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EARLY MIOCENE AGGLUTINATED FORAMINIFERA FROM THE BERMUDA ABYSSAL PLAIN: DSDP SITE 603 (NW ATLANTIC OCEAN)

by

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With 4 figures and 3 plates

ZUSAMMENFASSUNG

Bei den DSDP Leg 93 und 95 wurde versucht, in Site 603 die Jura-Basis der Bermuda Abyssal Plain zu erreichen. Dabei wurde an dieser Stelle ein größerer Hiatus im mittleren Känozoikum festgestellt. Diese wichtige lithologische Grenze zwischen den liegenden, grünen Radiolarien-Tonsteinen (Mitteleozän) und den hangenden, gelbbraunen, siltreichen Tonsteinen (Untermiozän) liegt in Site 603B in Kern 15, Abschnitt 4, bei 46 cm. Die untermiozänen Sedimdente enthalten häufig Ichthyolithen (Fischreste) und in einigen Proben guterhaltene, agglutinierte Foraminiferen. Diese umfassen sowohl einfache, röhrenförmige Typen als auch komplexe Taxa der Ammodiscacea und Lituolacea.

ABSTRACT

Both DSDP Leg 93 and Leg 95 attempted to drill the Jurassic basement at Site 603 in the Bermuda Abyssal Plain. At this site there is recorded a major hiatus in the mid-Cenozoic. This important lithological boundary between the underlying green radiolarian claystone (of Middle Eocene age) and the overlying, yellow-brown, silt-rich claystone (of Early Miocene age) is located at 603B-15-4, 46 cm. The Lower Miocene sediments contain abundant ichthyoliths (fish skeletal debris) and a few samples have yielded well-preserved agglutinated foraminifera. This includes a fauna of both simple tubes and more complex members of the Ammodiscacea and representatives of the Lituolacea.

INTRODUCTION

Legs 93 and 95 of the International Phase of Ocean Drilling were designed to complement each other as the "New Jersey Transect". Leg 93 was to drill in the deep waters of the foot of the continental rise (figure 1) with the coring of the Jurassic basement as a prime objective. Unfortunately the drill string failed and the re-entry hole 603B terminated in limestones of Valanginian age. With the reduced drilling capability, Sites 604 and 605 were drilled in the shallower waters of the Upper Continental Rise. Leg 95 returned to Site 603, but without a re-entry facility there was little chance of reaching the Jurassic basement. The upper levels of the succession were washed (not cored) in an attempt to preserve the drill bit for the lower levels of the succession. However, an interest in Horizon A[u] (Tucholke and Mountain 1979) allowed a core to be taken at 603E-1 (936.4-937.0 m). This sample (see approximate position on figure 2) was barren of radiolarians, foraminifera and calcareous nannofossils but contained abundant ichthyoliths (fish skeletal debris). As these appeared to have been missed by the Leg 93 shipboard scientists, further material from Site 603B was requested and incorporated into the present study. The ichthyoliths (plate 1, figures 4-8) indicate an Early Miocene age (Hart and Mountain, in press) and as can be seen from figure 2 they are found

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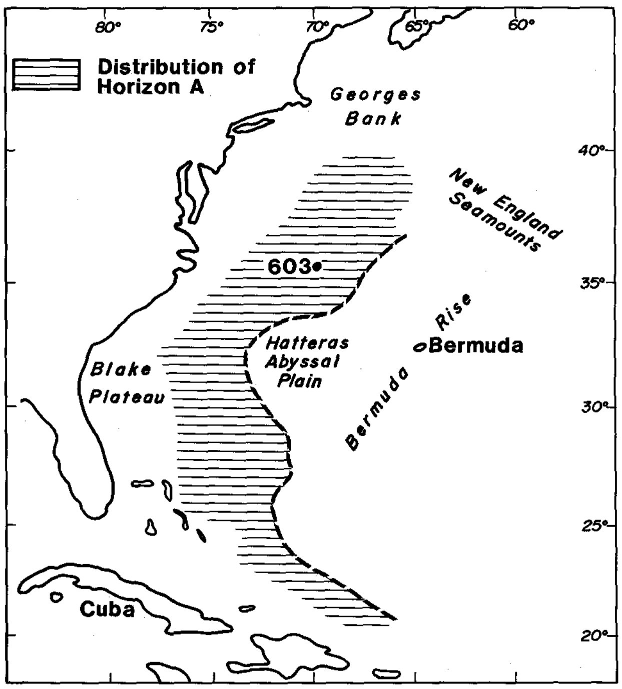

Fig. 1.
Location of Site 603 in the Northwest Atlantic Ocean and the development of Reflector A[u].

concentrated in the lowest levels of Unit 1c and in Unit 1d. It is in these yellow-brown, silt-rich claystones that the agglutinated foraminifera were recorded. They are also associated with an abundance of small crystalline aggregates (plate 1, figures 1-3), yellow-brown in color, that were initially thought to be either dolomite or perhaps a zeolite. Semi-quantitative analysis (figure 3) using the Link analysis system coupled with a scanning electron microscope has shown that these are in fact a manganese silicate with a composition very close to tephroite (Mn_2SiO_4). This mineral has a normal composition of 29.75% SiO_2 and 70.25% MnO, which would appear to be approximately the composition shown in figure 3 for both analyses.

