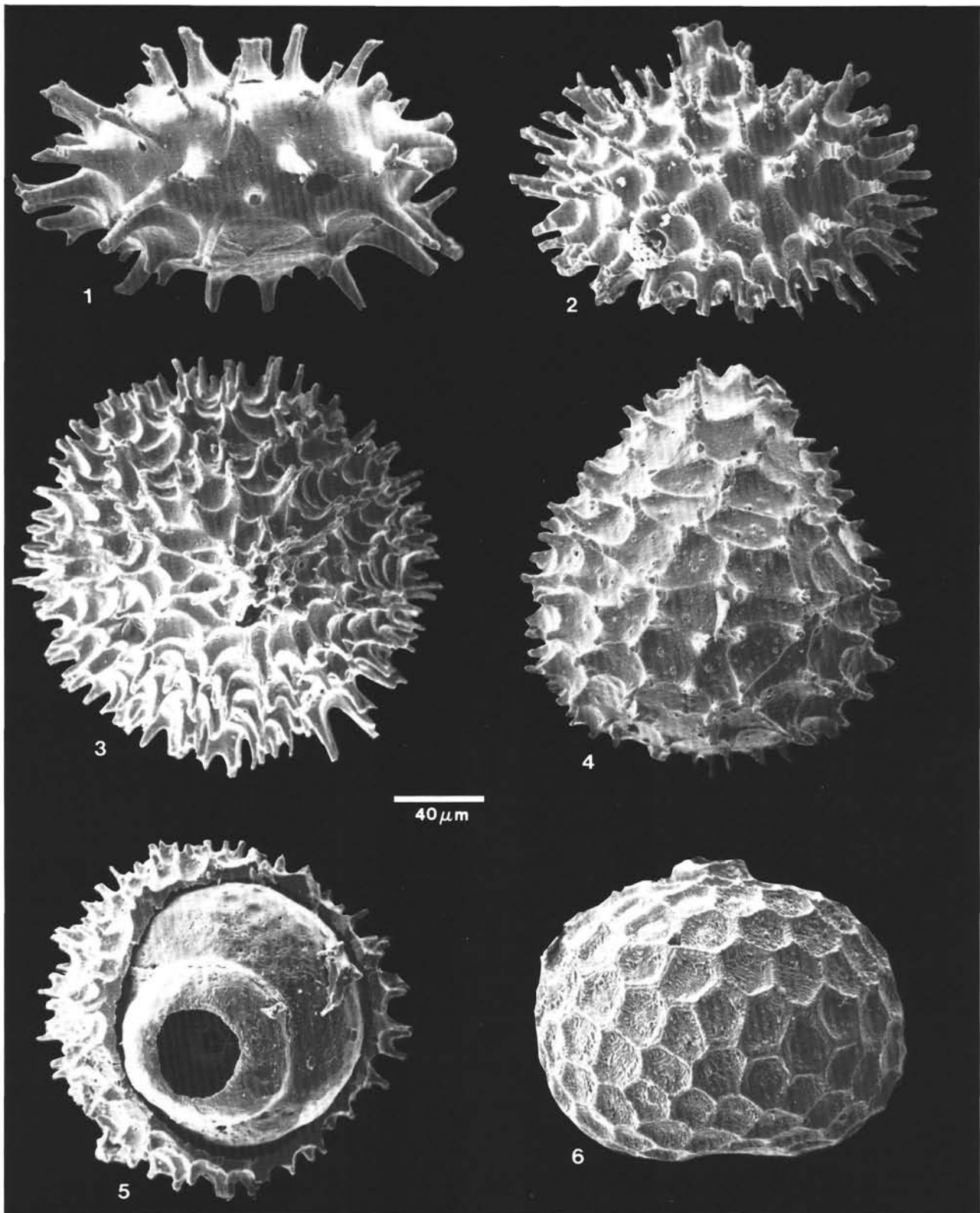


Plate 3. 1. *Bolboforma compressispinosa* Spiegler (in prep.), 104-642C-19H-4, 102 cm (GIK-3548). Bipolarly flattened, spinose empty outer test. Late Miocene. 2. *Bolboforma compressibadenensis* Spiegler (in prep.), 104-642C-20H-1, 102 cm (GIK-3549). Bipolarly flattened, reticulate and spinose, empty outer test. Middle to late Miocene. 3. *Bolboforma badenensis* Szczechura, 1982, 104-642B-18H-5, 102 cm (GIK-3550). Empty, reticulate and spinose outer test. Miocene. 4-5. *Bolboforma voeringensis* Spiegler, 1987. 4. 104-642C-19H-5, 102 cm (GIK-3551). Pear-shaped outer test with reticulation and spines. 5. 104-642B-18H-1, 102 cm (GIK-3531). Encapsulated test; outer test with reticulation and spines, inner test (cyst) with only weak reticulation. A smaller and a larger chamber are combined inside to form an elongated cyst with a very wide opening. Late Miocene. 6. *Bolboforma reticulata* Daniels and Spiegler, 1974, 104-642C-19H-6, 102 cm (GIK-3552). Flattened to spheroid outer empty test with coarse reticulation. Late Eocene to early late Miocene.