TAXONOMIC NOTES

The agglutinated foraminifera are concentrated in Cores 603B-14 and 603B-15 as shown in figure 2. The fauna is well-preserved and, in one or two samples, quite diverse. The samples available from Cores 603B-8 to 603B-18 were all very small, being only the standard 10 cc size. In many cases the taxa are represented by only two or three specimens and, as such, many identifications are tentative and some individuals have been left in open nomenclature. The primary interest of this paper is therefore paleoenvironmental and not taxonomic. Many of the taxa illustrated here have been discussed recently by Gradstein and Berggren (1981), Miller *et al.* (1982), Gradstein and Agterberg (1982), Willems (1983), King (1983), Hemleben and Troester (1984), Winkler (1984), McNeil (1984), Geroch and Nowak (1984), and Verdenius and Van Hinte (1983, and extensive bibliography). The fauna is dominated by two groups: straight tubes [*Saccorhiza ramosa* (Brady), *Bathysiphon* sp. cf. *B. filiformis* Sars, *Bathysiphon* sp. and *Rhabdammina cylindrica* Glaessner] and coiled tubes [*Ammodiscus cretaceus* (Reuss), *A. peruvianus* Berry, *Glomospira charoides* (Jones and Parker), *G. gordialis* (Jones and Parker), *G. irregularis* (Grzybowski), *Glomospira* sp. and *Glomospirella* sp.]. Approximately 5% of the fauna is composed of more complex members of the Lituolidae and Trochamminidae. Within the former, there are recorded rare specimens of *Haplophragmoides compressa* LeRoy, *H. eggeri* Cushman and *H. walteri* (Grzybowski). *Haplophragmoides walteri* is the better represented, with two typical examples shown in plate 3, figures 1-2. On the same plate there is shown an enlarged view (plate 3, figure 4) of the surface texture. All the fine clay-grade material is quartz (analyses performed independently on 8 separate grains). The specimen of *Haplophragmoides compressa* (plate 2, figure 13) and *Haplophragmoides* sp. cf. *H. eggeri* are poorly preserved and many of their diagnostic characters are obscured. The occurrence of two specimens of *Cyclammina placenta* (Reuss) is noteworthy. One is illustrated in plate 2, figure 15 while the other was damaged in an attempt at producing a thin section. The one surviving specimen shows the typical high number of chambers in the final whorl, the narrow slightly depressed sutures and the pores in the apertural face (*cf.* Gradstein and Berggren 1981, plate 8, figures 5-7). The specimen is however slightly distorted and this collapse of the chambers has produced an apparent faint 'keel', rather than the more typical rounded margin. Gradstein and Berggren (1981) indicate an Eocene-Oligocene age for this taxon, while this record (admittedly very rare) in the early Miocene would either indicate re-working (and the preservation is the same as all the other material) or a slight upwards extension of the range. This has also been indicated by Miller *et al.* (1982, zonation chart). An interesting single specimen is that described as *Alveolophragmium* sp. 1 by Gradstein and Berggren (1981). The specimen illustrated in plate 2, figure 17 is almost identical to their figured specimen (Gradstein and Berggren 1981, plate 6, figure 13). One unusual aspect of this fauna is the discovery of a few specimens of *Ammolagena clavata* (Jones and Parker). This adherent form (plate 2, figure 13) is almost identical to that illustrated by Verdenius and Van Hinte (1983, plate 3, figure 11).

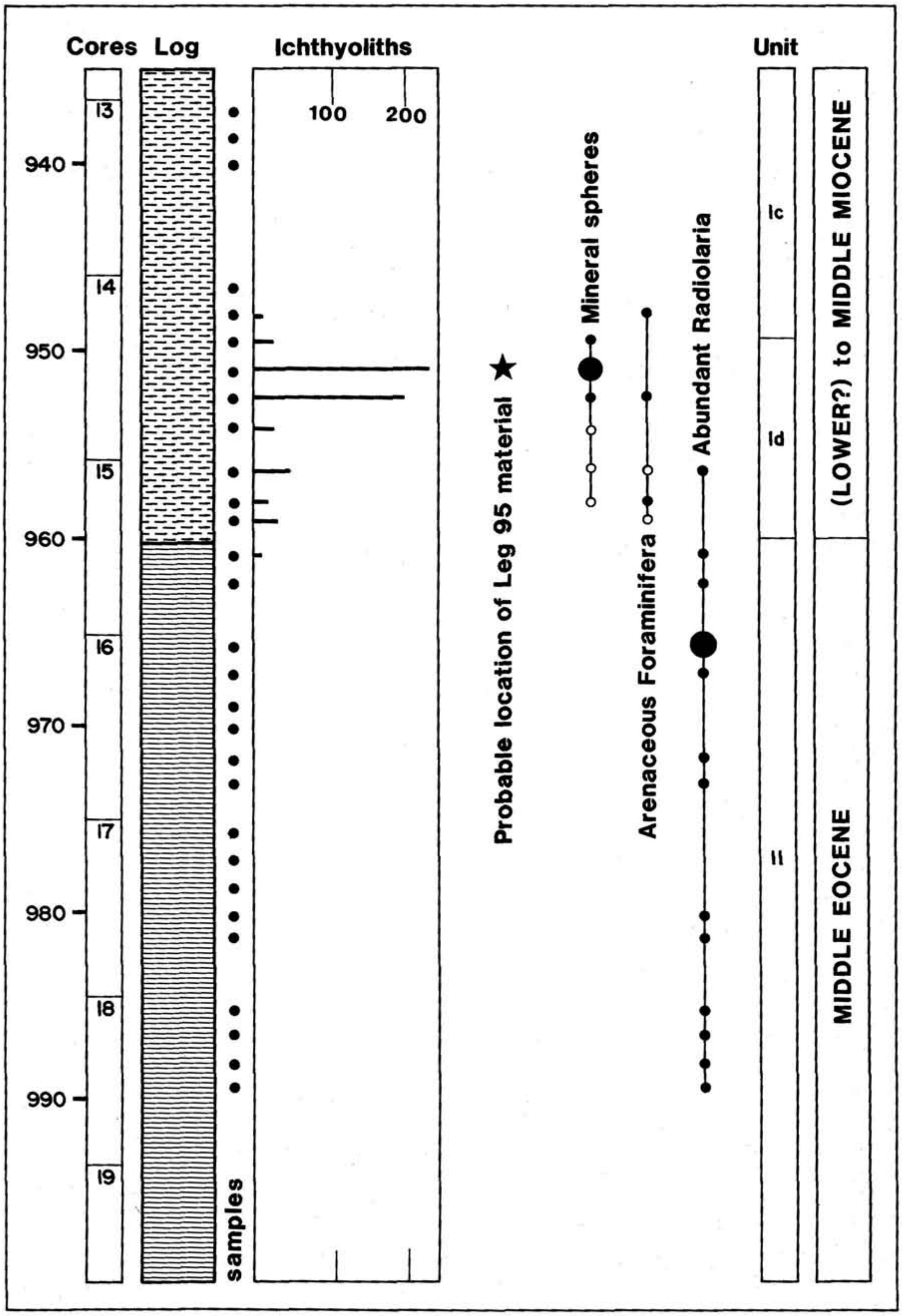

Fig. 2.
Abbreviated log of part of DSDP Site 603B showing location of samples and distribution of the foraminifera.
The bar graph for the ichthyoliths records the number of specimens per 10 cc sample. The star shows the probable equivalent level of 603E-1, 936.4–937.0 m.

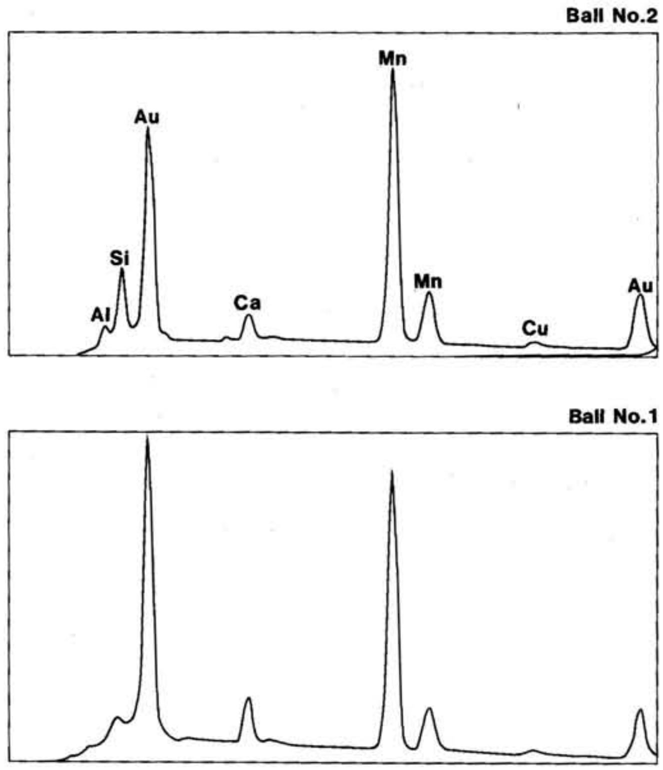

Fig. 3.
Semi-quantitative analysis of two mineral "spheres".
Note that the A^u comes from the coating medium and that the Al and Cu may be a contaminant from the stub on which the specimens were mounted.

PALEOENVIRONMENTAL IMPLICATIONS

The agglutinated foraminifera are found in Cores 603B-14 and 603B-15. As indicated in figure 2 this distribution parallels that of the Mn-rich 'spheres' and the ichthyolith debris. All three enter the succession immediately above the boundary between Unit 1d and Unit 11 of the shipboard terminology. The major hiatus at 603B-15-4, 46 cm is known as Horizon A^u. It is a prominent geophysical reflector (Tucholke and Mountain 1979; Poag 1985) and can be traced extensively along the Atlantic margin of the United States (see figure 1). The extent of Horizon A^u can also be seen in figure 4, which is a cross-section from the Hatteras Abyssal Plain, northwestwards through Site 603 and across the Continental Rise towards Long Island and New York. The green radiolarian claystones of Unit II are of Middle Eocene age while the ichthyolith data (Hart and Mountain, in press) suggests an Early Miocene age for Unit 1d. The occurrence of *Cyclammina placenta* would appear to confirm this dating as noted above. The hiatus can be estimated at 14 million years, during which time one or more erosional events took place (Mountain and Tucholke 1983; Hart and Mountain, in press). Mountain and Tucholke (1985) have suggested that the resumption of sedimentation following the Eocene/Oligocene ("A^u") event was in part a result of increased sediment supply as well as a reduction in bottom current velocity. The succession, together with the concentration of ichthyolith debris and the Mn-rich

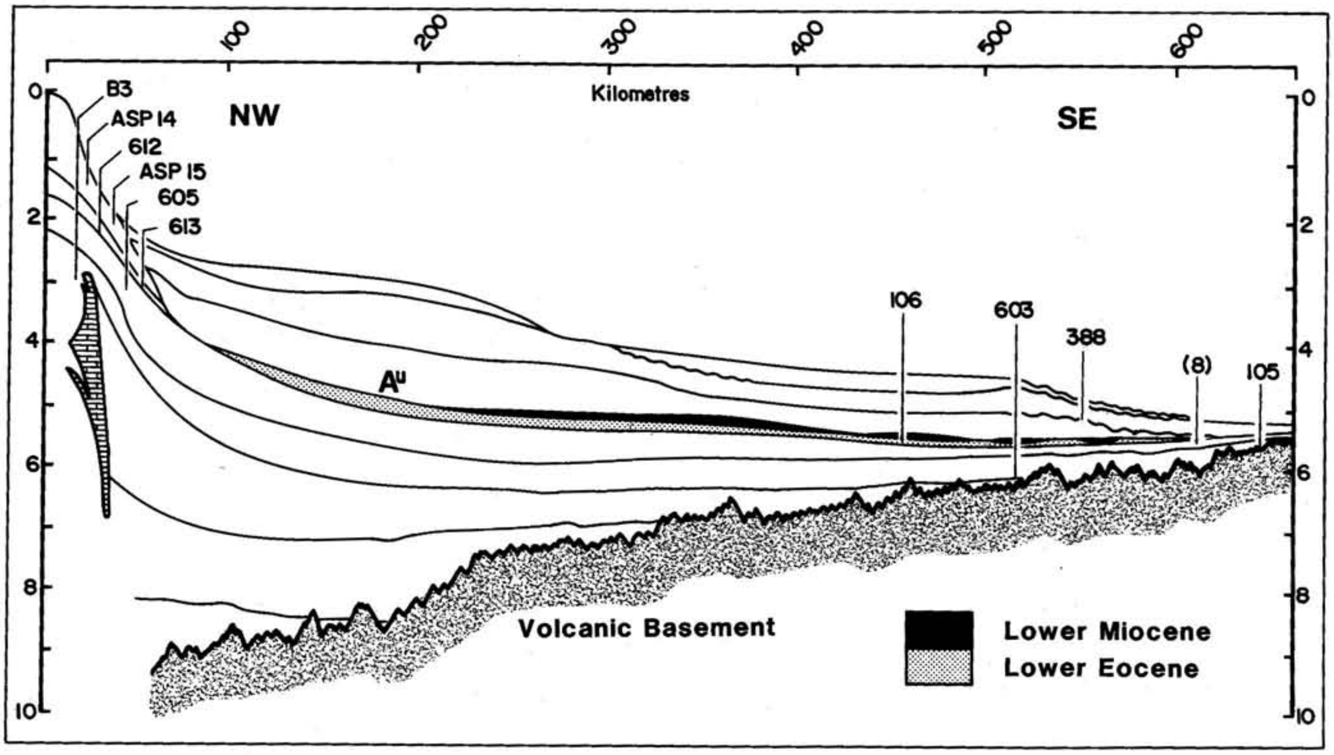

Fig. 4.
Line drawing depth section of composite multi-channel profiles from New Jersey continental shelf to lower continental rise.
All drill sites shown are located on this line except DSDP Site 8 which is projected from its true position 200 km to the NE.

'spheres', suggests that Unit 1d represents a condensed section that accumulated very slowly while the currents that formed reflector A^u were dropping to below erosional velocities.

This is in total contrast to other faunas that are dominated by agglutinated foraminifera. Such faunas from the Labrador Shelf and North Sea Basin (Miller *et al.* 1982; Gradstein and Berggren 1981) are normally associated with high sedimentation rates and a high organic content. While the abundance of fish skeletal debris must indicate a certain amount of organic material, the sediments are very low in organic carbon (<0.1%). The sedimentation rate is also extremely low. The water depth is, however, not in doubt; the whole succession from Barremian to Pleistocene being deposited below the CCD. This fauna was never associated with a calcareous fauna that has now been lost, nor was it the result of some environmental extremes produced in shallow waters (*e.g.* the North Sea Basin - Gradstein and Berggren 1981; Willems 1983; King 1983). As Verdenius and Van Hinte (1983) suggested on the basis of their work in the Norwegian Sea, this fauna, living in/on a siliceous mud, has a much smaller standing crop than those that are found in a more normal clastic environment. Verdenius and Van Hinte's calculation that the average sample from such siliceous mud represents at least three times as much geological time as the average clastic sample would appear to be correct. That being the case, the very low numbers of individuals present does point to a limitation by the nutrient supply. Unlike the high stress environments at the opposite end of the scale (hyposaline salt marsh) which have a very low fauna diversity, these samples do contain a wide range of taxa. While some may have suffered transport (*cf.* broken 'stems' of *Saccorhiza ramosa*), the lack of sedimentary structures visible in the succession would preclude wholesale transport of the fauna.

CONCLUSIONS

The occurrence of *Cyclammina placenta* has confirmed the suggestion, based on ichthyolith data, that Unit 1d at Site 603B is of Early Miocene age. The low sedimentation rate and the low numbers of foraminifera point to a sparse fauna that was living in deep waters below the CCD and in an environment of low nutrient supply. The relationship - if one exists - between the agglutinated foraminifera, the abundant ichthyolith debris and the abundant Mn-rich mineral 'spheres' requires further investigation, probably using additional samples from Unit 1d.

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REFERENCES

GEROCH, S. and NOWAK, W., 1984: Proposed zonation for the Late Tithonian-Late Eocene, based upon arenaceous foraminifera from the Outer Carpathians, Poland. - *In*: Oertli, H.J. (*ed.*), Benthos '83, 2nd International Symposium on Benthic Foraminifera (Pau, April 1983) - Bull. Centr. Rech. Explor. -Prod. Elf-Aquitaine Mem., v. 6, pp. 225-239, Pau-Bordeaux.

GRADSTEIN, F.M. and BERGGREN, W.A., 1981: Flysch-type agglutinated Foraminifera and the Maestrichtian to Paleogene history of the Labrador and North Seas. - Marine Micropaleontology, v. 6, pp. 211-268.

GRADSTEIN, F.M. and AGTERBERG, F.P., 1982: Models of Cenozoic Foraminiferal Stratigraphy - Northwestern Atlantic Margin. - *In*: Cubitt, J.M. and Reyment, R.A. (*eds.*), Quantitative Stratigraphic Correlation, pp. 119-170, J. Wiley & Sons Ltd.

HART, M.B. and MOUNTAIN, G.S., (in press): Ichthyolith evidence for the age of Reflector Au. - Init. Repts. DSDP, Leg 93, U.S. Govt. Printing Off.

HEMLEBEN, C. and TROESTER, J., 1984: Campanian-Maestrichtian deep-water foraminifers from Hole 543A, Deep Sea Drilling Project. - *In*: Biju-Duval, B., Moore, J.C., *et al.* **Init.** Repts. DSDP, v. 78A, pp. 509-534.

KING, C., 1983: Cainozoic micropalaeontological biostratigraphy of the North Sea. - Institute of Geological Sciences, Report *82/7*, 40 pp.

MCNEIL, D.H., 1984: Distribution of *Alveolophragmium* and *Cyclammina* in Paleogene shelf, slope and rise facies, Beaufort Sea, Arctic Canada. - *In*: Oertli, H.J. (*ed.*), Benthos '83, 2nd International Symposium on Benthic Foraminifera (Pau, April 1983) - Bull. Centr. Rech. Explor. -Prod. Elf-Aquitaine, Mem., v. 6, pp. 423-425, Pau-Bordeaux.

MILLER, K.G., GRADSTEIN, F.M., and BERGGREN, W.A., 1982: Late Cretaceous to Early Tertiary agglutinated benthic foraminifera in the Labrador Sea. - Micropaleont., v. 28, pp. 1-30.

MILLER, K.G. and TUCHOLKE, B.E., 1983: Development of Cenozoic abyssal circulation south of the Greenland-Scotland Ridge. - *In*: Bott, M.H., Saxov, S., Talwani, M. and Theide, J. (*eds.*), Structure and Development of the Greenland-Scotland Ridge, Plenum, N.Y., pp. 549-589.

POAG, C.W., 1985: Cenozoic and Upper Cretaceous Sedimentary Facies and Depositional Systems of the New Jersey Slope and Rise. - *In*: Poag, C.W. (*ed.*), Geologic Evolution of the United States Atlantic Margin, Van Nostrand, Reinhold, N.Y., pp. 343-365.

TUCHOLKE, B.E. and MOUNTAIN, G.S., 1979: Seismic stratigraphy, lithostratigraphy and paleosedimentation patterns in the North American Basin. - *In*: Talwani, M., Hay, W. and Ryan, W.B.F. (*eds.*), Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment, American Geophysical Union, Maurice Ewing Series, v. 3, pp. 58-86.

VERDENIUS, J.G. and VAN HINTE, J.E., 1983: Central Norwegian-Greenland Sea: Tertiary arenaceous foraminifera, biostratigraphy and environment. - *In*: Verdenius, J.G., Van Hinte, J.E. and Fortuin, A.R. (*eds.*), Proceedings of the First Workshop on Arenaceous Foraminifera, Continental Shelf Institute, Norway, No. 108, pp. 173-223.

WILLEMS, W., 1983: Agglutinating foraminiferids of the Ieper Formation (Early Eocene) in Belgium. - *In*: Verdenius, J.G., Van Hinte, J.E. and Fortuin, A.R. (*eds.*), Proceedings of the First Workshop on Arenaceous Foraminifera, Continental Shelf Institute, Norway, No. 108, pp. 227-247.

WINKLER, W., 1984: *Rhabdammina* fauna: what relation to Turbidites? Evidence from the Gurnigel-Schlieren flysch. - *In*: Oertli, H. (*ed.*), Benthos '83, 2nd International Symposium on Benthic Foraminifera (Pau, April 1983) - Bull. Centr. Rech. Explor. -Prod. Elf-Aquitaine, Mem., v. 6, pp. 611-617, Pau-Bordeaux.

PLATE 1

Figure 1	Manganese mineral, 603B-14-2, 64-67 cm, x100.
Figure 2	Manganese mineral, 603B-14-2, 64-67 cm, x100.
Figure 3	Manganese mineral, 603B-14-2, 64-67 cm, x300.
Figure 4	Ichthyolith, Type a3/b1, prominent polygon, 603B-15-3, 70-73 cm, x70.
Figure 5	Ichthyolith, Type a3,4/b1, 2 pointed and skirted, 603B-15-3, 70-73 cm, x70.
Figure 6	Ichthyolith, Type a9/b1, wide triangle straight inbase, 603B-15-3, 70-73 cm, x70.
Figure 7	Ichthyolith, Type a9/b1, triangle with curved base, 603B-15-3, 70-73 cm, x70.
Figure 8	Ichthyolith, Type a2/b2, skewed four or five peaks, 603B-15-3, 70-73 cm, x70.
Figure 9	Radiolarian, 603B-15-4, 63-66 cm, x50.
Figure 10	Radiolarian, 603B-15-4, 63-66 cm, x60.
Figure 11	*Ammodiscus cretaceus* (Reuss), 603B-14-2, 64-67 cm, x70.
Figure 12	*Ammodiscus cretaceus* (Reuss), 603B-14-2, 64-67 cm, x70.
Figure 13	Fragment of *Ammodiscus cretaceus* (Reuss), 603B-15-2, 80-83 cm, x70.
Figure 14	*Ammodiscus peruvianus* Berry, 603B-14-2, 64-67 cm, x50.
Figure 15	*Glomospirella* sp., 603B-15-2, 80-83 cm, x70.
Figure 16	*Glomospira* sp. cf. *G. irregularis* (Grzybowski), 603B-15-2, 80-83 cm, x70.

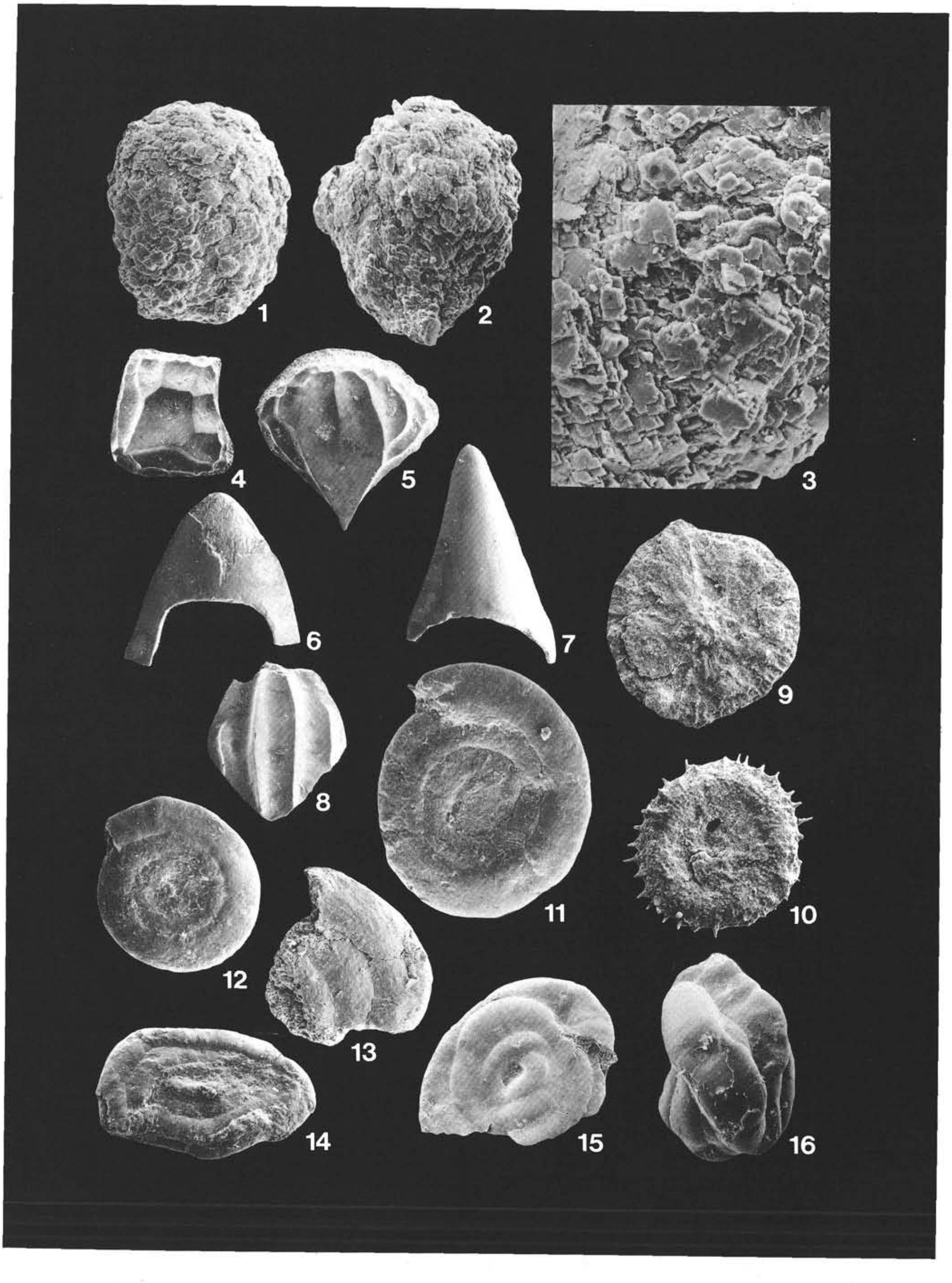
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PLATE 2

Figure 1 *Glomospira charoides* (Jones and Parker), 603B-15-3, 70-73 cm, x80.

Figure 2 *Glomospira charoides* (Jones and Parker), 603B-15-3, 70-73 cm, x80.

Figure 3 *Glomospira gordialis* (Jones and Parker), 603B-15-2, 80-83 cm, x100.

Figure 4 *Glomospira gordialis* (Jones and Parker), 603B-15-3, 70-73 cm, x80.

Figure 5 *Glomospira* sp., 603B-14-2, 64-67 cm, x90.

Figure 6 *Glomospira* sp., 603B-15-2, 80-83 cm, x100.

Figure 7 *Reophax* sp. cf. *R. pilulifera* Brady (deformed specimen), 603B-15-2, 80-83 cm, x50.

Figure 8 *Glomospira irregularis* Grzybowski, 603B-15-2, 80-83 cm, x60.

Figure 9 *Trochammina deformis* Grzybowski, 603B-14-2, 64-67 cm, x60.

Figure 10 *Trochammina* sp. cf. *T. deformis* Grzybowski, 603B-14-2, 64-67 cm, x70.

Figure 11 *Trochammina* sp. cf. *T. deformis* Grzybowski, 603B-15-2, 80-83 cm, x70.

Figure 12 *Trochammina* sp., 603B-14-2, 64-67 cm, x70.

Figure 13 *Haplophragmoides compressa* LeRoy with adherent *Ammolagena clavata* (Jones and Parker), 603B-15-2, 80-83 cm, x60.

Figure 14 *Trochammina* sp., 603B-15-2, 80-83 cm, x70.

Figure 15 *Cyclammina placenta* (Reuss), 603B-15-2, 80-83 cm, x50.

Figure 16 *Haplophragmoides* sp. cf. *H. eggeri* Cushman, 603B-14-2, 64-67 cm, x65.

Figure 17 *Alveolophragmium* sp. 1, of Gradstein and Berggren (1981), 603B-14-2, 64-67 cm, x60.

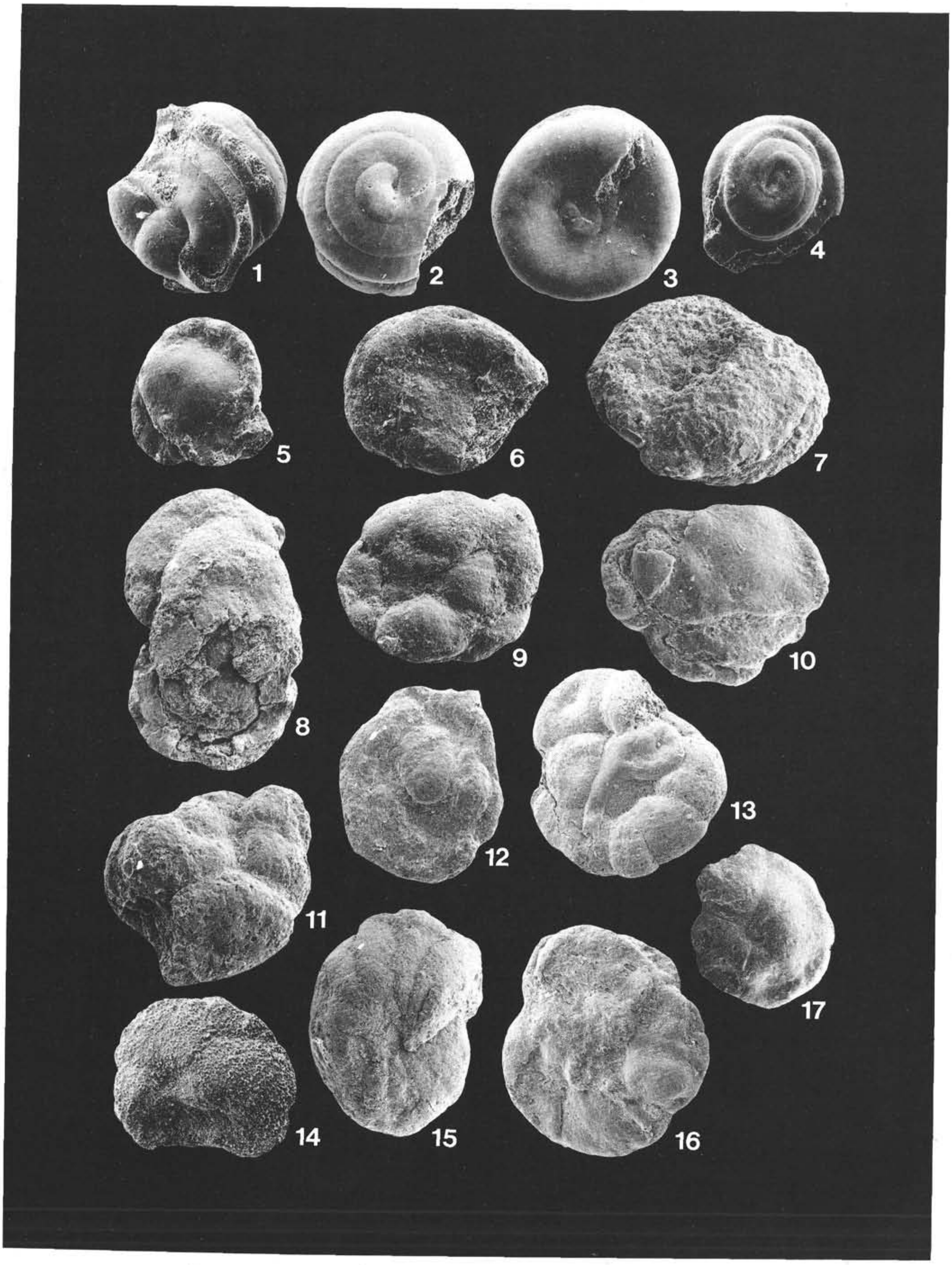
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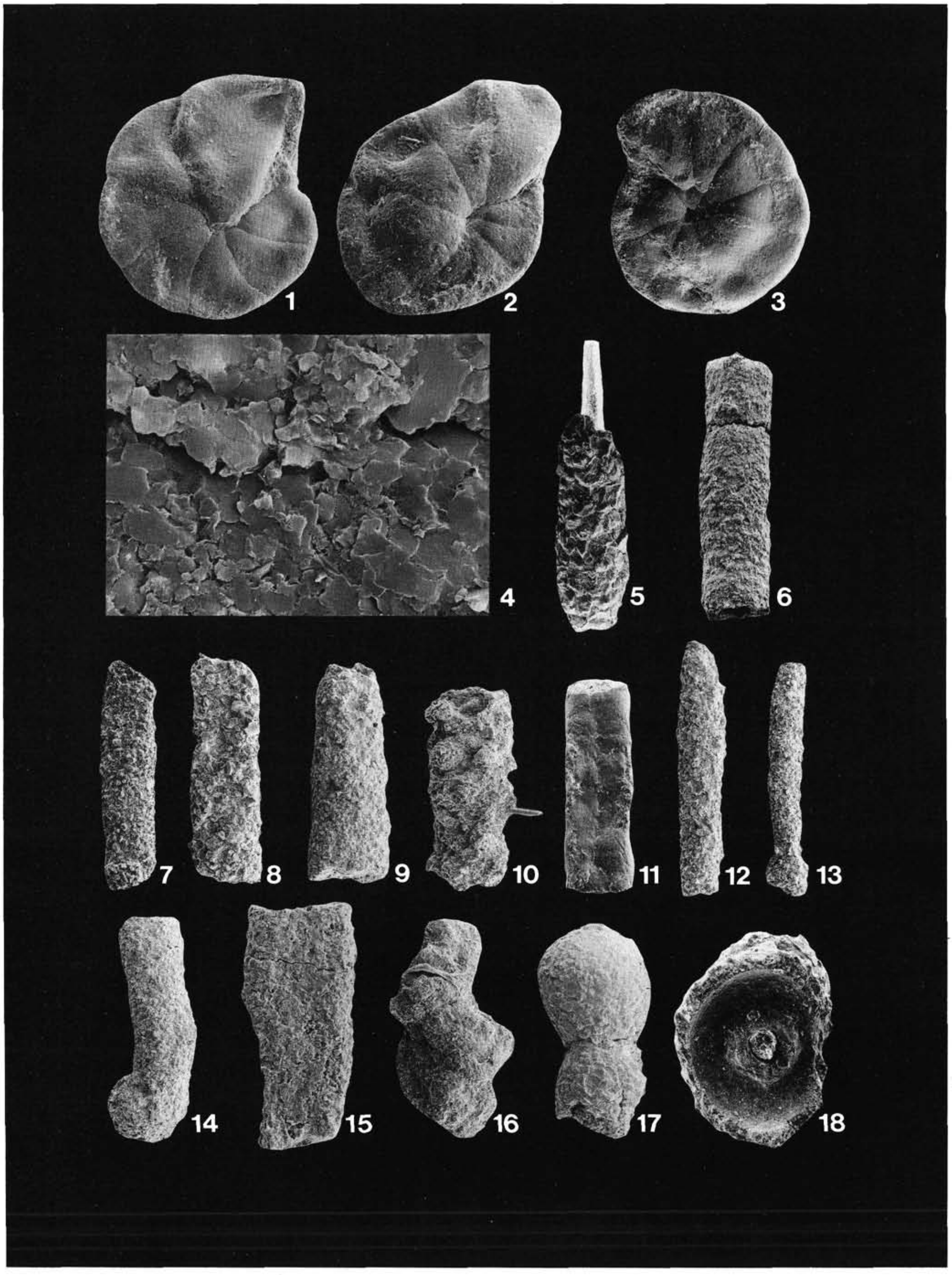
PLATE 3

Figure 1	*Haplophragmoides walteri* (Grzybowski), 603B-14-2, 64-67 cm, x65.
Figure 2	*Haplophragmoides walteri* (Grzybowski), 603B-14-2, 64-67 cm, x65.
Figure 3	*Haplophragmoides* sp. cf. *H. walteri* (Grzybowski), 603B-14-2, 64-67 cm, x40.
Figure 4	Magnification of suture between 2nd and 3rd last chambers of the specimen in figure 1, x300. The very fine grained, platy minerals are all quartz (based on SEM analysis).
Figure 5	Monaxon sponge spicule encased by arenaceous jacket, 603B-15-3, 70-73 cm, x55.
Figure 6	*Saccorhiza ramosa* (Brady), 603B-15-3, 70-73 cm, x55.
Figure 7	*Saccorhiza ramosa* (Brady), 603B-15-2, 80-83 cm, x40.
Figure 8	*Saccorhiza ramosa* (Brady), 603B-15-2, 80-83 cm, x50.
Figure 9	*Saccorhiza ramosa* (Brady), 603B-15-2, 80-83 cm, x30.
Figure 10	*Rhabdammina cylindrica* Glaessner, 603B-15-2, 80-83 cm, x50.
Figure 11	*Bathysiphon* sp. cf. *B. filiformis* Sars, 603B-14-2, 64-67 cm, x70.
Figure 12	*Lituotuba* sp., 603B-15-2, 80-83 cm, x40.
Figure 13	*Lituotuba* sp., 603B-15-2, 80-83 cm, x25.
Figure 14	*Ammobaculites* sp., 603B-15-2, 80-83 cm, x25.
Figure 15	*Bathysiphon* sp., 603B-14-2, 64-67 cm, x40.
Figure 16	*?Glomospira irregularis* (Grzybowski), 603B-15-2, 80-83 cm, x65.
Figure 17	*Reophax* sp. cf. *R. pilulifer* Brady, 603B-15-2, 80-83 cm, x50.
Figure 18	*Reophax* sp. cf. *R. pilulifer* Brady, 603B-15-2, 70-73 cm, internal view of broken specimen, x75.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